

Regular echinoids in the Upper Cretaceous of the Hashemite Kingdom of Jordan

Echinides réguliers dans le Crétacé supérieur du Royaume Hashémite de Jordanie

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(Plates III to IX)

Abstract. — Eleven species of regular echinoids, recently discovered in Upper Cretaceous deposits near Amman, Jordan, are systematically revised. Two new species are described: *Salenia ammonitorum* and *Trochotiara moabitorum*. The lithostratigraphy of the echinoid-bearing strata is outlined and the environment of deposition is inferred.

Résumé. — Onze espèces d'Echinides réguliers ont été découvertes récemment dans le Crétacé supérieur des environs d'Amman, en Jordanie. Ces espèces sont figurées et décrites systématiquement. Deux d'entre elles sont nouvelles: *Salenia ammonitorum* et *Trochotiara moabitorum*. La lithostratigraphie des différents gîtes de ces Echinides a été décrite schématiquement et le milieu de sédimentation a été précisé.

I. — INTRODUCTION

Echinoidal faunas of Cretaceous age in the Middle-East, outside Egypt, have rarely been studied. Egyptian echinoids have been described by Gregory (1906), by Fourtau (1914) and by Stefanini (1918). Apart from the short description of a small collection by Cotteau (1869), the Cretaceous echinoids of "Greater Palestina" (meaning Jordan, Southern Syria, the Lebanon and Israel jointly), have been described only by Blanckenhorn (1925). Bender (1968) lists only a few species from Jordan.

It is the aim of this paper to present a systematic description of the regular echinoids from some Cretaceous strata in the Amman-area, Jordan, and to characterize the lithofacies in which they were found. Collecting of specimens and lithostratigraphy was carried out by Bandel, who undertook the field-work within the frame of a Jordanian-German university partnership, during the years 1977 and 1978. Geys is responsible for the systematic descriptions of regular echinoids. We thus hope to contribute to the knowledge of the fossil faunas of Jordan.

Cotteau (1869) described 3 species of regular echinoids from the Cretaceous in the area east of the Dead sea: *Heterodiadema Libyicum* (Desor) (+); *Cy-*

phosoma Delamarrei Deshayes?; *Goniopygus Brossardi* Coquand.

Blanckenhorn (1925) mentions 9 species of regular echinoids from the Cretaceous of Palestina and a few more from Syria. The Palestinian species are: *Pedinopsis Desori* Coq.; *Heterodiadema libyicum* Cott. (+); *Diplopodia variolaris* Brongn. (+); *Diplopodia gileadensis* Blanck.; *Cyphosoma palaestinense* Blanck.; *Rachiosoma Delamarrei* Pom.; *Codiopsis doma* Desm.; *Goniopygus Menardi* Desm. (+); *Orthopsis miliaris* D'Arch.

Bender (1968) cites: *Salenia* sp.; *Heterodiadema libyicum* (+); *Diplopodia gileadensis*; *Codiopsis* sp.

The collections described herein confirm the presence of three species [marked (+)]. The other seven species, previously cited, were not found in the new material. On the other hand, seven other species, hitherto unknown from Palestina, were collected and described herein. Two of these are new.

The specimens are deposited in the collections of the Koninklijk Belgisch Instituut voor Natuurwetenschappen (K.B.I.N.), dept. of Palaeontology, Section of Secondary and Tertiary Invertebrate (I.S.T.). Some specimens are to be returned to the Geology department of the Amman university, in Jordan, when they can be properly accommodated.

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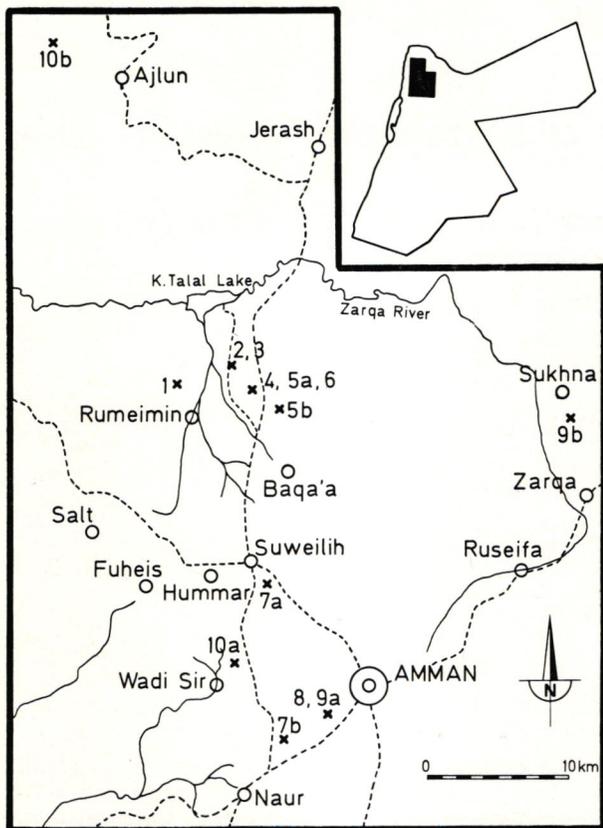


Fig. 1. — Map of the Amman area (Jordan) showing the location of the outcrops yielding regular echinoids.

Fig. 1. — Carte des environs d'Amman (Jordanie) montrant la localisation des gîtes fossilifères ayant livré des Echinides réguliers.

II. — SHORT DESCRIPTION OF LITHOFACIES AND PALAEOENVIRONMENT OF STRATA YIELDING REGULAR ECHINOIDS

1) Generalities.

In the area around Amman, Late Cretaceous rocks mainly consist of marls and limestones; silicified beds are only found in their uppermost portion. Echinoids were only found in the limy and marly units, underlying the chalky Ain Ghazal Formation. The complete sequence of the Upper Cretaceous is about 520 m thick in, and north and west of Amman. This sequence has been described, without much detail, by several authors (cf. Bender, 1968, for exhaustive literature). The subdivisions used herein have never before been published, but they are generally and informally used by

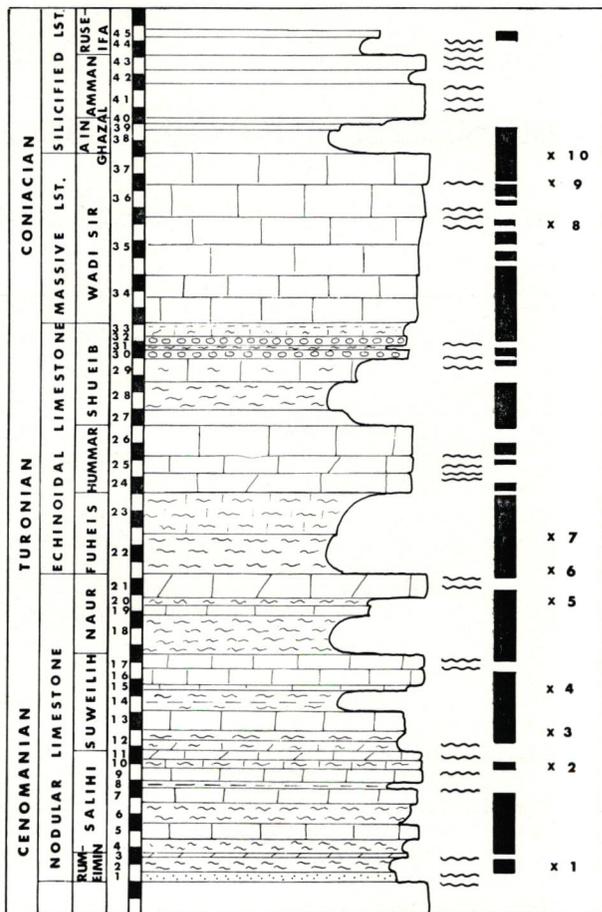


Fig. 2. — Generalized columnar section of the Upper Cretaceous in the Amman area. The meaning of the auxiliary columns its: 1, presumed chronostratigraphy. — 2, lithostratigraphy according to Bender (1968). — 3, proposed lithostratigraphical nomenclature, close to that currently in use by the Jordanian Geological Survey. — 4, proposed members, indicated by numbers. — 5, linear scale; each unit represents 10 m of rock column. — 6, wavy lines indicate intervals with continental or intertidal conditions. — 7, black bars indicate intervals of intense bioturbation. — 8, stratigraphical position of the localities yielding regular echinoids.

Fig. 2. — Colonne stratigraphique générale du Crétacé supérieur dans la région d'Amman.

Les colonnes auxiliaires désignent : 1, la chronostratigraphie probable. — 2, la lithostratigraphie selon Bender (1968). — 3, la nomenclature lithostratigraphique proposée, proche de celle utilisée couramment par le Service Géologique de Jordanie. — 4, les membres proposés (indiqués par des chiffres). — 5, l'échelle linéaire (chaque unité représente 10 m de sédiment). — 6, les lignes onduleuses indiquent les intervalles continentaux ou supralittoraux. — 7, les bandes noires indiquent des intervalles à bioturbation intense. — 8, la position stratigraphique des gîtes fossilifères.

the Jordanian Geological Survey (NRA). The sections have been measured; 11 formations could be differentiated and defined in the region around Amman. From bottom to top they are the Rumeimin, Salihi, Suweilih, Naur, Fuheis, Hummar, Shueib, Wadi Sir, Ain Ghazal, Amman and Ruseifa Formations. In the area west and north of Amman, from Es Salt to Jerash and Sukhna, these formations could be more finely differentiated into 45 members.

From the bottom of the calcareous Upper Cretaceous sequence, up to the sandy Kurnub Formation, the depositional environment repeatedly shifted from near shore and lagoonal environments to the shallow open sea. It is beyond the scope of this paper to present a full discussion of these strata, which will be published in detail later (Bandel, in preparation). A general outline, as given in fig. 2, might come in useful to the reader. Lithology is indicated schematically; lithostratigraphical terminology is according to Bender (1968) and in current, informal use in the Natural Resources Authority of Jordan (NRA) (approximately there, and detailed here). Faunal elements other than regular echinoids, present in these deposits, will be described in forthcoming papers.

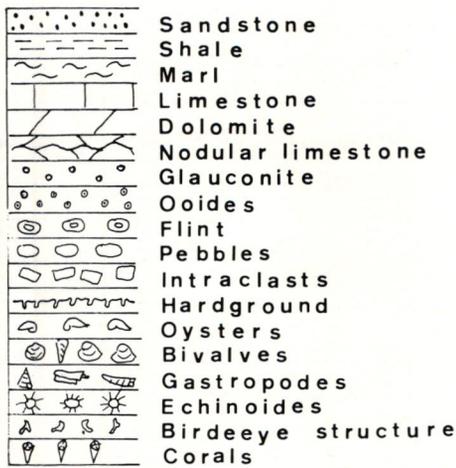


Fig. 3 to 8. — On each figure, the arrow points to the bed yielding regular echinoids.

Fig. 3 à 8. — Sur chacune de ces figures, la flèche indique le niveau ayant livré des Echinides réguliers.

Légende explicative: Sandstone: Grès. — Shale: Schistes. — Marl: Marne. — Limestone: Calcaire. — Dolomite: Dolomite. — Nodular limestone: Calcaire noduleux. — Glauconite: Glauconite. — Ooides: Ooides. — Flint: Silex. — Pebbles: Cailloux. — Intraclasts: Enclaves. — Hardground: Hardground. — Oysters: Huîtres. — Bivalves: Bivalves. — Gastropodes: Gastéropodes. — Echinoids: Echinides. — Birdseye structures: Structures « œil d'oiseau ». — Corals: Coraux.

2) Locality 1: Rumeimin.

Situation. The lowermost occurrence of a fauna of regular echinoids in the Cretaceous of Jordan was discovered below the town of Rumeimin, in the eastern flank of a steep wadi, downriver of the waterfall and the ruins

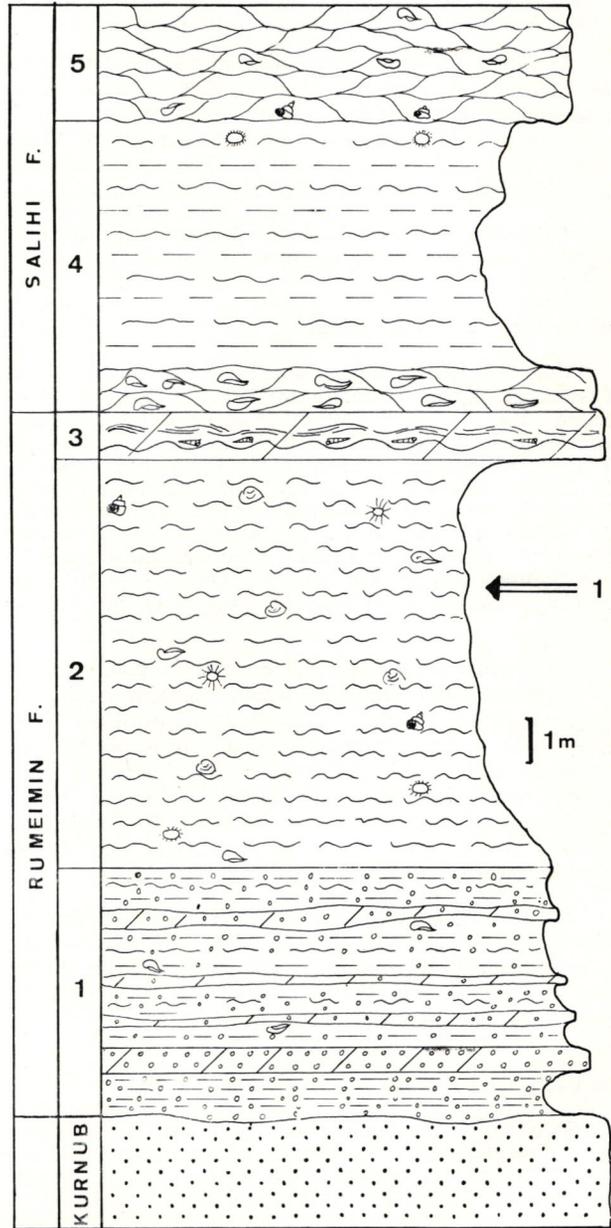


Fig. 3. — Columnar section of Locality 1 (Rumeimin).

Fig. 3. — Gîte n° 1 (Rumeimin): colonne stratigraphique.

rudists overlies the echinoid-bearing bed; this oyster bank is itself overlain by limestones with nerinean and opistobranch gastropods (Member 16).

Palaeoenvironment. The base of Member 16 has been deposited in a near shore environment, close to an oyster bank. Behind this bank, a lagoon was present.

6) Locality 5a : Salihi and Locality 5b : Baqa'a.

Situation. The uppermost Member (21) of the Naur Formation forms very conspicuous cliffs and rock exposures at both localities. At the base of the member a rich fauna can be collected. Locality 5a is situated in the eastern slope of the Wadi Salihi, above locality 4. Locality 5b is at the east side of the road from Baqa'a to Djerash, at the northern margin of the Baqa'a depression, after the road has reached the pass.

Stratigraphy (fig. 7). The strongly bioturbated marls of Member 20 (Naur Formation) contain a rich fauna of byssate and infaunal bivalves, oysters and various gastropods, of which strombids and neogastropods are characteristic. Regular and irregular echinoids are common in this member. Its central part yields large orbitolinid foraminifers. The base of the member is formed by an oyster coquina.

Member 20 rests upon the hard, styliolitic limestone of Member 19, with scattered corals, oysters, rudists, gastropods and irregular echinoids. Member 19 shows a hardground at its top.

The overlying Member 21 consists of hard limestones, forming a conspicuous cliff in all its outcrops.

Palaeoenvironment. Member 20 has been deposited in shallow, translucent water, in the open sea.

7) Locality 6 : Salihi.

Situation. Locality 6 is situated along the road from Salihi to the King Talal Reservoir, in the immediate vicinity of locality 5a. While locality 5a is found at the base of the massive dolomitic limestone cliff, locality 6 is situated at its top.

Stratigraphy (fig. 7). Member 22 (Fuheis Formation) consists of marly sediments with a very rich marine fauna, mainly containing oysters and echinoids. These beds were deposited during a transgression over the hard, dolomitic limestones of Member 21 (Naur Formation), which were, probably, subjected to continental or littoral conditions after deposition.

Palaeoenvironment. Member 22 has been deposited in a shallow, open sea.

8) Locality 7a : University and Locality 7b : Amman road-junction.

Situation. At two localities a rich fossil fauna was collected. Locality 7a is opposite the main gate of University of Jordan, just west of the road from Amman to

Suweilih. Locality 7b consists of temporary excavations for the construction of houses, just south of the road-junction Naur-Amman-Suweilih, on the road to Amman.

Stratigraphy. Highly fossiliferous marls of Member 22 (Fuheis Formation) are exposed. Typically, bivalved bivalves, both infaunal and epifaunal species, often in growth position, ammonites and calcareous

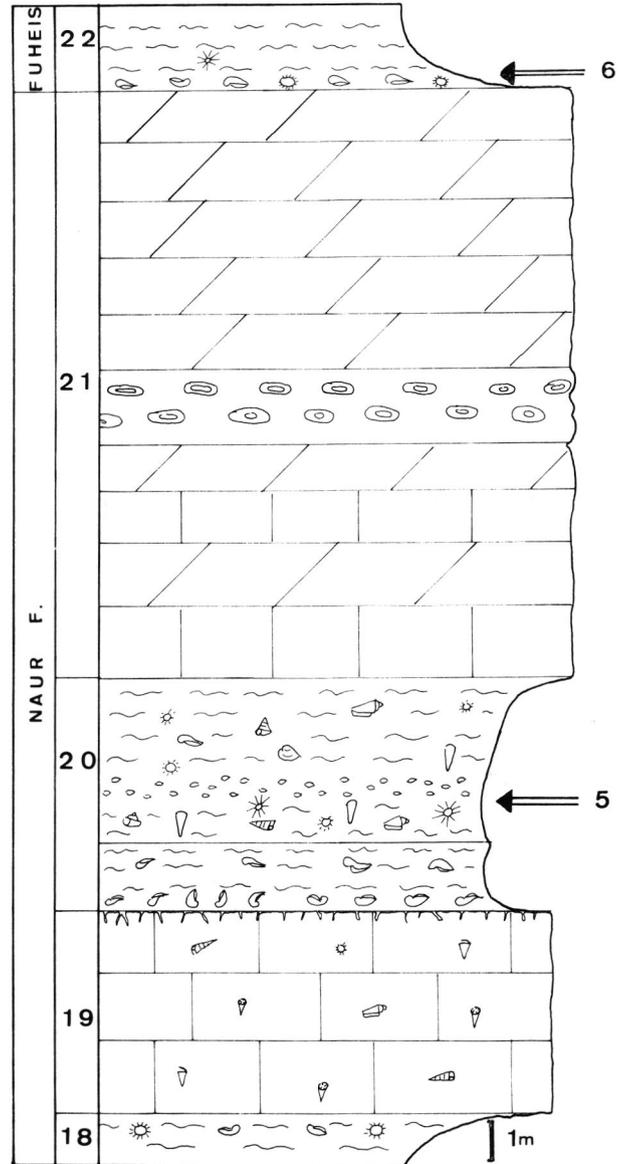


Fig. 7. — Columnar section of Localities 5 and 6 (Salihi).

Fig. 7. — Gîtes n°s 5 et 6 (Salihi) : colonne stratigraphique.

worm tubes are found together with regular and irregular echinoids. The ammonoids often have been reworked and their steinkerns are covered by encrusting bryozoans and bivalves.

Palaeoenvironment. Member 22 was deposited in a shallow open sea. Deposition and erosion alternated.

9) **Locality 8 : Ras el-Ain.**

Situation. Quarries on both sides of the road from Amman to Naur, above Ras el-Ain, and still within the city limits, were surveyed and sampled.

Stratigraphy (fig. 8). Member 35 of the Wadi Sir Formation contains numerous regular echinoids, many of them still with spines attached or lying nearby. Irregular echinoids are absent. Within the bioturbated nodular limestone, some beds consist of reworked carbonate concretions. Between these, the well preserved echinoids are embedded, probably without considerable transport. The member grades upwards into laminated dolomitic limestones; its top is formed by laminated limestones with clay partings. Both these limestones lack any trace of bioturbation.

Palaeoenvironment. Sheltered lagoonal conditions prevailed. Echinoids lived on a sea-bottom, covered with washed-out limestone nodules. These nodules provided shelter and a substrate on which algal growths could be grazed.

10) **Locality 9a : Ras el-Ain and Locality 9b : Sukhna.**

Situation. A fossiliferous outcrop of this bed was found in the same quarries as locality 8 (9a). Another was exploited above the river Zarqa in the cliffs between Sukhna and Zarqa (locality 9b). Here the beds can easily be observed below the massive unit of Member 37, which forms the top of the cliffs.

Stratigraphy. Member 36 consists of alternating bioturbated limestones and marls, with chert concretions, oolitic beds, laminated limestone beds, hardground and intraclast layers. The member ends with a fossiliferous marl, containing numerous bivalves, as well as regular and irregular echinoids.

Palaeoenvironment. The rapid changes between the lithologies indicates a continuous movement of the sea, back and forth. Deposition in a shallow sea, near and at the shore, and deposition in lagoonal and intertidal environments alternated.

11) **Locality 10a : Wadi Sir and Locality 10b : Steffena.**

Situation. On the slope opposite the road towards the village of Wadi Sir and coming from Amman, the Wadi Sir Formation is exposed in its full thickness. Locality 10a is found, just below the uppermost beds of this formation in the upper part of the massive limestone, forming the last cliffs. At about the same stratigraphical position, near the village of Steffena. NW of Ajlun, a rudist reef is developed (locality 10b). Its talus is very fossiliferous, among the fossils are some echinoids.

Stratigraphy. Member 37 of the Wadi Sir Formation consists of a coarsely bedded, massive limestone, into which caves have been formed. In its upper portion, the member shows abundant, thick-shelled bivalves with shells often intensively bored, mainly by sponges. In the uppermost 2 m, fossils are commonly silicified, among them many gastropods and bivalves (especially near Sukhna). The echinoids of the Wadi Sir outcrop are also silicified and usually broken.

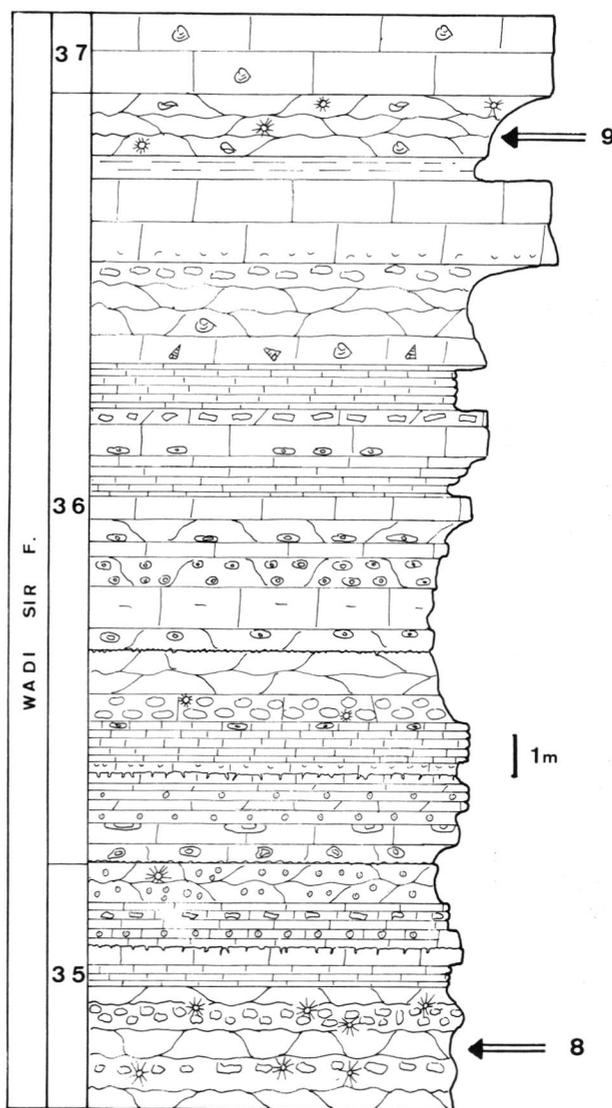


Fig. 8. — Columnar section of Localities 8 and 9 (Ras el-Ain).

Fig. 8. — Gîtes n^{os} 8 et 9 (Ras el-Ain) : colonne stratigraphique.

Underlying are beds of similar lithology; overlying beds consist of a soft, marly chalk. At Steffena, echinoids are part of the rich fauna of a rudist reef, which represents the top of the Wadi Sir Formation.

Palaeoenvironment. The rich, shelly, autochthonous molluscan fauna indicates open shallow sea condition, on the offshore side of a rudist reef.

12) **Conclusion.**

It is obvious that all localities, with the exceptions perhaps of localities 7a and 7b, show rock facies, deposited near the shore on an indurated or shelly bottom. The echinoidal tests found are autochthonous and have been embedded in their living environment, without considerable transport, on the bottom of a shallow sea, with translucent water. At localities 7a and 7b, episodes of erosion produced hardgrounds that could be colonised by regular echinoids. Biostratigraphical data, gathered from ammonite faunas indicate that the rock column between localities 1 to 4, and probably also 5, was deposited during Cenomanian times. Localities 6 and 7 are of Turonian age; localities 8, 9 and 10 are of Coniacian age (Bandel and Wiedmann, in prep.). The stratigraphical distribution of the collected species is given in table I.

Stage	Formation	Member	<i>Salenia ammonitorum</i>	<i>Salenia batnensis</i>	<i>Heterodidagma lybicum</i>	<i>Tetragramma cf. varicelare</i>	<i>Trochotaria moabiticum</i>	<i>Phymosoma maraei</i>	<i>Phymosoma maraei</i>	<i>Rachiosoma major</i>	<i>Rachiosoma reutlickeatum</i>	<i>Goniopygus menardi</i>	<i>Goniopygus</i> sp. indet.
S	Wadi Sir	37	--	--	--	--	--	--	--	--	--	--	02
S	Wadi Sir	36	--	--	--	--	--	01	--	01	--	--	--
S	Wadi Sir	35	--	--	--	--	--	--	--	09	05	--	--
T	Fuheis	22	--	--	01	--	--	--	12	--	--	--	--
C?	Naur	20	--	--	11	--	--	--	--	--	--	01	--
C	Suweilih	16	--	01	--	01	--	--	--	--	--	04	--
C	Suweilih	13	--	--	01	--	--	--	--	--	--	--	--
C	Salihi	10	01	--	--	--	--	--	--	--	--	--	--
C	Rumeimin	2	--	--	--	01	01	--	--	--	--	--	--

Table I. — Stratigraphical distribution of regular echinoids in the Upper Cretaceous of the Amman area (Jordan). S, Coniacian. — T, Turonian. — C, Cenomanian. (number of specimens)

Tableau I. — Distribution stratigraphique des Echinides réguliers dans le Crétacé supérieur des environs d'Amman (Jordanie). S, Coniacien. — T, Turonien. — C, Cénomannien. (nombre de spécimens)

III. — **SYSTEMATIC DESCRIPTION**

Ordo SALENOIDA Delage and Herouard, 1903

Familia SALENIIDAE Agassiz, 1838

Subfamilia SALENIINAE Agassiz, 1838

Genus *SALENIA* Gray, 1835

Type species: *Cidarites scutigera* Münster (in Goldfuss), 1826; original designation.

Diagnosis: « Differs from *Salenocidarites* and *Salenidia* only in its ambulacra which consist throughout of bigeminate plates, each with one primary tubercle and two pore pairs (Fell and Pawson, 1966; Mortensen, 1935).

SALENIA AMMONITORUM nov. sp.
(Pl. III, fig. 1-6)

LOCUS TYPICUS: Wadi Salihi, near Amman, Jordan (locality 2).

STRATUM TYPICUM: Member 10, Salihi Formation, Nodular Limestone, Cenomanian.

DERIVATIO NOMINIS: from the Ammonites, biblical tribe, living on the left bank of the River Jordan.

LOCATION OF HOLOTYPE: K.B.I.N. collections, n° IST 10232.

SPECIMENS STUDIED: Locality 2; Member 10, Salihi Formation, Cenomanian: 1 specimen (IST 10232).

Dimensions. (*)

D = 15.7 mm; h = 9.7 mm; h/D = 0.60; ds = 5.6 mm; ds/D = 0.36.

Description.

Medium sized *Salenia*, with moderately elevated test and almost flat apical system. The preservation of the specimen does not allow a description of peristome and girdle.

The apical system is relatively small and pentagonal, its angles directed towards the interradial sutures. Its 11 plates are smooth, without ornamentation. They are solidly welded together and the sutures are not visible. However, there are 16 large, deep, rounded sutural depressions. Oculars II, IV and V are surrounded by 3 sutures each; oculars I and II by 2 each. Genital plates 3 and 4 are surrounded each by 5 depressions; genital 1 and 5 each by 3 depressions; genital 2 is surrounded by 4 depres-

(*) D: ambital diameter of the test; h: height of the test; ds: diameter of the apical system, from III to V; dp: diameter of the peristome, gill slits not included.

sions. The suranal plate is surrounded by 3 depressions. Genital pores are situated in deep, rounded depressions, similar to sutural depressions, in the center of each genital plate. The madreporite, 2, carries a large, rounded poriferous depression. The periproct is large, subtriangular and surrounded by slightly protruding lips.

Ambulacra are relatively wide. It is impossible to establish the exact number of ambulacral tubercles in each series. We counted 5 ambulacral plates for each interambulacral plate, at the ambitus. Each plate has one non-crenulate, non-perforate primary tubercle. These tubercle are very small: they are hardly larger than granules. Perradial extrascrobicular surfaces are covered by a fine, very dense granulation. Poriferous zones are almost straight and wide. The plates are very regularly bigeminate. Pore pairs are almost horizontal and close together. They are surrounded by an inconspicuous ridge. Interporiferous partitions are present but poorly developed.

Interambulacral primary tubercles are crenulate, non perforate. The areoles are large at the ambitus, but small adapically. They are not confluent. Adapical areoles are separated by wide, granulated zones. All areoles are shallow. Scrobicular rings are complete and consist of 12 small scrobicular tubercles at the ambitus. Interradial extrascrobicular surfaces are covered with a very fine, very dense granulation. The granulated surfaces are very conspicuous adapically, where the scrobicules diminish in size.

Diagnostic features.

1. Smooth pentagonal apical system, with interradian angles and large sutural depressions.
2. Genital pores in depressions, similar to sutural depressions, in the centres of the genital plates.
3. Ambulacra straight; ambulacral tubercles hardly larger than granules.
4. Granulated extrascrobicular surfaces very important adapically, where interambulacral scrobicules and tubercles are small.

Discussion.

This is a very characteristic species, which cannot be confused with other saleniids. I do not know any salenioid echinoid corresponding to the description above, nor even resembling it superficially. So I had to consider this specimen a new species. Comparisons to other known species can only be trivial.

SALENIA BATNENSIS Peron and Gauthier, 1879
(Pl. IV, fig. 1-5)

- *•1879. *Salenia batnensis*, Cotteau, Peron and Gauthier, p. 183-185, Pl. 13, fig. 7-13.

- *•1889. *Salenia tunetana*, Gauthier, p. 65, Pl. 4, fig. 8-13; fide Fourtau (1914).
•1910. *Salenia batnensis*, Lambert and Thiery, p. 210.
1914. *Salenia batnensis* race *tunetana*, Fourtau, p. 9-10.
•1918. *Salenia batnensis* var. *tunetana*, Stefanini, p. 122-123, Pl. 5, fig. 2a-c.
•1921. *Salenia batnensis*, Checchia-Rispoli, p. 9.
•1932. *Salenia batnensis*, Lambert, p. 157.

LOCUS TYPICUS: Djebel Iche-Ali gorge, south of Batna, Algeria.

STRATUM TYPICUM: Cenomanian.

OTHER OCCURRENCES OUTSIDE JORDAN: Lybia: Cenomanian at Gusbat (Checchia-Rispoli, 1921); Tunisia: Cenomanian (Gauthier, 1889); Egypt: Cenomanian near St. Paul's Convent (Eastern Desert) and at Wadi Thal (Sinai) (Fourtau, 1914).

SPECIMEN STUDIED: Locality 4; Member 16, Suweilih Formation, Nodular Limestone, Cenomanian: 1 specimen (IST 10211).

Dimensions.

D = 20.4 mm; h = 16.1 mm; h/D = 0,79;
ds = 10,5 mm; ds/D = 0,51.

Description.

Medium to large sized *Salenia*, with high, globular shape.

The peristome is small and not sunken. Gill slits are fairly deep and surrounded by a fold of calcareous material.

The apical system is relatively small. Its 11 plates are separated by clearly visible sutures, marked by sutural depressions. These sutural depressions are situated: a) at the contacts of 1 ocular and 2 genitals, b) at the contacts of the suranal and 2 genitals, c) in the middle of the sutures between any two adjacent plates. The plates are smooth. The ocular plates are triangular, the genital plates are hexagonal. The genital pore is situated in an oval depression, near the distal border of the genital plate and sometimes connected to it. Genital plate 2, the madreporite, shows a conspicuous, rectangular, poriferous depression, occupying some 70 % of the plate's surface. This depression is densely granulated. The pores open between the granules. The periproct is oval and larger than in most salenioids. As a result, genital plates 1 and 5, as well as ocular plate I are exceedingly small. The periproct is surrounded by a high ridge, giving it a protruding appearance.

Primary tubercles are 29 or 30 in each ambulacral series. These primary tubercles are non crenulate, non perforate. The ambulacra are sinuous and very regularly bigeminate. A coarse granulation is concentrated along the perradial suture. The interporous partitions carry a coarse granule. The pore pairs are

closely spaced and separated by a furrow-like suture. The axes of the pore pairs have an inclination of about 20°.

Interambulacral primary tubercles are crenulate, non perforate. They are 7 in a series. The scrobicules are smooth, conical and surrounded by a ring of about 17 scrobicular tubercles. The scrobicules are not confluent. Interradial extrascrobicular surfaces are narrow, sinuous and coarsely granulated.

Diagnostic features.

1. Conspicuous rectangular, granular poriferous depression, occupying the larger part of the madreporite 2.
2. Huge protruding periproct.
3. Sinuous ambulacra, with about 30 primary tubercles in each series.
4. Closed scrobicular rings; scrobicules not confluent.

Discussion.

Salenia batnensis is a readily recognizable species, because of its large, rectangular poriferous depression and its huge, protruding periproct. These features give the apical system a very characteristic appearance.

I agree with Fourtau (1914) in rejecting *S. tunetana* Gauthier, 1889 as a separate species, and in uniting it with *S. batnensis*. The differences between both species are few and subtle (apical system slightly larger, peristome slightly smaller and one interambulacral plate less in *S. tunetana*). Since only a few specimens of each species are known, the differences seem subjective and insufficient to justify the establishment of a separate species, or even subspecies. Hence, I consider *S. tunetana* as a junior synonym of *S. batnensis*.

A closely related species is *S. choffati* de Loriol, 1887 (Pl. 3, fig. 2-3) (Cenomanian of Portugal). It differs from *S. batnensis* by its much smaller and triangular poriferous depression, by the shape of its genital plates, by its narrower extrascrobicular surfaces and by its narrower ambulacra.

Ordo HEMICIDAROIDA Beurlen, 1937

Familia HEMICIDARIDAE Wright, 1857

Genus *HETERODIADEMA* Cotteau, 1862

Type species: *Pseudodiadema martinianum* (Cotteau, 1859) [= *H. lybicum* (Agassiz and Desor, 1846), *sensu* Cotteau, 1864]; original designation.

Diagnosis: « Apical system penetrating deeply into interambulacrum 5; ambulacral plates trigeminates throughout (Fell and Pawson, 1966) ».

HETERODIAMEMA LYBICUM

(Agassiz and Desor, 1846)

(Pl. IV, fig. 6-7; Pl. V, fig. 1-2)

v. 1980. *Heterodiadema lybicum*, Geys, p. 445-451, Pl. 8 (extensive synonymy in this paper).

SPECIMEN STUDIED: Locality 3: Member 13, Suweilih Formation, Nodular Limestone, Cenomanian: 1 crushed specimen; Locality 5a: Member 20, Naur Formation, Nodular Limestone, Cenomanian?: 1 poorly preserved specimen; Locality 5b: Member 20, Naur Formation, Nodular Limestone, Cenomanian?: 10 specimens (among which IST 10212); Locality 7a: Member 22, Fuheis Formation, Echinoidal Limestone, Turonian: 1 specimen.

Dimensions.

D = 24.3 - 38.4 mm; h = 10.5 - 20.0 mm; mean h/D = 0.48; ds = 10.8 - 15.5 mm; mean ds/D = 0,40; dp = 8.2 - 12.7 mm; mean dp/D = 0.32.

Description.

Given at length by Geys (1980).

Diagnostic features.

1. Pentagonal apical system, extending deeply into depressed interradian zone of interambulacrum 5.
2. Aboral side slightly convex, but peristome not sunken; gill slits fairly deep.
3. Fine and dense granulation on all extrascrobicular surfaces.

Discussion.

The Cenomanian specimen from Locality 3 is much smaller than the Turonian individuals (D = 15 mm; h = 7 mm). This agrees with the observations of Fourtau (1914) who mentioned similar differences in size between Cenomanian and younger specimens.

Familia PSEUDODIADEMATIDAE Pomel, 1883

Genus *TETRAGRAMMA* Agassiz, 1840

Type species: *Cidarites variolare* Brongniart, in Cuvier, 1822; by subsequent designation of Lambert and Thiery, 1910.

Diagnosis: « Flattened test of moderate size; apical system not penetrating deeply into interambulacrum 5; poriferous zones diplopodous adapically; two large tubercles on each interambulacral plate (Mortensen, 1935; Fell and Pawson, 1966) ».

TETRAGRAMMA cf. *VARIOLARE*
(Brongniart, 1822)

(Pl. V, fig. 3-4)

v. 1985. *Tetragramma variolare*, Geys (forthcoming)
(extensive synonymy in this paper).

SPECIMENS STUDIED: Locality 1: Member 2, Rumeimin Formation, Nodular Limestone, Cenomanian: 1/2 specimen; Locality 4: Member 16, Suweilih Formation, Nodular Limestone, Cenomanian: 1 specimen (IST 10213).

Dimensions (of specimen IST 10213).

$D = 44.4 \text{ mm}$; $h = 16.3 \text{ mm}$; $h/D = 0.37$.

The state of preservation of the specimen is such, that no other dimensions can be measured.

Description.

Given at length by Geys (forthcoming).

Diagnostic features.

1. Presence of 4 series of interambulacral primary tubercles.
2. Poriferous zones strongly diplopodous adapically.
3. Peristome slightly sunken (not visible in the specimens under discussion).

Discussion.

Owing to their poor state of preservation, the specific identification of the specimens from Jordan remains slightly uncertain. Therefore I added cf. to their name.

Genus *TROCHOTIARA* Lambert, 1901

Type species: *Diadema priscum* Agassiz, 1840; by original designation.

Diagnosis: « Small, flattened test; poriferous zones straight, widening near the peristome; ambulacral plates trigeminate at the ambitus; adapical part of interradial extrascrobicular surfaces naked and depressed (Fell and Pawson, 1966) ».

TROCHOTIARA MOABITORUM sp. nov.

(Pl. V, fig. 5-7; Pl. VI, fig. 1-3)

LOCUS TYPICUS: Rumeimin (Locality 1), near Amman, Jordan.

STRATUM TYPICUM: Member 2, Rumeimin Formation, Nodular Limestone, Cenomanian.

DERIVATIO NOMINIS: from the Moabites, inhabitants of the biblical kingdom of Moab, on the left bank of the River Jordan.

LOCATION OF THE HOLOTYPE: K.B.I.N. collections n° IST 10214.

SPECIMENS STUDIED: Locality 1: Member 2, Rumeimin Formation, Nodular Limestone, Cenomanian: 1 specimen (IST 10214).

Dimensions.

$D = 12.7 \text{ mm}$; $h = 4.7 \text{ mm}$; $h/D = 0.37$;
 $ds = 7.9 \text{ mm}$; $ds/D = 0.62$; $dp = 5.5 \text{ mm}$;
 $dp/D = 0.43$.

Description.

Small *Trochotiara*, with strongly flattened, wheel-shaped test. The adoral surface is distinctly concave, the peristome being sunken.

The peristome is circular and shows distinct gill slits, surrounded by calcareous folds.

The apical system is large. Its plates are lost, but it leaves a pentagonal hole, penetrating deeply into interambulacrum V.

Ambulacra are narrow and slightly swollen. Primary tubercles are perforate and crenulate; there are 9 or 10 in a series. Scrobicules are small, not confluent and surrounded by a complete scrobicular ring. Per-radial extrascrobicular surfaces are narrow and covered by a dense granulation. Ambulacral plates are compound diadematoid and trigeminate. The axes of the pore pairs are slightly oblique at the ambitus. Poriferous zones are simple and straight at the ambitus. They broaden slightly in the immediate vicinity of the peristome. Adapically the poriferous zones are slightly zigzagging, without being really biserial.

Interambulacra are almost twice as large as the ambulacra. Primary tubercles are perforate, crenulate and 9 or 10 in a series. Their size is the same as that of the ambulacral tubercles. Scrobicules are not confluent: one or two rows of tiny granules separates them. Interradial extrascrobicular surface are covered by a dense and coarse granulation, except adapically, where they are naked, smooth and very slightly depressed. Agradially, wide extrascrobicular surfaces bear a regular series of small secondary tubercles and a dense, coarse granulation. Interambulacral plates are horizontally elongated.

Diagnostic features.

1. Concave adoral surface; sunken peristome.
2. Poriferous zones simple, zigzagging adapically, very slightly widened near the peristome.
3. Wide extrascrobicular surfaces on adradial side of interambulacra, carrying tiny secondary tubercles.
4. Large, pentagonal apical system, penetrating deeply into interambulacrum 5.

Discussion.

This new species is closely related to *Pseudodiadema macilentum* Cotteau, Peron and Gauthier, 1878 (Pl. 14, fig. 6-11) (Cenomanian of Algeria). *T. moabitorum* differs from the latter in its interambulacra. Interradial extrascrobicular surfaces are less developed and primary tubercles are more numerous in *P. macilentum*.

Ordo PHYMOSOMATOIDA Mortensen, 1904

Familia PHYMOSOMATIDAE Pomel, 1883

Genus *PHYMOSOMA* Haime, 1853

Type species: *Cidaris koenigi* Mantell, 1822, by subsequent designation of Lambert and Thiery (1910).

Diagnosis: « Low, flattened test; polyporous ambulacral plates; poriferous zones biserial adapically; no conspicuous radiating grooves on interambulacral scrobicules (Mortensen, 1935; Fell and Pawson, 1966) ».

PHYMOSOMA MANSOUR

(Peron and Gauthier, 1881)

(Pl. VI, fig. 4-7)

- *•1881. *Cyphosoma mansour*, Cotteau, Peron and Gauthier, p. 108, Pl. 7, fig. 10-15.
- 1910. *Phymosoma mansour*, Lambert and Thiery, p. 225.
- 1932. *Phymosoma mansour*, Lambert, p. 157.

LOCUS TYPICUS: Mansourah, Constantine, Algeria.

STRATUM TYPICUM: Santonian.

SPECIMEN STUDIED: Locality 9a: Member 36, Wadi Sir Formation, Massive Limestone, Coniacian: 1 specimen (IST 10215).

Dimensions.

$D = 35.5 \text{ mm}$; $h = 21.0 \text{ mm}$; $h/D = 0.59$;
 $ds = 14.8 \text{ mm}$; $ds/D = 0.42$; $dp = 15.7 \text{ mm}$;
 $dp/D = 0.44$.

Description.

Large *Phymosoma* with high, hemispherical test. The adoral side is flattened, the peristome is not sunken. The adapical side is hemispherical to conical.

The peristome is of medium size and circular. Gill slits are well developed and surrounded by calcareous folds.

The plates of the apical system are lost. They leave a fairly large, pentagonal hole in the top of the test.

Each ambulacral series consists of 14 crenulate, non perforate primary tubercles. The scrobicules are smooth and slightly swollen. They are not confluent, but separated by a single row of coarse granules. The perradial extrascrobicular surface is sinuous and shows a double row of coarse granules; the interstices between them are covered with a very fine granulation. The ambulacral plates are 5-geminate. The poriferous zones are undulating at and below the ambitus; adapically they are biserial and straight; they widen in the immediate vicinity of the peristome. The pore pairs are very slightly inclined to subhorizontal.

Interambulacra are wider than the ambulacra. Primary tubercles are crenulate, non-perforate, in a series of 13. Scrobicules are smooth, slightly conical and not confluent. Simple horizontal rows of small granules separate them. Interradially, a fairly wide, densely and coarsely granulated extrascrobicular surface separates the series of tubercles. Near the apical system the extrascrobicular surfaces are naked and smooth. Adradially regular series of secondary tubercles occur. These secondary tubercles are crenulate, non-perforate and hardly larger than the small scrobicular tubercles, which surround the primary tubercles. On each plate are 4 secondary tubercles.

Diagnostic features.

1. Not flattened, conical shape of the test.
2. Scrobicules not confluent.
3. Peristome not sunken.
4. Poriferous zones biserial adapically and widening near the peristome.
5. Regular series of small secondary tubercles.

Discussion.

Phymosoma mansour differs from *Rachiosoma said* (Peron and Gauthier, 1881) (Cotteau, Peron and Gauthier, 1881, Pl. 19, fig. 3-10; Campanian of Algeria) in its poriferous zones, which are undulating and biserial adapically in the former, straight and simple throughout in the latter.

Confusion with *Phymosoma foukanense* (Peron and Gauthier, 1881) (Cotteau, Peron and Gauthier, 1881, Pl. 6, fig. 1-6; Santonian of Algeria) is possible. Interambulacral secondary tubercles are considerably smaller in *P. mansour* than in *P. foukanense*.

The same feature permits the distinction between *P. mansour* and *Phymosoma archiaci* (Agassiz, 1846) (Cotteau, 1863, Pl. 1149; Lower "Senonian" of SW and S France). Moreover, *P. archiaci* has three series of tubercles on each half interambulacrum, while *P. mansour* has only two.

Also *P. solignaci* Lambert, 1931 (Pl. 4, fig. 1, 3; Santonian of Tunisia) has three series of tubercles in each half interambulacrum. In spite of superficial

resemblance, this species can be distinguished easily from *P. mansour*.

Also easy to distinguish are *P. mansour* and *Phymosoma palaestinense* (Blanckenhorn, 1925) (Pl. 7, fig. 4-6; Turonian-Santonian of Palestina). In the former, ambulacral plates are 5-geminate, scrobicules are not confluent and secondary tubercles are 4 on each plate. In the latter, ambulacral plates are 6-geminate, scrobicules are confluent and there are only two secondary tubercles on each plate.

Differences with *P. maresi* (Cotteau, 1864) are discussed under the next heading.

PHYMOSOMA MARESI (Cotteau, 1864)

(Pl. VII, fig. 1-5)

- *•1864. *Cyphosoma maresi*, Cotteau, p. 619, Pl. 1150.
- 1881. *Cyphosoma maresi*, Cotteau, Peron and Gauthier, p. 98-99.
- 1910. *Phymosoma maresi*, Lambert and Thiery, p. 225.
- 1932. *Phymosoma maresi*, Lambert, p. 157.
- 1975. *Phymosoma maresi* Zaghbib-Turki, p. 31-32, Pl. 1, fig. 19-21.

LOCUS TYPICUS: right bank of Oued Djelfa (between salt rock and Djelfa), Ain Zemera, Algeria.

STRATUM TYPICUM: Santonian.

OTHER OCCURRENCES OUTSIDE JORDAN. Tunisia: Coniacian, Santonian and Campanian of Central Tunisia (Zaghbib-Turki, 1975).

SPECIMENS STUDIED: Locality 7a: Member 22. Fuheis Formation, Echinoidal Limestone, Turonian: 12 specimens (among which IST 10216).

Dimensions.

D = 15.8 - 27.2 mm; h = 7.0 - 13.3 mm;
mean h/D = 0.51; ds = 6.7 - 11.3 mm;
mean ds/D = 0.38; dp = 6.7 - 11.2 mm;
mean dp/D = 0.41.

Description.

Medium sized *Phymosoma*, with flattened to hemispherical test. The adoral side is flat; the peristome is not sunken. The adapical side is hemispherical to conical.

In some specimens the corona is distinctly pentagonal at the ambitus. The peristome is circular. Gill slits are well developed and surrounded by a calcareous fold.

Each ambulacral series consists of 15 crenulate, non perforate tubercles. The scrobicules bear a very faint radiating striation. The bosses are low. The scrobicules are not confluent, but separated by narrow

belts of fine granules. The perradial extrascrobicular surfaces are narrow, sinuous and granulated. The ambulacral plates are 4-geminate. The poriferous zones are almost straight at and below the ambitus; adapically they are biserial. There is some widening of the poriferous zones in the immediate vicinity of the peristome. The pore pairs are horizontal throughout.

Interambulacra are almost twice as wide as the ambulacra. Crenulate, non perforate primary tubercles form series of 11. The bosses are low and very faintly sculptured with radiating grooves. Scrobicules are not confluent. Simple horizontal rows of fine granules separate them. Interradial extrascrobicular surfaces are fairly wide and covered by a fine granulation, which fades out towards the apex. Adapically, the interradial extrascrobicular surfaces are naked and smooth. Adually, regular series of well developed secondary tubercles are present. These secondary tubercles are crenulate, non perforate and, at the ambitus the secondary tubercles abruptly diminish in size.

Diagnostic features.

1. Rounded, to pentagonal outline of the test.
2. Scrobicules not confluent.
3. Peristome not sunken.
4. Poriferous zones widening near the peristome.
5. Regular series of secondary tubercles, large at the ambitus, small adapically.

Discussion.

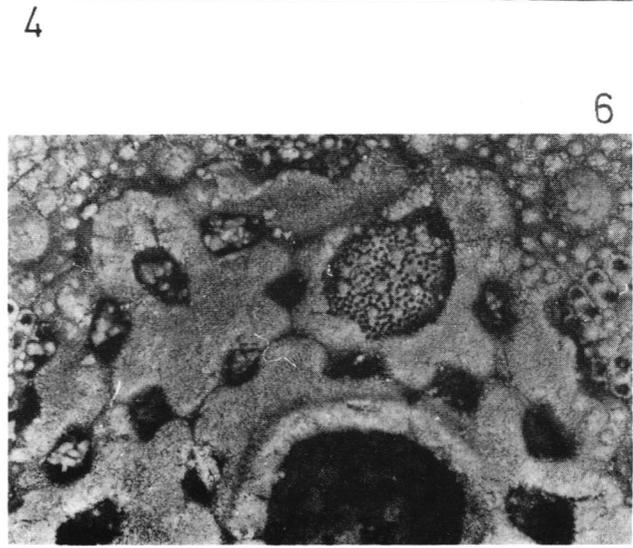
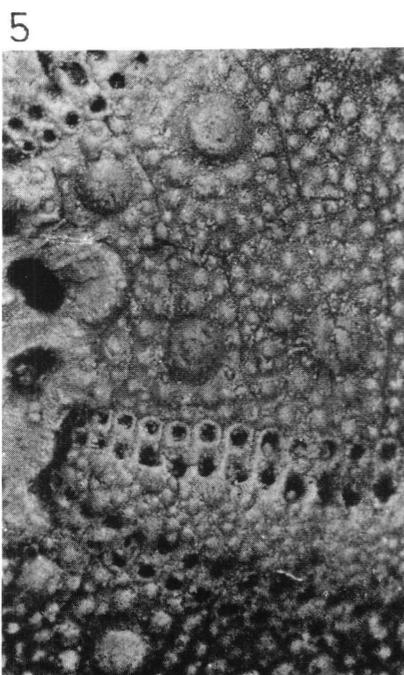
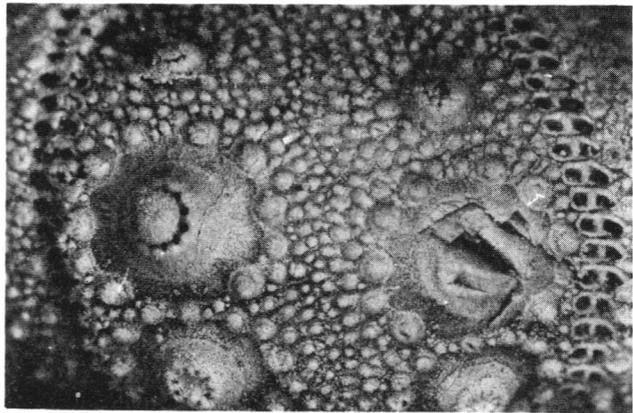
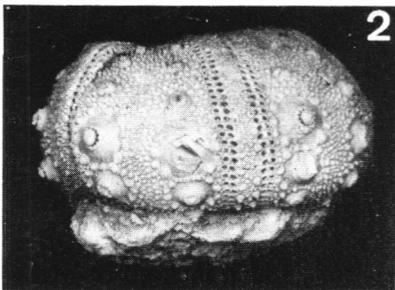
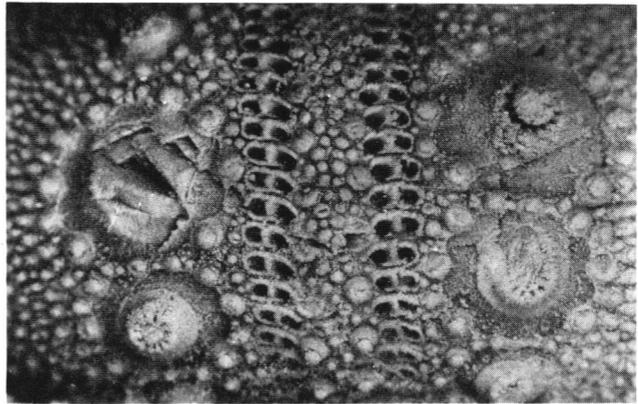
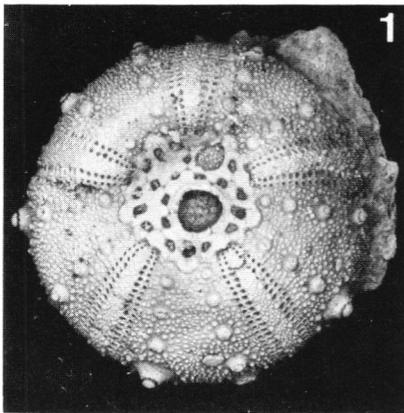
Phymosoma bourgeoisi (Cotteau and Triger, 1860) (Cotteau, 1865, Pl. 1153; Lower Senonian of W France) bears a superficial resemblance to *P. maresi*, owing to its hemispherical test. The shape of the former is more conical, its poriferous zones are straight and its secondary tubercles are less well developed.

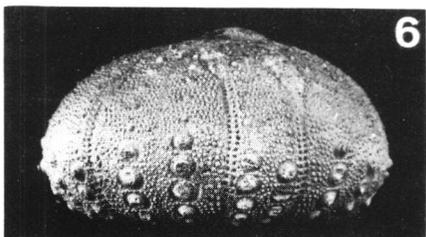
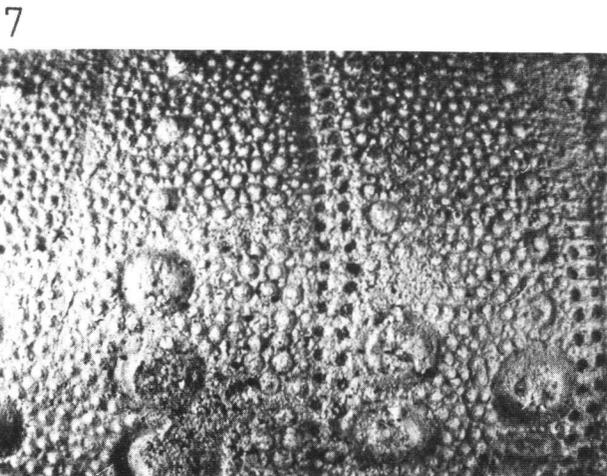
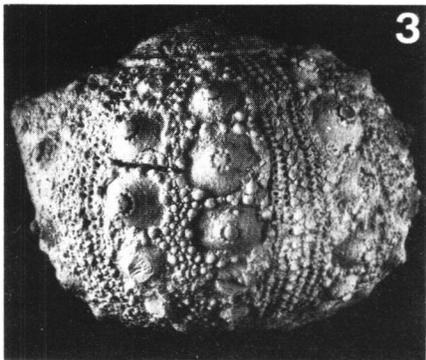
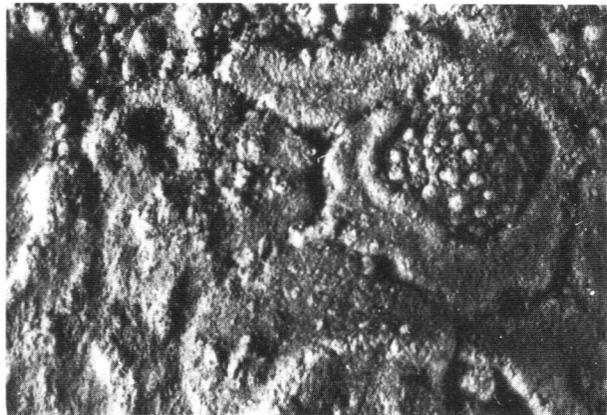
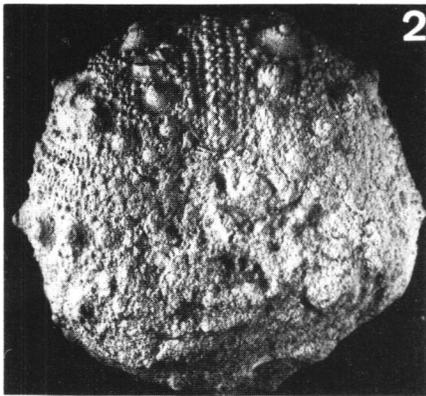
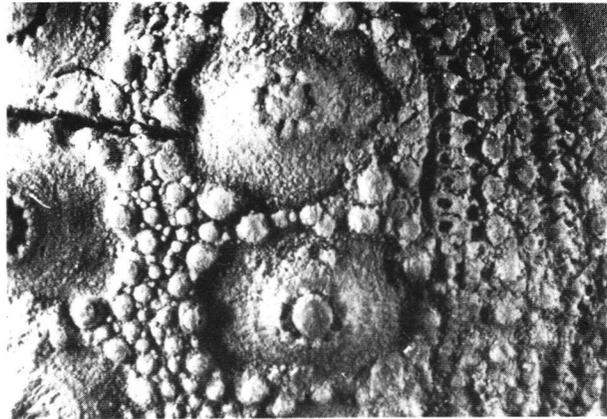
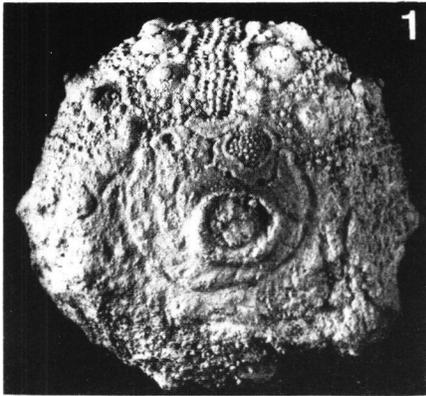
P. maresi can be distinguished from *Phymosoma mansour* (Peron and Gauthier, 1881) (see above) by the better developed secondary tubercles, the smaller size, the more flattened shape and the less sinuous poriferous zones, in the former species.

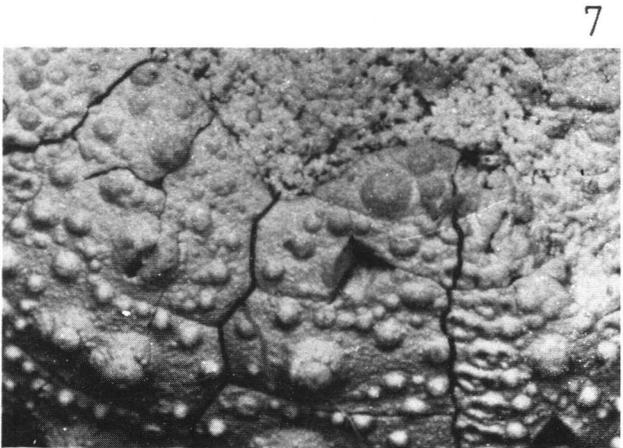
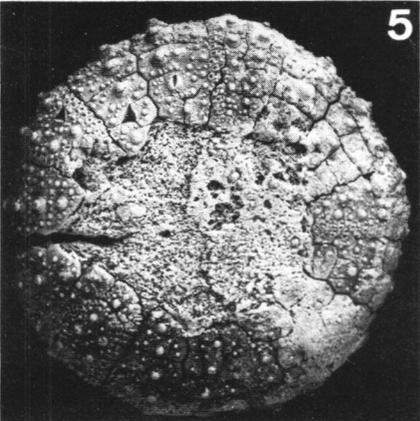
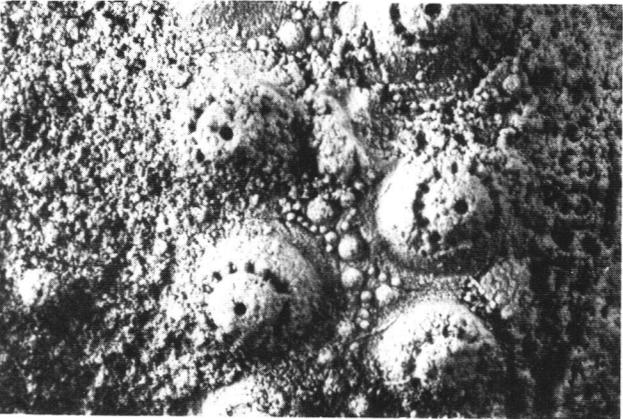
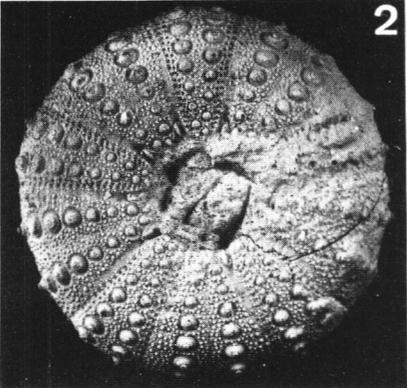
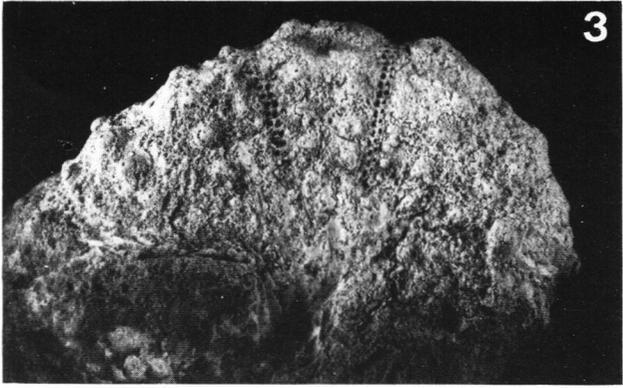
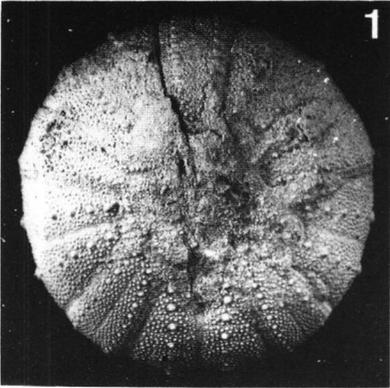
Ambulacral plates are 4-geminate, scrobicules are not confluent in *P. maresi*, while ambulacral plates are 6-geminate and scrobicules are confluent in *Phymosoma palaestinense* (Blanckenhorn, 1925) (Pl. 7, fig. 4-6; Turonian-Santonian of Palestina).

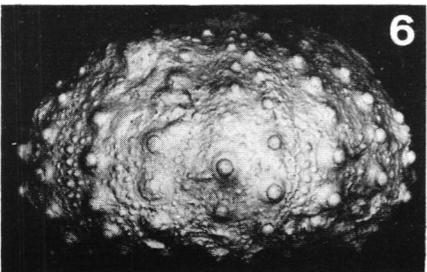
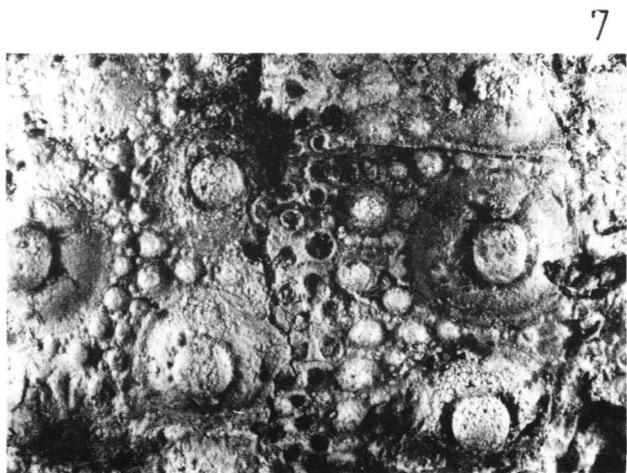
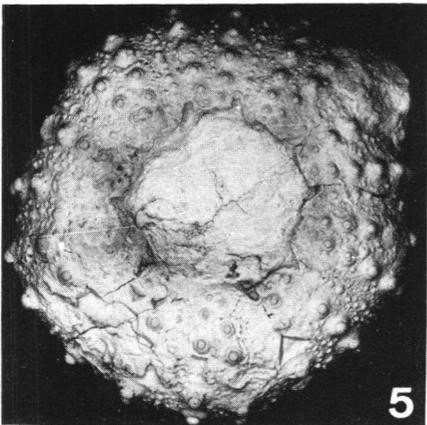
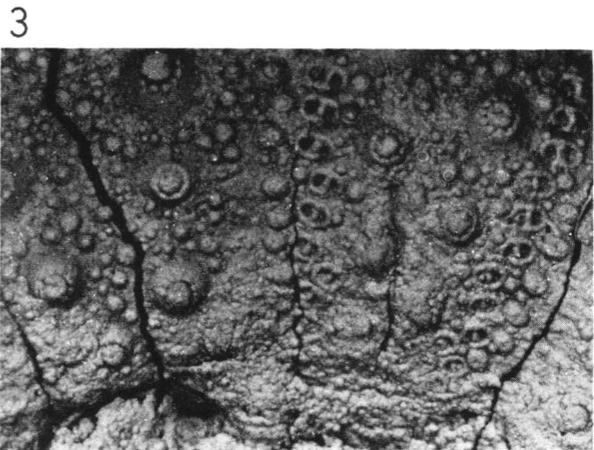
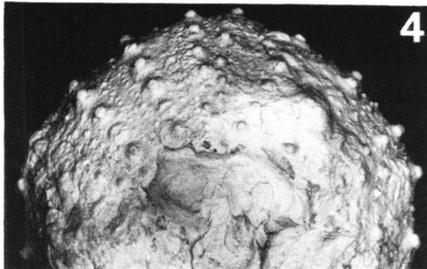
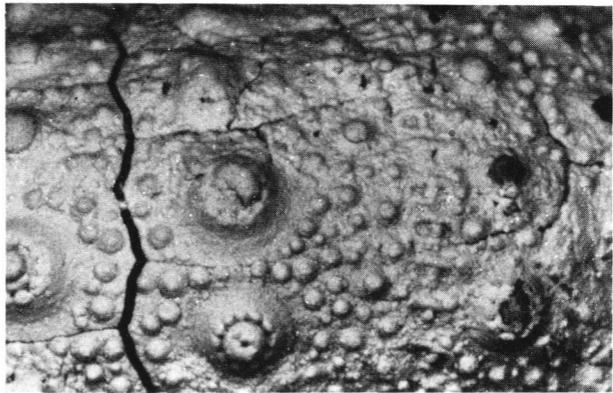
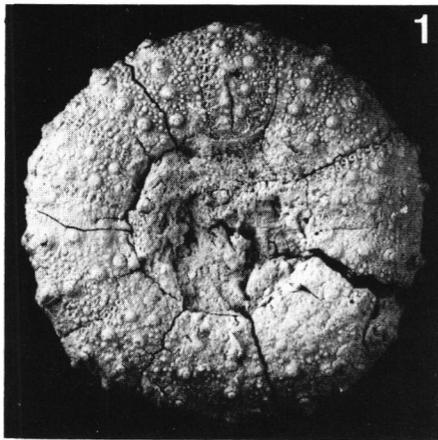
Genus *RACHIOSOMA* Pomel, 1883

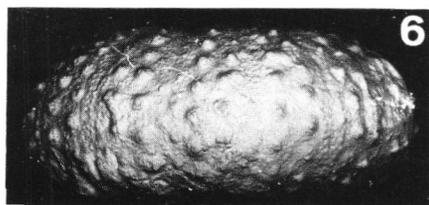
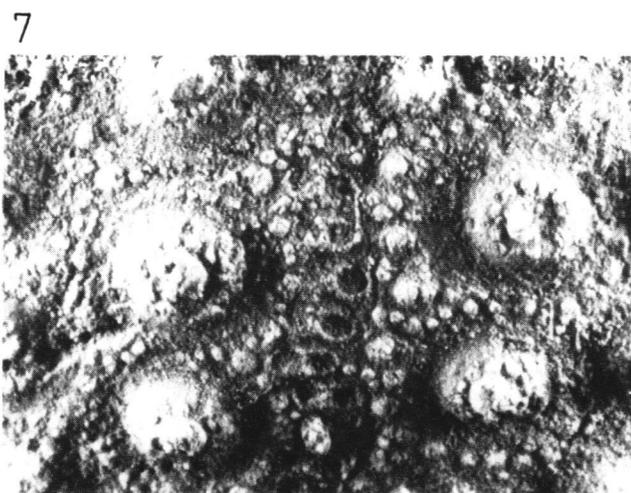
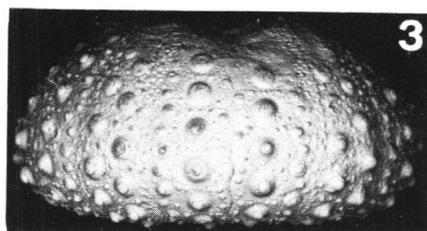
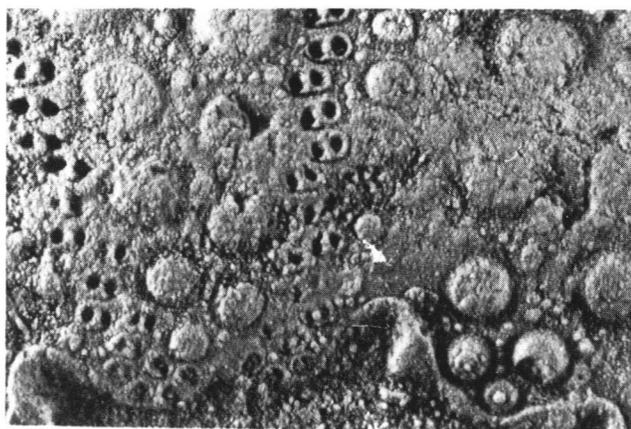
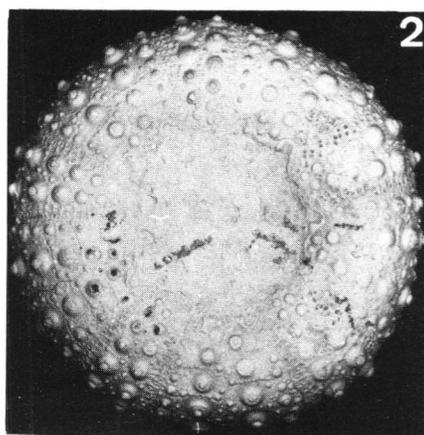
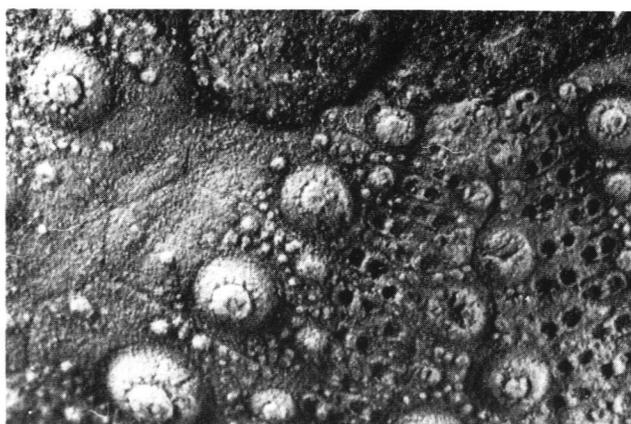
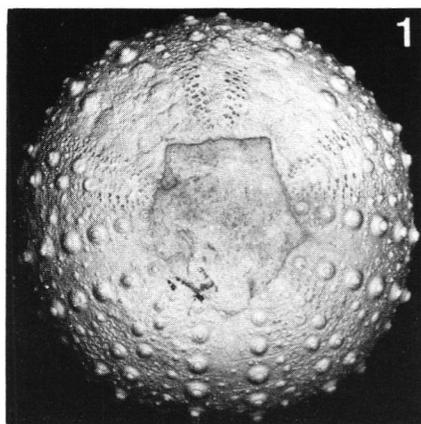
Type species: *Cyphosoma delamarrei* Deshayes, in Agassiz and Desor, 1846; by subsequent designation of Lambert and Thiery, 1910.

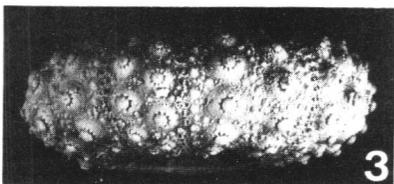
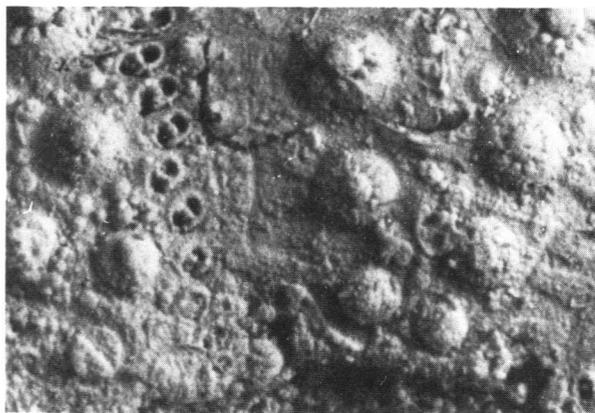
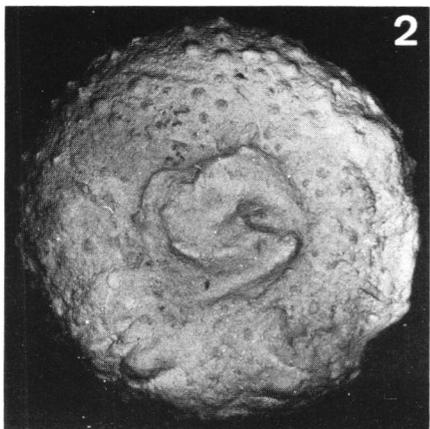
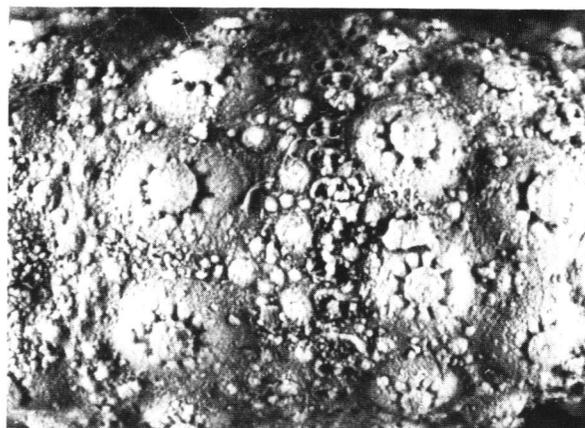
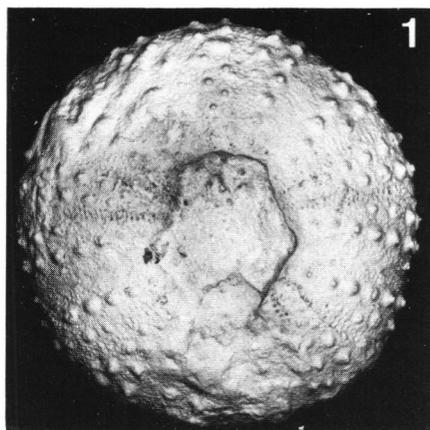












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