The tertiary stratigraphy and echinoid palaeontology of Gozo, Malta

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THE TERTIARY STRATIGRAPHY AND ECHINOID PALAEONTOLOGY OF GOZO, MALTA

by

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GRID REFERENCES in the thesis give the exact location of places referred to and are accompanied by the name of the nearest important locality. The grid used is that shown on the two-inch sheets of Malta and Gozo, G.S.G.S. 3859, 4th Edition, 1954.

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GOZO – an aerial view from the north-west

Abstract.

The following succession of Tertiary rocks is established on the Maltese island of Gozo (youngest beds first):

Upper Coralline Limestone, over 290 feet; Transitional Greensand, 0 to 40 feet; Blue Clay, 0 to 200 feet; Upper Globigerina Limestone, 40 to 110 feet; Middle Globigerina Limestone, 0 to 60 feet; Lower Globigerina Limestone, 17 to 75 feet; Scutella Bed, $\frac{1}{2}$ to 20 feet; Lower Coralline Limestone, over 450 feet.

The algal and foraminiferal Lower Coralline Limestone was probably deposited in shallow water. The prominent Scutella Bed resembles a near-surface shell bank. Two phosphatic nodule beds, possibly marking stagnant periods, separate the Globigerina Limestones. The lower and upper divisions are formed of pelagic foraminifera with lamellibranchs and neritic echinoids. The middle division, a marly limestone, may be a deeper water deposit but has an upper, coarser facies in south-west Gozo. The Lower and Middle Globigerina Limestones thin eastward and the latter is absent over much of the eastern area where the nodule beds coalesce. The Upper Globigerina Limestone—Blue Clay boundary, despite some previous opinions, is always sharp. The two beds have faunal similarities, their lithological differences are probably caused by a sudden onset of mud deposition. Variations in thickness of the Blue Clay are considered to have an erosional origin. There is a gradual passage through the glauconitic Transitional Greensand, which varies in thickness and lithology and has a thick-shelled fauna suggesting a shallow water origin, to the Upper Coralline Limestone, which has a soft, lower division and a hard upper one, complicated by

lateral variation and later recementation.

The echinoids from the above succession are listed and the following ten species are described and figured:

Scutella subrotunda, *Scutella* sp. nov., *Hemiaster scillae*, *Hemiaster cotteaui*, *Pericosmus latus*, *Gregoryaster lorioli*, *Schizaster eurynotus*, *Schizaster parkinsoni*, *Eupatagus dekonincki*, *Echinolampas* ~~sp.~~ *lucae*.

P R E F A C E

The Maltese Islands have been well known for their rocks and fossils since man's early days. Probably the earliest extant reference to fossils, made by Xenophanes of Colophon (c. 614 BC), mentions the remains of animals preserved in the exposed rocks along the sea-shore of Malta. Some of these fossils were figured by the Sicilian, Scilla, in 1747 and the first systematic geological descriptions were started about a hundred years later.

Little has been added to the detail during the present century, particularly in the case of the lesser-known, second island, Gozo. The material presented in this thesis consists of two parts, first a stratigraphical description of the Tertiary rocks of the Maltese island of Gozo, accompanied by a six inch to the mile geological map of the island, and secondly, a systematic palaeontological description of selected echinoids from the rocks, with a list of all the echinoids collected in Gozo.

This work is based on visits made to Gozo in the autumn of 1958 and the spring of 1960, during which geological field-mapping on a scale of 25 inches to the mile and intensive collecting of echinoids, with representatives of the rest of the fauna, were carried out.

In addition, visits were made to examine the collections of Tertiary echinoids at the British Museum (Natural History) in London, the Sedgwick Museum in Cambridge, the École National Supérieure des Mines, the Muséum National d'Histoire Naturelle, and the Université de Paris, Sorbonne, in Paris.

The remainder of the period from 1959 to mid 1961 was spent in the Department of Geology of the Durham Colleges and was occupied mainly in cleaning, describing, photographing and identifying part of the collection of echinoids.

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GENERAL INTRODUCTION

Gozo is the second largest of the islands which make up the present British colony*of Malta. The Maltese Islands form an isolated group, situated on a submarine ridge which divides the Mediterranean into two hydrographic basins. Sicily lies 50 miles north-north-west of Gozo, the volcanic islands of Linosa, Lampedusa and Pantellaria are 70 and 100 miles south-west and 120 miles north-west respectively. The nearest part of Africa is Tunisia, 175 miles to the west. The Libyan coast lies 225 miles to the south, yet the same distance to the east is the deepest part of the Mediterranean, over 14,000 feet below sea-level.

Gozo is at the north-western end of the Maltese archipelago. Its length from east to west is nine miles, the greatest width is four miles and it has an area of 26 square miles. Like the other Maltese Islands, Gozo is almost entirely composed of Tertiary limestones, marls, clays, glauconitic sands and phosphatic nodule beds. Of these the limestones predominate. The Tertiary rocks have a gentle north-eastern regional dip with considerable flexing and faulting in the southern half of the island.

In addition, there are small patches of Pleistocene conglomerates and marls coating the sides of some valleys and sections of cliff. Recent blown sand covers earlier deposits at the head of Ramla Bay. The Tertiary rocks of Gozo contain a rich fauna. It includes vertebrate remains, most

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* newly-independent

noticeable of which are shark teeth, echinoids, lamellibranchs, gastropods, (including pteropods), nautiloids, brachiopods and foraminifera. Apart from the microfauna, the most abundant and varied fossils are the echinoids which occur throughout the stratigraphical succession and provide some information about both the sequence of depositional conditions and the relationship with other Tethyal Miocene deposits.

The present relief features of the island are closely related to the underlying geology. High and sheer limestone cliffs exist round the north, west and south-west coasts (see frontispiece), while along the north-eastern coast, where the regional dip carries these lower limestones below sea-level, there are four bays separated by crumbling headlands of an upper limestone which rests on unstable clay slopes. A similar coast-line occurs in the south-east where faulting has brought the clays down to sea-level. At least four of the small fishing harbours owe their existence to faulting, and inland there are several fault-line scarps prominent enough to affect human settlement patterns. The latter are also strongly affected in the northern half of Gozo by a series of distinctive mesas produced by protective caps of the upper limestone which rest on the easily eroded clays with limestone below. Within the limestones prominent features result from the variations in hardness and the nodule beds in particular form striking ledges around much of the coast.

Previous Literature:

The two most important papers on Maltese geology, at least as far as the scope of this study is concerned, appeared within a year of each other.

In 1890 Sir (then Dr.) John Murray published a full description of the geology of the Maltese Islands which included a half inch geological map, details of the chemical composition of the rocks and suggestions about the conditions of deposition. In 1891 Professor (then Mr.) J.W.Gregory described the fossil echinoids of Malta with the evidence they provide for correlations.

Subsequently published work has not added a great deal to the above except for details of the echinoid correlation (Stefanini, 1908 and Cottreau, 1914), the Pectinid fauna (Roman and Roger, 1939 and Eames and Cox, 1956), Quaternary conditions (Trechmann, 1938), and water supply (Morris, 1952). Hyde (1955) provides a general summary which is rather inadequate, particularly for palaeontology, and Bowen-Jones et al. (1961) gives a short, up-to-date account.

In addition, for the study of the echinoids, the classic monograph of Mortensen (1928) formed the basis of the identifications made, supplemented in particular by studies by Durham (1955) on the clypeasteroid echinoids and by Kier (1962) on the cassiduloid echinoids. A complete bibliography of papers and books consulted is found at the end of the thesis.

STRATIGRAPHICAL INTRODUCTION

The following succession of Tertiary rocks has been established for Gozo (from top to bottom with the ranges of thickness measured):

Upper Coralline Limestone -	- over 290 feet
Transitional Greensand	- 0 to 40 feet
Blue Clay	- 0 to 200 feet
Upper Globigerina Limestone	- 40 to 110 feet
Middle Globigerina Limestone	- 0 to 60 feet
Lower Globigerina Limestone	- 17 to 75 feet
Scutella Bed	- ½ to 20 feet
Lower Coralline Limestone	- over 450 feet

This succession differs little from that drawn up by Murray in 1890. Detailed modifications for each formation are mentioned in the descriptions which follow. Most important are the separation of the Scutella Bed as a formation, mainly as a consequence of its great stratigraphical value, and the three-fold division of the Globigerina Limestone on the basis of two prominent phosphatic nodule beds.

As far as depositional conditions are concerned, Murray's views (1890, p.479-80) provide a reasonable general picture. He envisaged a series of deposits laid down at varying distances from a continental coast-line, beginning with shallow oceanic banks during the Lower Coralline Limestone period. These banks subsided and then re-emerged during the time of Globigerina Limestone deposition. River-borne sediments from the approaching shore-line produced the Blue Clay, whilst the Transitional Greensand marked a period of even shallower water and the Upper Coralline Limestone deposits were produced during a reversion to the initial shallow banks.

Important in Murray's views were his opinions that ''the diversity observed in the various Maltese rocks is to be referred rather to the depth of the sea and distance from land at which they were formed than to difference in time'' and that these rocks ''could quite well have been forming along a coast-line at one and the same time.'' Although there is an element of exaggeration in Murray's views, for example, his opinion on the contemporaneity of the Blue Clay and the Upper Globigerina Limestone (1890, p.469 - discussed under Blue Clay), his views accord with the paleontological results (discussed in the Paleontological Introduction) and with recent correlations of the Maltese succession, mentioned below. Most important of the additions to Murray's picture are the significance of the phosphatic horizons in the Globigerina Limestone, the facies-variations and local non-sequence in the Middle Globigerina Limestone, and facies-variations in the Transitional Greensand and Upper Coralline Limestone.

As far as correlation with other Tertiary sediments is concerned, the present study has provided no direct evidence. Indirect evidence has come mainly from the reduction in the number of echinoid species and the consequent simplification of comparison with neighbouring successions. This is discussed later in the Palæontological Introduction.

Eames et al (1962, p.16 ff.) have given the most recent allocation of the Maltese succession to the standard European stages. On the basis of the planktonic foraminifera they consider that the whole of the succession falls within the Aquitanian and Burdigalian stages of the Miocene with the junction occuring somewhere in the Globigerina Limestone. At the opposite extreme, Gregory (1891, p.634-638) considered the Lower Coralline Limestone to be of Tongrian (Lower Oligocene) age and the Upper Coralline Limestone to be in the Tortonian (Upper Miocene) stage. The former identification already created difficulties for Gregory (1891, p.634-5) and has since been shown by several people (especially Durham, 1953, p.349-50) to have been due to a mistaken echinoid identification which is mentioned under Scutella in the Palæontological section.

The allocation of the Upper Coralline Limestone to the Tortonian, with the placing of the Transitional Greensand in the Helvetian stage, had been adopted until Blow (in Eames et al) showed that the Blue Clay has a position low in the Burdigalian, which suggests that the Transitional Greensand and Upper Coralline Limestone are also probably in the Burdigalian.

The present study tends, if anything, to support this reduction in range of the Maltese succession. There is no evidence of a major break above the Blue Clay and the echinoid Schizaster eurynotus ranges from the

Middle Globigerina to the Upper Coralline Limestone.

The geological map which accompanies the stratigraphical account shows the distribution of the rocks according to the divisions adopted in the description. It can be noted that the Transitional Greensand fails to form a mappable unit over much of the island and that, on the other hand, a three-fold division of the Upper Globigerina Limestone proves possible over part of its outcrop. Comparison with the recently published two inch to the mile geological map of the island (see bibliography) shows differences in the pattern of faults recognised and in the inliers of Coralline Limestone mapped.

LOWER CORALLINE LIMESTONE

Name. The lowest exposed rock formation on Malta and Gozo was named 'Lower Coralline Limestone' by Murray (1890, p.474). Coralline, calcareous algae do occur in some areas on Malta, for example around the Attard Mental Hospital (485710), but they are not seen on Gozo. The earlier name, 'Lower Limestone', used by Spratt and Adams (Adams in Wright, 1864, p.473), was more accurate but less distinctive and has not been used since.

Thickness. Only an approximate value for the thickness of the Lower Coralline Limestone can be obtained and as a result variations in its thickness cannot be proved. On Malta a test bore-hole for oil in 1958 penetrated the enormous thickness of about 2,000 feet of Aquitanian sediments (Eames et al, 1962, p.16). All of this should be referred to the Lower Coralline Limestone on the basis of a uniform lithology. On Gozo only 450 feet are exposed at the surface and the greater part is seen in vertical, inaccessible cliffs. The general appearance is of a series of dense, semi-crystalline, detrital limestones which show clear bedding planes, with a few cross-bedded units and occasional, irregular marly horizons.

Area of Outcrop. The impressive sea cliffs which rim the island west of Ras ir-Reqqa (315932) and right round the south coast as far east as Mġarr ix-Xini (347861), as well as the east coast near Qala (390895 to 403878) are almost completely made up of Lower Coralline Limestone.

Inland exposures are of two types, those produced by complex faulting and those formed by simple anticlinal structures, sometimes with an associated normal fault. The former exist inland from Xlendi (296876),between Sannat and Mġarr ix-Xini (330860), below Qala at Hondoq ir-Rummien (390873), and inland from Qala tad Dwejra (274898). The latter are exposed north of Gharb (287918), east of Kerċem (309888) and between Victoria and Marsalforn (342894 and 327908).

Lithology. The Lower Coralline Limestone is usually a dense, semi-crystalline, massive to moderately bedded limestone, ranging in colour from pure white to red and buff. The best exposure of the upper part is found west of Ras ir-Reqqa (308933), see ~~text fig.~~ plate 1. The cross-bedded nature is clearly developed through much of the exposure but one level contains cidarid plates and spines with some of the latter up to six inches in length, unbroken, which suggests a period of less disturbance. The softer horizons, more often met with in water supply bore-holes and galleries (see Morris, 1952, p.54) wedge out very rapidly, whilst the cross-bedded units persist for long stretches of the cliff. Typical appearance in thin-section is shown in Eames et al, 1962, pl.2,a.

An unpublished report has claimed the presence near the top of the Lower Coralline Limestone of derived fossils of Upper Cretaceous age with reworked rock pellets of 'Mesozoic aspect' at two places on Malta (Eames, 1952). No supporting evidence has been found on Gozo.

PLATE ONE

Soft levels and cross-bedding at the top

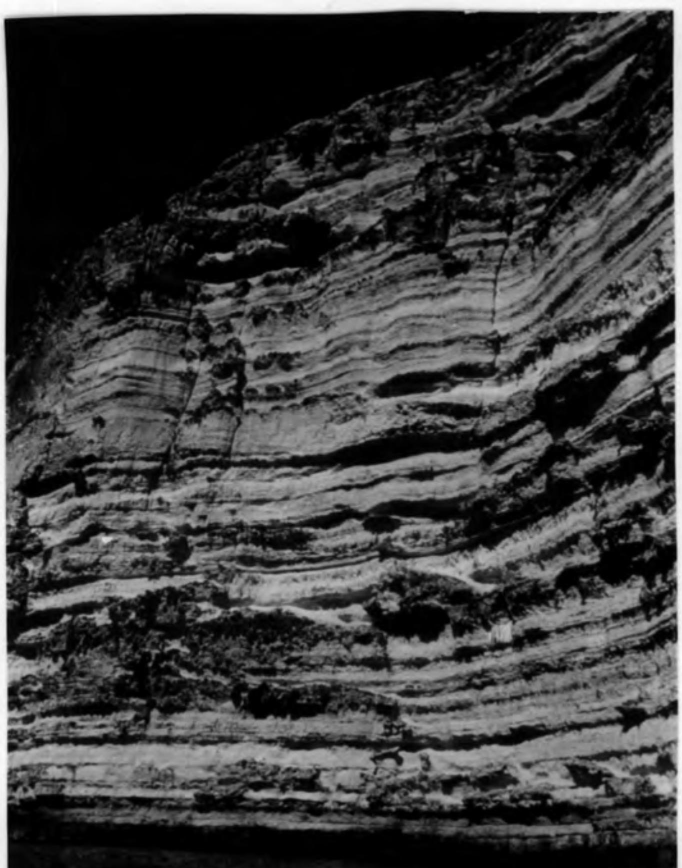
of the Lower Coralline Limestone

Ras ir-Reqqa 308933

300feet high cliff of thin-bedded

Lower Coralline Limestone

Ġebel Ben Ġorġ 274879



Fauna. In addition to cidarid plates and spines, the sand dollar, Scutella occurs at restricted levels, accompanied by the spatangoid echinoid, Eupatagus. Pectinids, bryozoans and large foraminifera of the Lepidocyclina type are found at various levels. Locally, nests of gastropods and lamellibranchs occur, for example, on the coast between Dahlet Qorrot (385896) and Ghar Dorf (398885). They are never as abundant nor as large as in south west Malta (see House et al in Bowen-Jones et al, 1961, p.26). This also applies to the foraminifera.

Conditions of Formation. The evidence from the upper part of the Lower Coralline Limestone points to a shallow water depositional environment. The regular cross-bedded units could have been formed in shallow waters by the reworking in local currents of foraminiferal deposits. The unbroken cidarid spines suggest that at least some periods were calmer. The sand dollars indicate shallow water since they are normally found today in littoral waters (Wythe Cook in Hedgpeth, 1957, p.1191). The irregular base of some units, for example, the marls at Ras ir-Reqqa, could have been produced by scouring currents which existed subsequent to some compaction of the limestone. It is considered unlikely to have been caused by compaction effects themselves since the irregularities are in soft beds overlying hard ones and not the reverse.

The suggestion, mentioned above, that derived Mesozoic material exists within the Lower Coralline Limestone would imply that Mesozoic rocks were exposed fairly close to the islands during the period of Lower Coralline

Limestone deposition . This is difficult to reconcile with the recently recognised great thicknesses of the limestone. Either there is considerable lateral change in thickness, for which no other evidence is known, or else the few fragments were mistakenly referred to the Mesozoic.

Economic Uses. Around Hondoq ir-Rummien (390875) and Ghar Dorf (399885) the Lower Coralline Limestone has been quarried in large quantities. Known locally as 'zonqor', the rock was used for ornamental purposes and for hard wearing functions such as steps. A good example forms the base to the memorial in the main square of Victoria. There are now no working quarries of this rock on Gozo.

SCUTELLA BED

Name. The softer, less compact rocks at the top of the Lower Coralline Limestone were distinguished from those below and referred to as the 'Scutella bed' by Trechmann (1938, p.2). Similarly Roman and Roger (1939, p.60) called this level, 'banc de transition avec lumachelle de Scutella melitensis'. The horizon is so distinct and is of such stratigraphical value that it is here considered as a separate formation between the Lower Coralline and Globigerina Limestones.

Thickness and Lithology. The Scutella Bed varies in thickness from six inches, as seen in the inlier north-east of Victoria (324894), to some 20 feet on the coast west of Fort Chambray (355861) where there are five levels with Scutella. At the extreme eastern end of Gozo, Ras il-Qala, (403877), there is an horizon of densely packed scutellids about three feet thick. Normally, however, there is only one level, about a foot thick, with abundant but not densely packed scutellids. The latter are often crushed or broken (see Conditions of Formation, below). Except when condensed, the matrix of the Scutella Bed is very much like that of the succeeding Lower Globigerina Limestone, that is, yellow, soft and composed of foraminifera with a sparse calcitic cement. Typical exposures are on the west coast, north of Dwejra (272897) and on the south coast near Xlendi (292872).

Area of Outcrop. The Scutella Bed outcrops as a narrow band at the base of the Lower Globigerina Limestone exposures. Eames et al.(1962, p.16-17) are mistaken in saying that the bed is 'near the base of the exposed Lower Coralline Limestone'. It is found all round the coast, with the exception of a five mile stretch from Ras ir-Reqqa(315932) south-eastwards to Dahlet Qorrot (388897). Additional inland exposures occur round the Lower Coralline Limestone inliers north of Gharb (287918), between Victoria and Marsalforn (324894 and 327908), and west of Victoria (309888 and 278888).

Fauna. As discussed in the systematic palæontology section, two species of Scutella have been recognised in the Scutella Bed and these are the dominant members of the fauna. Scutella subrotunda, the larger form, is the more common. Eupatagus dekoninckí is nearly always found in association, often with Schizaster parkinsoni, which reaches a very large size at this level. Less common are specimens of Echinus tortonicus (of which Gregory's misleading specific name dates from the time when he assigned the beds to the Oligocene), and Pericosmus latus.

Occasional pectinids occur, and were collected below Fort Chambray (355861), along with some oysters and sheet bryozoa. The pectinids and the echinoid genera Eupatagus and Schizaster are represented by species that range upwards into the Lower Globigerina Limestone. Scutella is extremely rare above the Scutella Bed, one specimen has been found about four inches above it, but occurs below (see Lower Coralline Limestone fauna). This confirms the impression that the rocks are transitional.

Conditions of Formation. A shallow water origin for the Scutella Bed is suggested by the broken nature of some scutellids, the quite frequent occurrence of overturned individuals and, by comparison with the shallow water, frequently tidal estuarine, habitat of living sand dollars (Wythe Cooke in Hedgpeth, 1957, p.1191; MacGinitie and MacGinitie, 1949, p.238-9; Rickets and Calvin, 1948, p.180-1). In addition, according to Mortensen (1951, p.457 ff.), the five living species of Eupatagus are found at depths of 30 to 190 feet. Murray (1890, p.476) suggested a deep water origin on the basis of the smaller fragments and the rarity of the algae. However, the absence of the latter could be explained by the turbulent conditions, whilst the smallness of the fragments, relative to the lower rocks, could be the result of longer resorting. The concentration of fossils at this level over almost the whole of Gozo and Malta, with the exception of south-east Malta where giant foraminifera are found at the same level, can be considered to indicate a wide area of steady sedimentation close to sea level on some kind of shell bank. Subsequent compaction resulted in considerable crushing of the weak central coelom of the scutellids and their cracking open along the radial sutures when the thin shells were pressed against the firmer beds below. This compaction effect can be distinguished both from wear during deposition and from recent weathering. The former produced worn edges on scutellid fragments broken off during the turbulent depositional conditions and then covered by matrix until revealed by cleaning in the laboratory. Recent weathering has normally produced a frosting effect on exposed test surfaces which sometimes reveals plate sutures but more often conceals them.

Economic Uses. The Scutella Bed was quarried with the Lower Coralline Limestone in eastern Gozo, the scutellids in section providing a decorative effect for ornamental stonework.

GLOBIGERINA LIMESTONE

Name. The commonest rocks on both Gozo and Malta, golden-yellow, soft and fine textured, are often mistaken for sandstones. Spratt (quoted by Wright, 1855, p.105) and Adams (in Wright, 1864, p.472-3) called the formation the Calcareous Sandstones, but Murray, partly on the evidence of thin sections, very suitably renamed it the Globigerina Limestone (1890, p.460).

Various subdivisions have been drawn up for the Globigerina Limestone. Spratt recognised five but his contemporary, Earl Ducie, only regarded three of these as reliable away from cliff sections (Wright, 1855, p.105). Galea, in 1915, separated 14 subdivisions but the most workable classification was adopted by Morris in his diagrams (1952, plate 15), having previously been used in part by Macfadyen (1930) and Roman and Roger (1939, p.60). The first detailed, systematic use occurs in House et al., in Bowen-Jones et al. (1961, p.27-28). Three subdivisions are recognised on the basis of two persistent nodule bands. Locally, a further three-fold division is made in the upper subdivision, resulting in the following scheme:

Upper Globigerina Limestone C
B
A

Middle Glob. Lst. bounded at top by Upper Nodule Bed (N 2)

Lower Glob. Lst. bounded at top by Lower Nodule Bed (N 1)

Thickness. The Globigerina Limestone within Gozo varies considerably in thickness. A general thinning towards the Comino Channels is the most important feature. Dr.M.R.House (personal communication) has observed a corresponding reduction in thickness on Malta. This is probably explained by the existence of a stable belt in the Comino area with regions of more rapid subsidence on either side. Unfortunately, no rocks below the Upper Coralline Limestone are exposed on Comino to corroborate this. The greatest variation takes place within the Lower and Middle Globigerina Limestone and includes a non-sequence in the eastern part of Gozo, caused by the absence of the middle subdivision. This is discussed below under the various subdivisions.

Area of Outcrop. Globigerina Limestone underlies most of the inhabited and farmed areas of Gozo and Malta. It forms a gently rolling landscape with the hills of clay and Upper Coralline Limestone rising from it.

Lithology. Compared with the Lower and Upper Coralline Limestone the Globigerina Limestone has been described as a 'thick series of, in the main, impervious marly beds' (Morris, 1952, p.53). From the point of view of water circulation the limestone is impervious but almost all the rocks in the series are 'pelagic limestones', using Pettijohn's terminology (1957, p.400), with only parts of the Middle Globigerina and the middle part of the Upper Globigerina as true marly limestones. Most of the series are made up of pelagic foraminifera with a calcitic cement. There are two important phosphatic nodule bands and local, thin ones, also levels containing ferruginous concretions and horizons that show prominent track-marking. These details are discussed below.

LOWER GLOBIGERINA LIMESTONE

Name. The term Lower Globigerina Limestone is here used to describe the rocks above the Scutella Bed up to and including the Lower Nodule Bed (N 1). This follows the usage of House et al.(1961, p.27-8).

Thickness. The Lower Globigerina Limestone varies in thickness from 17 to about 75 feet. It is thickest in the north-west of Gozo, near Ras San Dimitri (268926) and thinnest along the south coast around Mġarr. There is a slow increase in thickness north-westwards from S.E. Gozo, which becomes more pronounced N.W. of Victoria. This is similar to , though not as pronounced as that observed in the Middle Globigerina Limestone (see text-fig. 2). The Lower Nodule Bed varies in thickness between one and three feet but no pattern is discernible. Its base is always irregular and its top flat.

Area of Outcrop. The Lower Globigerina outcrops round most of the coastline with the exception of the stretch S.E. of Marsalforn as far as Dahlet Qorrot (336924 to 386897). Along its top the nodule band forms a prominent platform, best seen on the north coast eastwards from Ras San Dimitri. Inland, the Lower Globigerina is most fully exposed in the N.W. of Gozo, where the working quarries are mainly found. The Lower Nodule Bed can be traced across the whole of the Globigerina Limestone areas, except in the badly exposed, flat regions N.W. of Kercem and S: of Victoria.

Lithology. The Lower Globigerina Limestone has a uniform lithology of a similar character to the matrix of the Scutella Bed, that is, a fine-grained, massive, yellow, foraminiferal limestone. On the coast S. of Ghajnsielem (356861) it is clear that the scutellids have an abrupt upper limit but above this the lithology remains the same. The macrofauna is restricted to a few definite levels with other scattered clusters of echinoids and pectinids. In addition, there are levels which show track-marking. These are best developed on the coast N. of Zebbug (315932). Other horizons develop large-scale honeycombing. Ferruginous concretions occasionally form near the top of the limestone and scattered iron-stained grains can be found at any level. The general lithology is very constant. Where the beds are thin, bedding planes develop, for example, S.W. of Fort Chambray (360863). The colour of the Lower Globigerina varies a little, from golden yellow to a paler yellow where it is harder. Weathered surfaces are a little darker.

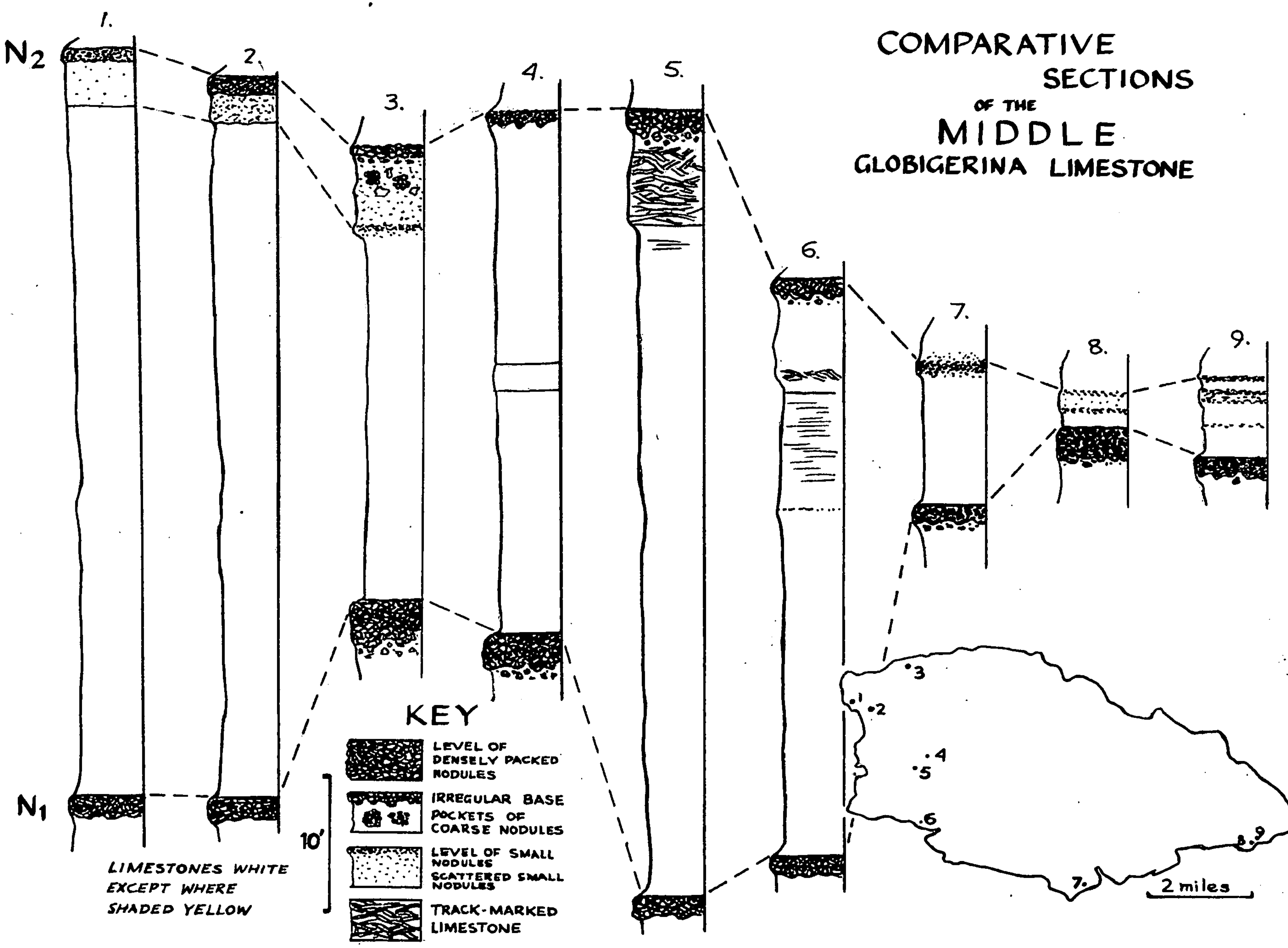
The Lower Nodule Bed, which is the lower of the two present everywhere in the Globigerina Limestone (except where they coalesce, as discussed below), has an irregular base on the yellow limestone with a few, isolated red-brown nodules near the top of the limestone. The nodules are mostly large, an inch or two across, irregular in outline and closely packed together. The bed has a level top, on which normally rests the white Middle Globigerina Limestone. On the coast S. of Qala, at Tac-Cawl (386871), another nodule band develops in the Lower Globigerina. It is lighter brown, about nine inches thick and is easily separable from the main two nodule beds. It has not been recognised elsewhere.

Infilled Joints. An important feature of the Lower Globigerina is the presence in the south-east area, between Dahlet Qorrot and Mgarr, of prominent jointing, usually in a north-south direction. The joints cannot be traced in or above the Lower Nodule Bed and they are frequently infilled with small nodules derived directly from the nodule bed. The infilling extends downwards in some cases as far as 12 feet below the nodule bed. In addition, there frequently develops a bleaching of the limestone on both sides of the joints, possibly the result of reduction of some of the oxidised iron. It is significant that the jointing occurs in the same area as the thinning of the Lower and the absence of the Middle Globigerina Limestones. This is farther discussed below.

Fauna. Echinoids and pectinids form the bulk of the macrofauna. Of the former, the genera Eupatagus and Schizaster continue up from the Scutella Bed, and Hemiaster is found abundantly. Flabellipecten is the main pectinid genus. The fossils are found irregularly throughout the Lower Globigerina Limestone but are rare in the track-marked parts. W. of San Lawrenz (274905) one or two distinct levels of shells are seen. They are composed of broken pectinid fragments with occasional echinoid plates and no complete specimens were recovered. It did not prove possible to use the bands for mapping purposes owing to their lack of persistence laterally. In the Lower Nodule Bed there are a few phosphatised echinoids, corals , pectinids, sharks teeth and vertebrate bones. The corals and echinoids are not as well preserved as in the Upper Nodule Bed.

Conditions of Deposition. The Lower Globigerina Limestone was apparently laid down under uniform conditions of steady accumulation of foraminiferal debris, which were inhabited by burrowing echinoids, and, presumeably, active pectinids. Murray suggested a depth of 1,800 to 6,000 feet for the Globigerina Limestone (1890, p.475) but it has been argued above that the Scutella Bed is most readily explained as a shallow-water deposit. The rapid subsidence needed to reconcile these two views is not in evidence. Mortensen (1950, p.377) states that living Hemiasters occur between 1,200 and 2,700 feet, and probably also at lesser depths. Schizaster is found over a wide range. This can be taken to allow a moderate depth, possibly less than 1,000 feet, for the Lower Globigerina. The horizons with broken shells point to local current action and the onset of phosphatic deposition at the top, marks a change in conditions. Pettijohn (1957, p.470-8) discusses the limited information about nodular phosphatic deposits, much of it deriving from the work of Murray himself. Estimates of the depth of origin vary (Murray found nodules off the Cape of Good Hope at 900 to 11,400 feet) and may well not be decisive. It is clear that a period of stagnant conditions must have existed, with no foraminiferal accumulation but with an abundant supply of calcium phosphate, at least in part from vertebrate material, as evidenced by the presence of bones and sharks' teeth.

Economic Uses. The Lower Globigerina provides the chief building stone of the island. Known locally as 'franka', the massive limestone is an easily worked freestone when fresh, yet it weathers with a harder, protective crust. The quarries are large with completely smooth, vertical faces. Those at present worked are where the limestone is thickest, that is, N. of Gharb (285916), W. of San Lawrenz (274905) and S.E. of Dwejra (276887). The rock directly above the Scutella Bed is too hard and the levels developing honeycombed weathering are also avoided now.


COMPARATIVE SECTIONS OF THE MIDDLE GLOBIGERINA LIMESTONE
N2
N1
1.
2.
3.
4.
5.
6.
7.
8.
9.
KEY
LEVEL OF DENSELY PACKED NODULES
IRREGULAR BASE POCKETS OF COARSE NODULES
LEVEL OF SMALL NODULES SCATTERED SMALL NODULES
TRACK-MARKED LIMESTONE
10'
LIMESTONES WHITE EXCEPT WHERE SHADED YELLOW
2 miles

TEXT - FIG. 2

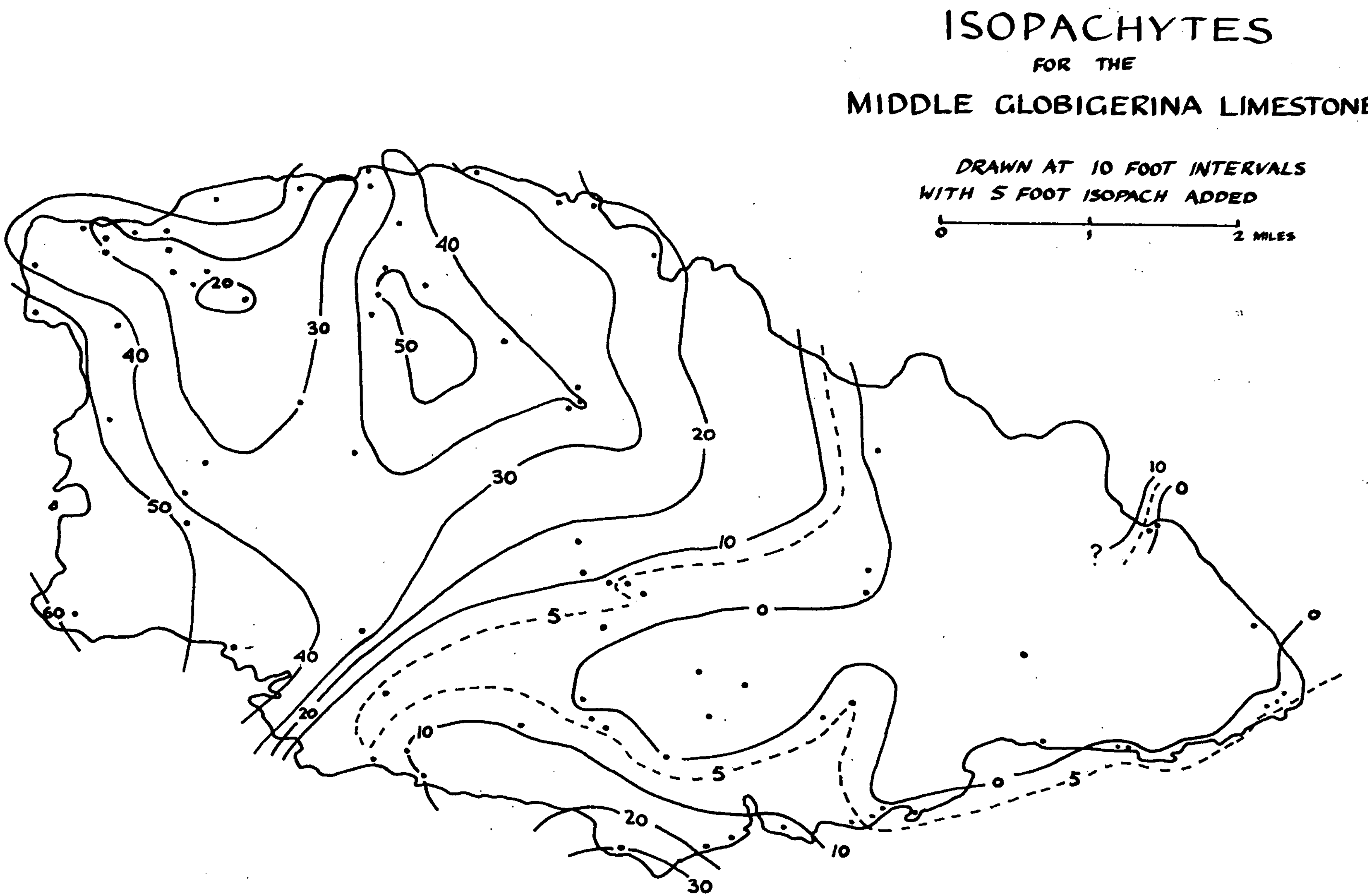
MIDDLE GLOBIGERINA LIMESTONE

Name. The Term Middle Globigerina Limestone is here used to describe the rocks above the Lower Nodule Bed (N1) up to and including the Upper Nodule Bed (N2). This follows the usage of House et al. (1961, p.28).

Thickness. This is the most variable part of the Globigerina Limestone. Within Gozo it ranges from zero to 60 feet in thickness, of which N2 forms up to two feet six inches but averages about one foot. In south-east Malta a maximum thickness of 390 feet is attained (Dr.M.R.House, personal communication). The broad pattern is one of eastward thinning towards the Comino Straits, corresponding to a north-westerly thinning on Malta towards the same area. A tongue of thin deposition reaches south-westwards on Gozo to il-Bajjada (300865) and there is also an isolated area of thinner sediments around San Dimitri church, north of Gharb (288917). **

Area of Outcrop. As the thinnest part of the Globigerina Limestone, the Middle is less exposed than the other subdivisions. Because of its softer nature it often forms the base of the steeper gradients within the Globigerina outcrops. It is best seen in various roadside sections on these minor slopes. The Upper Nodule Bed forms flat ledges around parts of the coast, though not to the same extent as the lower one. It also forms a flat cap to small areas near the road east of Ben Gorg (280833).

**See text-fig.3.


ISOPACHYTES
FOR THE
MIDDLE GLOBIGERINA LIMESTONE
DRAWN AT 10 FOOT INTERVALS
WITH 5 FOOT ISOPACH ADDED
0
1
2 MILES
10
20
30
40
50
60
5
0
?

TEXT-FIG. 3

PLATE TWO

Thinning-out of the Middle Globigerina Limestone

Dahlet Qorrot 387897

Merging of Upper and Lower Nodule Beds-

ten yards east of upper photograph

Lithology. Although variable in thickness, the Middle Globigerina Limestone shows little corresponding variation in lithology. Almost everywhere, except the extreme south-west, it consists of a soft, pure white, fine-grained limestone. Its unweathered colour, seen in deep excavations on Malta but not observed on Gozo, is a darker grey. Towards the top, beneath N2, the rock nearly always has limonitic patches which produce a rusty and streaked appearance.

About six inches below the nodule bed, patches of a coarser grey limestone develop within the fine white limestone, often but not invariably containing small, isolated nodules. This coarser rock predominates within a few inches above, leaving isolated patches of the white limestone without nodules, and forms the matrix of the nodule bed. In most cases it is only a minor part of the nodule bed, except in the area around Gebel tal Halfa (396873, see text-fig 2) where the nodules are thinly dispersed through a bed of grey matrix.

In the areas west and south of Ghajn Abdul (290890) a coarser, yellow facies develops above the fine, white limestone and beneath the nodule bed. It thickens rapidly and reaches a maximum of 25 feet north-east of il Qasam ta Ben Gorg (278890). Apparently in association with this yellow facies is a reduction in the number of phosphatic nodules in the upper nodule bed, seen , for example, north-east of il Qasam ta Ben Ġorġ (284889), though this does not take place over the whole extent of the yellow facies.

The upper nodule bed is similar to the lower one but it is usually slightly thinner. The individual nodules are smaller and the proportion of recognisable fossils is higher. Around Gebel tal Halfa there is a tendency for the nodules to be concentrated at the top and the base of the bed with six inches of fine matrix between. Where the Middle Globigerina Limestone is absent the upper nodule bed lies directly on the lower one and in most exposures the two have lost their separate identity.

Fauna. The white limestone facies of the Middle Globigerina has a meagre fauna, consisting of broken and squashed echinoid plates and fragments of pectinids. Even these are not common. The yellow limestone of the western area contains some complete echinoids. On the track to the south side of Ghajn Abdul (285892) and immediately below the upper nodule bed, pectinids and the spatangoid echinoid, Schizaster eurynotus, are fairly common. Schizaster eurynotus ranges from the Middle Globigerina Limestone to the Upper Coralline Limestone and is distinguished from S.parkinsoni, which is found in the Scutella Bed and the Lower Globigerina Limestone. This suggests that the subdivision of the Globigerina Limestone has some stratigraphical significance despite the lack of evidence for such subdivisions from the foraminifera (W.H.Blow, 1959, personal communication).

The upper nodule bed contains phosphatised gastropods, corals, sharks' teeth, mammalian bones and spatangid echinoids of the Hemiaster group.

Conditions of Deposition. After the formation of the lower nodule bed, limestone deposition recommenced over all Gozo, except in the eastern area which probably rose relative to the rest. The interesting coast sect-

-ion from Dahlet Qorrot (387897) south-eastwards shows extensive north-south jointing in the Lower Globigerina Limestone but not the rocks above, suggesting a region behaving differently from the surrounding ones during the period between the Lower and Upper Globigerina Limestone. In this area the Middle Globigerina thins out rapidly from at least seven feet to nothing, in under a hundred yards. The Upper Nodule Bed comes to rest on the lower one and merges with it.. Minor nodule bands at the base of the Upper Globigerina are seen to converge on the combined nodule bed (plate 3), all of which indicates that this was the edge of limestone deposition. There is no evidence of erosion of the Lower Nodule Bed or of any other suggestion that the Middle Globigerina Limestone was removed subsequent to deposition.

The general westward increase in thickness of the white limestone facies suggests a more regular depositional environment with some local movement to account for the local thickness variations. The fine, marly nature of the limestone and the rarity of fossils could have been produced by conditions of lime mud sedimentation. The few fossils were probably squashed during compaction. There is no evidence of reworking by currents or marine organisms and the pockets of nodules at the top would have been disarranged by any such disturbances.

The coarser, yellow limestone facies with its echinoid and pectinid fauna indicates that in the west of Gozo conditions, that were more typical of the Globigerina Limestone as a whole, obtained towards the close of the Middle Globigerina period. This may have been the edge of an outer zone, away from the Comino Straits but there is no evidence of a corresponding development in southern Malta.

After this, conditions suitable for phosphate formation set in over the whole of the island.

Economic Uses. The Middle Globigerina Limestone is unsuitable for building stone or for ornamental purposes. Its thickness is too variable, its lithology is too soft and even if the phosphate beds ever became useful, the upper one is far less suitable than the lower one.

PLATE THREE

Upper Nodule Bed with track-marked,
harder, yellow Middle Globigerina Limestone
overlying softer white facies

South-west of Ghajn Abdul 286893

Colour-banded Blue Clay above
Upper Globigerina Limestone (showing
salt pans)

Coast South-east of Qala 397875

UPPER GLOBIGERINA LIMESTONE

Name . The term Upper Globigerina Limestone is applied to the rocks above the Upper Nodule Bed and below the Blue Clay.

Thickness. There is less variation in thickness within the Upper Globigerina Limestone than within either the Middle or the Lower. Over most of the island the Upper has a thickness of about 65 feet, locally it increases to about 110 feet at Dahlet Qorrot (387897), and decreases to about 40 feet on the south side of Ghajn Abdul (285892), but there is apparently no pattern in this variation. The control earlier exerted by the Comino Straits area seems to have ended.

Lithology. For most areas a three-fold division is recognisable. The map indicates these areas and those where it is not feasible. The lower and upper parts are similar to the Lower Globigerina Limestone. They are made up of yellow, foraminiferal limestone and are harder than the middle part which has a marly texture, similar to the Middle Globigerina Limestone in most exposures.

Typically, there are some 15 feet of coarse and massive yellow rock followed by a rapid change in colour and hardness to some 15 or 20 feet of grey or white, soft rock. South of Ramla Bay (353895) and north of Victoria (314898) the wieds cut steep-sided courses through this middle part and run along the dip surface of the lower division. Above the soft section, rocks almost indistinguishable from the lower part are found for some 25 feet or more, often with a honeycombed surface, though this feature is not restricted to this part of the Globigerina Limestone. South-east of Qala (388873) this upper part is characterised by a thin-bedded top and base, otherwise the unit is massive.

The three-fold division breaks down around Marsalforn. North-east of the harbour the coastal section shows that the colour boundary changes level, with thicker areas of grey rock much of which is not marly at all, whilst, west of the town, at Qbajjar (326928), the upper part is completely grey. The probable reason for this variation is an irregular distribution of iron in the matrix of the limestone. The fresh rock is grey wherever seen; the yellow colour comes from the oxidation of the iron. These variations, together with the fact that the marly middle part is apparently absent in some areas, for instance, to the west of Xewkija (326877), make it impossible to apply the three-fold division throughout Gozo.

Fauna. The fauna is sparse in the Upper Globigerina Limestone except in a few areas where the base of the lower part contains a large number of conoclypeid echinoids with a few pectinids. Such areas are; around Tac-Cawl (386872), on the coast west of Gebel tal-Halfa (396873) and the north-east edge of Marsalforn Bay (336924). In all three localities the echinoids, together with thick-shelled pectinids, are in a limestone which contains scattered, very small phosphatic and ferruginous nodules. The fossils, despite their thick shells, are often squashed. This is best seen at Taċ-Ċawl. This damage was suffered at, or soon after, the time of burial, since the matrix coats crushed echinoid plates and infills sutures that were opened by pressure.

The lower part also contains phosphatised pteropods (including the genus Cavolinia) which at first appear to be very small, polished nodules, and some small phosphatised gastropods.

Macrofossils are very rare in the middle part and none were collected. The upper part has a few pteropods scattered throughout.

Conditions of Formation. The Upper Globigerina Limestone was probably laid down in conditions similar to those for the Lower Globigerina Limestone, that is, fairly clear and moderately deep water in which there was little sediment transported from areas of sub-aerial erosion but which had a dense population of pelagic foraminifera. A gradual increase in depth of the water gave rise in most areas to lime mud deposits similar to those of the Middle Globigerina. This was in turn followed by a resumption of conditions producing a foraminiferal limestone. Murray (1890, p.472 ff.) mentions a falling off in lime content in the Upper Globigerina Limestone from a range of 63 to 95% down to between 30 and 40%. This suggests a gradual alteration in the sedimentary environment. Murray goes on to envisage a rising sea-floor, the shore line nearing Malta at the top of the Globigerina Limestone with a resultant increase in river detritus, finally giving clay deposits. The Blue Clay deposits are identified with the Schlier facies (see below), and it would seem that these were produced by a more widespread change in conditions than the increased proximity of a river.

However, no evidence bearing on this was produced during the present work.

The crushing of the macrofauna at the base, mentioned under Fauna, suggests that considerable compaction of the sediments took place and that these fossils were crushed on the dense phosphate nodules immediately below them. It is not certain what significance can be attached to the thick-shelled nature of these fossils. It is possible that the Upper Globigerina Limestone started in turbulent conditions but the presence of nodules conflicts with this.

BLUE CLAY

Name. The name Blue Clay was first used by Murray (1890, p.468). Previously, the rocks above the Globigerina Limestone and below the Greensand and Upper Coralline Limestone were named 'the clay bed' (Wright, 1855, p.104) and 'The Marl' (Adams in Wright, 1864, p.472). The colour is normally a dark, slate grey with less common yellow-grey bands.

Thickness. The Blue Clay varies considerably in thickness. Murray gave it as between 0 and 40 feet (1890, p.468) but in Gozo it is often much thicker. 60 feet of clay are present on the west side of Ghajn Abdul (286896), 95 feet west of Fort Chambray (362866), 135 feet on the coast south-east of Qala (395875), and 200 feet of dark grey clays form the cliff on the west side of Ramla Bay (351912). On the other hand, several isolated hills have much reduced thicknesses, for example, the small hill west of Ġordan (293920) with about 20 feet of clay. Other hills have no clay at all, for example, il Qolla s-Safra (330923) has Upper Coralline Limestone resting directly on the Upper Globigerina Limestone. This is further discussed under Conditions of Formation. There does not appear to be any pattern in the variations related to deposition.

Area of Outcrop. The Blue Clay forms the gentler slopes below the main outcrops of the Upper Coralline Limestone. These are more common in the eastern part of the island since the regional east-north-east dip has resulted in greater erosion of the higher beds in the west of Gozo.

Where the clay outcrops along the coast, that is, along the north-east and south-east coastline, there is large-scale landslipping of the overlying limestone. A few patches of Blue Clay without any Upper Coralline Limestone occur north of Gharb (284924), at Qawra (273902) and nearby at Dwejra (275894).

Lithology. Many writers have pointed out that the main difference between the Blue Clay and the Globigerina Limestone lies simply in the increased clay fraction in the former; both the fauna and heavy mineral content are similar. There is, however, a distinct lower limit to the Blue Clay. It is well exposed to the south-west of Fort Chambray (362863) and south of Qala (396873). At Ramla Bay (353911) the boundary is not so obvious since the Upper Globigerina Limestone top is grey-blue and the clay is grey. This may be what led Murray (1890, p.469) to state that the boundary is transitional in some (unspecified) places.

The Blue Clay has a uniform lithology except for a colour-banding which frequently develops a third to half way up. This consists of broad layers of blue-grey and grey-yellow clay. The best exposures are below Fort Chambray (362863), to the north of the road between Zebbuġ and Għasri (309909) and on the southern slope of Tad Dabrani (322912). The edges of each band appear sharp from a distance but are gradational. The thicker bands extend across whole exposures, that is, up to 20 yards, but cannot be correlated from one exposure to another. Large crystals of selenite are common on the clay slopes, produced by sulphuric acid from pyrite decomposing the calcium carbonate.

Fauna. Murray lists 122 species of foraminifera from the Blue Clay, 47 of these are also found in the Globigerina Limestone and there is only one Globigerina Limestone genus which does not continue into the Blue Clay. Macrofossils are usually crushed. Echinoids are rare, one recognisable Schizaster eurynotus was recovered. This form ranges from the Middle Globigerina Limestone up to the Upper Coralline Limestone. Pectinids are common and are of the Flabellipecten type (Roman and Roger, 1939, p.66, 70-1). They are all dark brown and blue in colour. Small gastropods are common in some exposures, for example, below Fort Chambray. The nautiloid, Aturia aturi, occuring widely in the Burdigalian, is occasionally found.

Conditions of Formation. Fuchs (1874, p.97) mentioned the affinity of the Blue Clay to the Badner Tegel of the Vienna Basin and subsequent writers have considered it to be part of the Schlier facies of Suess' Second Mediterranean Stage on the basis of the pelagic pectinids, the nautiloid Aturia and the clay lithology. The present work has produced no evidence modifying this identification.

There is no evidence of variations in depositional conditions in the island and this accords with the concept of the Schlier facies. The lighter bands mentioned above could indicate periods of less clay deposition and a greater proportion of iron oxide. Murray's explanation for the yellow parts (1890, p.469), that it was produced by oxidation through contact with water from the overlying glauconitic sands, does not account for the banding nor for its occurrence well down the clay beds.

The great variations in thickness which do exist are considered to be caused by post-depositional movement of the clay as a result of pressure from the thick and fairly massive overlying Upper Coralline Limestone. Several lines of evidence suggest this. Firstly, the Blue Clay is at present undergoing rapid removal in the rainy seasons and considerable areas are not cultivated because of the resultant gullying and slumping. Secondly, a sequence of erosional forms can be recognised. South-west of Marsalforn, the conical hill, Il-Mirzuq (329916), shows evidence of recent movement. The Upper Coralline Limestone cap is shattered and tilted in towards the centre of the hill and the statue on the top had to be replaced recently. There is 100 feet of clay but this is nearly half the thickness of that on Tad Dabrani, a quarter of a mile to the west (323914), with no faulting between. Half a mile to the north, Il Qolla s-Safra (330923) consists of tilted limestone and sand, resting with a discordant dip directly on the Upper Globigerina Limestone with no trace of clay. Again, north of Gharb (284924) are several blocks of Upper Coralline Limestone alongside a small mound of Blue Clay and an isolated outlier of Upper Coralline Limestone, resting on a slope of Middle Globigerina Limestone at the extreme south-western corner of Gozo (269883). These also indicate the progressive removal of clay with disturbance of the Upper Coralline Limestone.

There is, nevertheless, one problematic exposure close to the mound of clay north of Gharb, mentioned above. It consists of a large slab of sandstone and limestone, some 500 feet by 250 feet, lying at a dip of 15° across almost horizontal Upper, Middle and Lower Globigerina Limestone. It is difficult to imagine this slab, now less than ten feet thick, sliding off the clay without breaking up (though in one exposure coarse, re-cemented breccia underlies the limestone and could have been produced by movement). The alternative explanation, that is, of a facies change involving little or no clay sedimentation, presents greater difficulties. A similar, but far larger, outlier exists in Malta (House et al. in Bowen-Jones et al., 1961, p.28). South-east of Valletta, near San Anard (597704), there is half a mile of Upper Coralline Limestone lying across Middle and Lower Globigerina Limestone. The nearest outcrop of Blue Clay is seven miles away, on the Victoria Lines Fault. It is possible that facies changes and non-deposition of Blue Clay could have caused this outlier but that would not invalidate sliding and removal of clay as an explanation on Gozo.

Economic Uses. The economic importance of the Blue Clay lies in its sealing effect on the water draining through the permeable Upper Coralline Limestone. This produces the 'Upper Water Table' which was the earliest source of water on the Maltese islands and which is now being carefully exploited since the 'Lower Water Table' in the Coralline Limestone, held above the sea water, is insufficient. The spring-line along the top of the clay shows all over the island by the presence of bushes that are absent above and below. The best area is along the Wied tal-Lunzjata, southwest of Victoria (310885), with its springs, rich vegetation, near-permanent stream and wash houses. The Blue Clay has also been used occasionally for pottery.

TRANSITIONAL GREENSAND

Name. Murray (1890, p.463) gave the name Greensand to the rocks between the Blue Clay and the Upper Coralline Limestone. The frequent occurrence of glauconite, either as dense bands or scattered through a coarse, sandy limestone, was his reason. Unweathered, these grains have a shining, dark green to black appearance which on weathering changes to a rusty orange, except when in a clay matrix, where the green colour remains even in old exposures. Earlier writers, including Wright (1855, p.103-4), called the group the Yellow Sand or simply, the Sand-bed (Adams in Wright, 1864, p. 472).

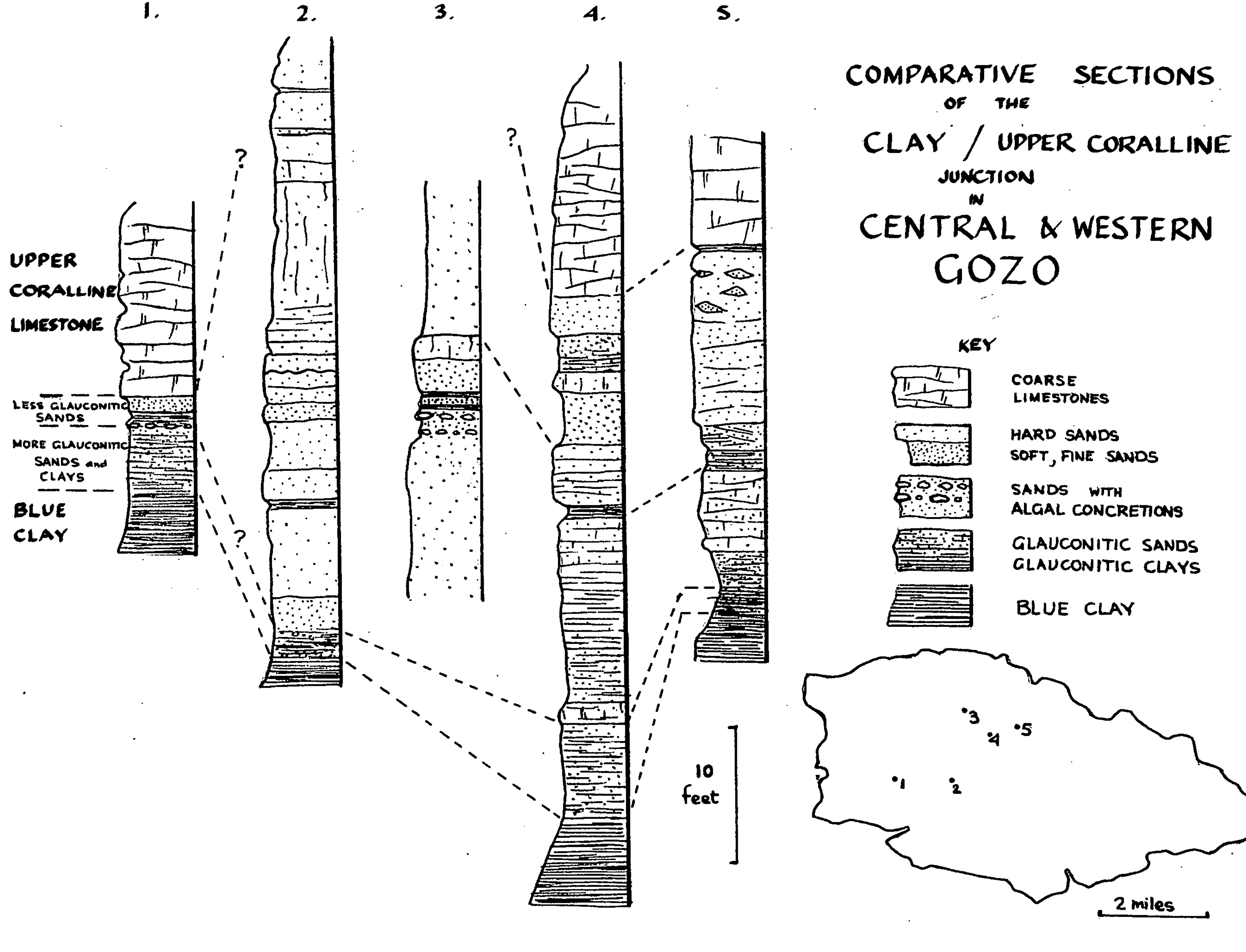
Discussion. The boundaries of the Greensand are difficult to map, even when the beds are well exposed. They are most often observed as coarse-grained, open-textured, orange sandstones with an upward, gradational passage into coarse, soft, yellow limestones of the Upper Coralline Limestone. At the base there is a gradual downward change from glauconitic clay to pure clay. Consequently the Greensand has unsatisfactory mapping boundaries. The best horizon to map between the Blue Clay and the Upper Coralline Limestone is where the matrix changes from clay to coarser material. This is the level where water seeps out and where the landslipping of the Upper Coralline Limestone begins, sliding over the wet clay and along the weak line of the unconsolidated glauconite.

Lithology. Text-fig. 4 shows the kind of variation seen in surface exposures. The east side of il Gelmus(column 2 on text-fig.4), just west of Victoria (311894), is made up of some 40 feet of beds showing an upward change from a soft, densely glauconitic base to harder, less glauconitic beds above, with minor hard levels within the sequence. To the NNE, ta ċKuljat (316907 - column 4) and tad Dabrani (322913 - column 5), show the development of hard and soft bands, whilst west of these, below Zebbuġ (312916 - column 3), a series of algal horizons are prominent along the roadside. They are also present two miles to the south-west on Ghar Ilmar (219895 - column 1) in a much condensed succession, but they are absent further east below Nadur, where the glauconitic beds rapidly vary in thickness from zero to 25 feet.

Only a broad pattern of thickness variation seems to have any significance. A claim has been made (Newberry, 1958, p.3), on the basis of borings to investigate the Upper Water Table, that a 10 to 20 feet thick, half mile wide, sandy limestone belt runs for about two miles NNW-SSE across the Nadur-Mġarr road but there is no surface evidence and the available bore-hole data hardly bear it out. However, they do corroborate an impression of thickening of the sandy beds towards the north coast, around Xaghra, in the Ghajn Barrani area (344916). A distinct reduction is clear in the west of the island with a slighter thinning in the south-east.

Murray (1890, p.464) mentions a band consisting entirely of calcite grains grown around particles of limonite, which often marks the top of

TEXT-FIG. 4


COMPARATIVE SECTIONS
OF THE
CLAY / UPPER CORALLINE
JUNCTION
IN
CENTRAL & WESTERN
GOZO
1.
2.
3.
4.
5.
UPPER
CORALLINE
LIMESTONE
LESS GLAUCONITIC
SANDS
MORE GLAUCONITIC
SANDS and
CLAYS
BLUE
CLAY
?
?
?
KEY
COARSE
LIMESTONES
HARD SANDS
SOFT, FINE SANDS
SANDS WITH
ALGAL CONCRETIONS
GLAUCONITIC SANDS
GLAUCONITIC CLAYS
BLUE CLAY
10
feet
2 miles

these transitional beds, but in the present study no such bed has been recognised. From it Murray had inferred a period of elevation above sea level prior to the deposition of Upper Coralline Limestone, even though a note by Colson (in Murray, 1890, p.465n) mentions an upper sandy hardening by lime brought from above. This is sometimes seen, though not always, right at the top of the beds. This is clearly best explained by relatively recent weathering, perhaps contemporary with the tufa formation in fractures within the Upper Coralline Limestone. There is no evidence for pre-Upper Coralline Limestone sub-aerial erosion and this makes separation of a Greensand formation less significant.

Fauna. The lower, more glauconitic beds have a meagre macrofauna, consisting of very small, thick-ribbed pectinids and clusters of the large foram, Heterostegina. Higher up, with increasing amounts of coarser sediment, whole areas of forams produce a 'Heterostegina rock'. Elsewhere, large echinoids of the thick-shelled Clypeaster altus group and the genus Echinolampas ~~Hypsoclypus~~ produce a striking fauna. Cottreau (1914, p.29), mentions an almost identical association in Helvetian rocks in Calabria, S.Italy, and on Crete, with similar ones over a wide area from Morocco to the Crimea. It is best seen on Malta in the Dingli cliffs, but it does occur in Gozo, east of Mgarr (373872), on Is 'Safra, west of Marsalforn (330923) and on the outlier at Wardija Point (269882). The robustness of the echinoids and the abundance of damaged specimens suggests turbulent conditions and contrast with the echinoids in the succeeding finer-grained beds, where the slender Clypeaster marginatus occurs in what presumeably were much calmer conditions. Records in Malta of dugong, manatee, dolphin and whale bones have not been confirmed for Gozo, though unidentifiable vertebrate bones were collected. Identifiable material must, at least, be very rare on Gozo.

Conditions of Formation. The following depositional sequence may be inferred. The widespread clay sedimentation, suggesting fairly deep water, gradually gave way to glauconitic deposition, probably in clear, still water with iron made available from the breakdown of basic rocks perhaps located to the north of the Maltese islands. Sandy material then began to be brought to the area, related to further uplift (or fall in sea level) and a sediment source to the north. After this came a reduction in clastic material and calmer waters to start the deposition of the Upper Coralline Limestone. Throughout there is an indication of transitional conditions with local variations, particularly in the periods of shallowest deposition, On one hand there are the algal banks produced in very clear, shallow water and on the other, the damaged, thick-shelled echinoids existing in turbulent conditions. The beds are part of a gradual return to limestone deposition after the sudden onset of clay sedimentation above the Globigerina Limestone.

UPPER CORALLINE LIMESTONE

Name. The youngest Tertiary formation on Gozo and Malta was named the Upper Coralline Limestone by Murray (1890, p.461) and this name has been used since. Spratt's earlier term, 'Upper Limestone' (Spratt, 1843, p.225) had the advantage that 'Coralline' refers to coral-like calcareous algae which are not at all common, particularly on Gozo.

Thickness. It is impossible to estimate the original thickness of the Upper Coralline Limestone or its, probably considerable, variations. In the Bingemma syncline on Malta (430740), close to the Victoria Lines fault, nearly 500 feet were penetrated in a borehole, without reaching the Clay (Morris, 1952, table II & pl.12c), and on Comino at least 250 feet is exposed. On Gozo the greatest exposed thickness is 100 feet at Mgarr but water-borehole records show up to 286 feet near the big fault below Nadur (367878) in a very similar structural position to the Bingemma occurrence. Present-day thicknesses are mainly determined by structural and erosional factors. In general, the larger the area of an outlier the thicker it is.

Area of Outcrop. The areas of Upper Coralline Limestone are larger to the east since the beds dip in this direction. In the west the limestone forms the small caps of the isolated mesas such as Ta 'Dbiegi (293899) and Ġordan (298922). The Żebbuġ ridge, farther east (313917), is larger and the Xaghra and Nadur plateaus, farther east again, are the largest, high Upper Coralline Limestone areas. Rabat, the main town, is on a down-faulted limestone block, and the major Ghajnsielem - Qala fault produces a large limestone area above Mġarr. The remaining Upper Coralline Limestone exposures are small outliers on reduced or absent clay and have been discussed above (p.38).

Lithology. Murray's excellent description of the lithology (1890, p.461) states, 'the texture of these rocks varies greatly, being sometimes rubbly, sometimes granular and porous, at other times compact and crystalline. Some layers appear to be wholly crystalline and to have lost all trace of the original organisms of which they were doubtless composed'. A further facies has been recognised, a white, soft, thin-bedded limestone which develops in the most westerly exposures in Gozo, on Ghajn Abdul(288895).

No widely applicable divisions of the Upper Coralline Limestone can be made, though several have been attempted (see Hyde, 1955, p.54-5). If the basal, sandy facies is included, a broad three-fold subdivision can be made for the eastern areas. This is clearly seen on the north side of Mġarr harbour (368871). The top hard part of the limestone there can be recognised over all the Upper Coralline Limestone exposures, but to some extent this must be the result of having been the cap-rock for a long time. A hardening effect can be seen along many recent tracks on the softer subdivision. This evidence of recementation suggests that no estimates of thickness variation can safely be made on the basis of the division into hard and soft levels.

Fauna. The macrofauna, including gastropods, lamellibranchs, brachiopods, bryozoa, echinoids, serpulids, corals and occasional shark's teeth occur in bands within the lower beds and in the irregular softer pockets of the higher beds. The lower beds are made up of algal fragments of Lithothamnium type with a fine, calcitic matrix containing forams and terebratulid brachiopods, which appear to be confined to this horizon. Other fossils present include rhipidoglossid gastropods of the Trochus and Turbo type, and lamellibranchs of the Nuculacea and Cardiacea groups, (Pectenacea are relatively rare). Corals are occasionally found, one locality being the small outlier below Il Gelmus (309891). A large number of echinoid species have been recorded but none are abundant. Schizaster eurynotus, which ranges from the Middle Globigerina Limestone, is present with Echinus duciei.

The pockets in the higher beds have not yielded many fossils in the present work. From an examination of the matrix of the fossil echinoids in museum collections it can be presumed that Clypeaster altus, Brissopsis duciei and one or more cidarids do occur at this level.

Conditions of Formation. Broken gastropods, lamellibranchs, echinoids, foraminifera, bryozoa and serpulids all bear witness to disturbed depositional conditions. The detrital minerals recorded by Murray (1890, p.462), quartz, feldspar, augite, zircon and tourmaline suggest some source of sediment in basic volcanic or plutonic rocks. The distinctive facies recognised at the western ends of Gozo (see above) could indicate a boundary to the depositional area in the north-western part of the Maltese Islands, since the thin-bedded deposits there are succeeded by hard limestones in what appears to be a reduced development of the Upper Coralline Limestone (though the caution mentioned in 'Lithology' must be borne in mind).

The recrystallised areas, the tufa veins - which are an infilling of later joints and which extend down to the Lower Globigerina Limestone near Dahlet Qorrot (385896) - and the hardened upper surface all show the post-depositional alteration of the Upper Coralline Limestone. Recent weathering has produced large areas of limestone pavement and caves with stalactites and stalagmites. An example of the latter can be seen at Xaghra.

The soil, which is easily eroded, is a thin, red-brown loam or clay, similar to that of the Lower Coralline Limestone. It is classed as terra fusca and terra rossa (Lang in Bowen-Jones et al., 1961, p.92, fig.27).

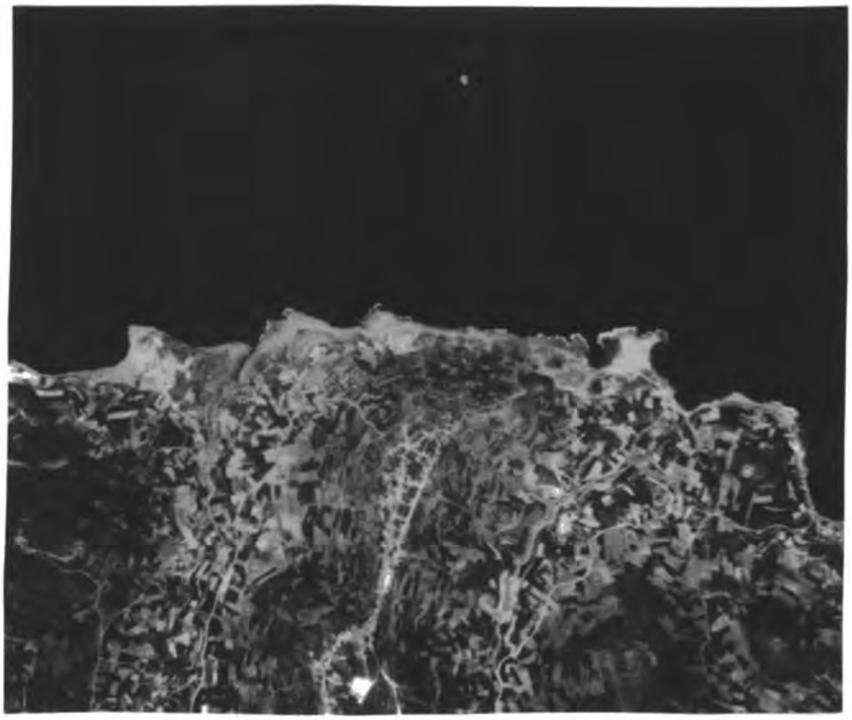
Economic Uses. The Upper Coralline Limestone is used locally for walling when the more suitable Globigerina Limestone is not available. In addition, certain levels are quarried at Xaghra for use as an ornamental stone, known as 'Gozo Marble'. Coloured red or yellow and taking a good polish, this is a recrystallised part of the limestone, probably formed at the same time as the tufa veins. The limestone is also quarried for lime at Ghajn Abdul (288895) and at Xaghra. In the former place the rock used is soft and pure white.

PLATE FOUR

Aerial view of coast west of Marsalforn,
showing darker Blue Clay over light Globigerina
Limestone and Upper Coralline Limestone mesas
(compare the frontispiece)

Qala Tax-Xlendi from the north-east,
showing, in the foreground, a major
fault-line scarp and, behind the village,
westward dipping Globigerina Limestone

Taken from 297880



P A L A E O N T O L O G I C A L   I N T R O D U C T I O N

The fossil echinoids of Gozo and Malta make up a major part of the macrofauna of the Tertiary rocks described above. Certain of the more abundant of these echinoids are described in the succeeding pages. The classification is basically that of Mortensen (1928 - 1951), modified where appropriate from the studies of Durham (1955), Durham and Melville (1957), Keir (1957 and 1962) and Cooke (1959). The descriptive terminology closely follows that given by Morley Davies (1935, pp. 109 - 114).

A table of echinoid distribution is given. This is based on previous records, revised where possible from personal collecting and the following systematic descriptions. In addition, the evidence provided by the echinoids for correlation purposes is discussed with reference to previous opinions. Evidence about depositional conditions has been set down where appropriate in the preceding stratigraphical account.

Class	ECHINOIDEA	Leske 1778
Order	CLYPEASTEROIDEA	L.Agassiz 1835
Suborder	SCUTELLINA	Gray 1825
Family	Scutellidae	Gray 1825
Genus	Scutella	Lamarck 1816

Type species Echinodiscus subrotundus Leske 1778

Diagnosis:

Flattened, thin-edged, scutellid echinoids; petals closed, about half radius of test in length, pore-pairs conjugate, outer ones elongate; four genital pores; peristome central, small; periproct on oral surface, removed from margin, 0.4 to 0.8 of mouth to margin distance from mouth and between first or second pair of post-basicoronal plates; margin of test with broad indentations corresponding to sutures of all columns, especially central ones of rear ambulacra; food grooves on oral ambulacra, bifurcating immediately outside basicoronal plates with variable secondary branching near margin; basicoronal plates moderately large, interambulacrals slightly larger than ambulacrals, interamb columns narrower at their contact with basicoronals than ambulacrals, which touch both interamb and basicoronals; amb and interamb columns of about equal width at margin; six or seven post-basicoronal plates in each column.

This diagnosis differs from that of Durham (1953, p349; 1955, p.150-1) in one important respect. Forms with the periproct between the second pair of post-basicoronals, and up to four-fifths of the way to the margin, are placed within the genus. Such forms have been recognised in the Scutella Bed of Malta and Gozo, and though they are specifically distinct from Scutella subrotunda they are clearly very similar. Durham, discussing his revival of Lambert's genus Parmulechinus (1955,p152-3), mentions British Museum specimens labelled Scutella striatula with the periproct near the margin, these are probably examples of this second species. Durham said: 'if the Maltese specimens and Scutella subtetragona are congeneric with S.agassizi... then Parmulechinus is characterised by: a marginal or sub-marginal periproct between the fourth or fifth pair of post-basicoronal interambulacral plates; interambulacra about half width of ambulacra at the ambitus; and petals about half the length of the corresponding radius' (1955, p.152). In fact the Maltese forms do not have narrower interambs or the periproct on the fourth or fifth pair of post-basicoronals and so cannot be classed as Parmulechinus, nor do they bear much relationship to Scutella subtetragona.

On the other hand, the genus Parascutella, created by Durham, (1953, p.349-50), includes forms with the periproct between the third pair of post-basicoronal plates and thus excludes the Maltese form. Durham goes on to mention the existence of some species with the periproct between the third and second post-basicoronals. Of the examples he later cited (1955, p.152), the figure by Agassiz (1841, pl.16f.2) is the only one that can with any certainty be said to show this.*

In fact this figure shows a situation almost identical to that of the Maltese form and is better described as having the periproct within the second pair of post-basicoronals.

As shown in text-figures 6 & 7, there appear to be three or four positions for the periproct within the scutellid group. The question arises whether these warrant generic separation. Their stratigraphical usefulness has not been proved and it is often difficult to establish the plate structure of the lower surface. At present it is proposed that the diagnosis of Scutella is widened and that these positions are used as specific criteria.

*Agassiz identified the specimen figured as Scutella truncata Valenciennes 1830, actually Bory 1824, but his specimen has its periproct much farther from the margin and was grouped by Lambert (1908, p.3) with Scutella stellata Agassiz (1841, p.83).

Scutella subrotunda (Leske) 1778

plates 5, 6, 7, text-figs. 5, 6 & 7.

1778 Echinodiscus subrotundus Leske, p.206-7, pl.47, f.7

1816 Scutella subrotunda Leske apud Klein; Lamarck, p.11-12 (partim)

1827 Scutella subrotunda Lamarck, (partim); Defrance, p.230

1829 non Scutella subrotunda Lamarck; de Serres, p.156 (fide Lambert, 1912)

1836 Scutella subrotunda Lamarck, (partim); Grateloup, p.87 or 232

1837 Scutella subrotunda Lamarck, (partim); Desmoulins, p.80

1841 non Scutella subrotunda Lamarck; Agassiz, p.76-78, pl.17 (sed vide p.87)

1847 non Scutella subrotunda Lamarck; Agassiz and Desor, p.132

1853 non Scutella subrotunda Eichwald; Eichwald, p.47, pl.3, f.1a-c

1855 Scutella striatula de Serres, (partim); Wright, p.119-20

Scutella subrotunda Leske, (partim); Wright, p.118-9

1858 non Scutella subrotunda Lamarck; Desor, p.232, pl.28

1861 non Scutella subrotunda Lamarck; Michelotti, p.23 (fide Lambert, 1912)

1864 Scutella subrotunda Leske; Wright, p.479 (partim)

1868 non Scutella subrotunda Lamarck; Laube, p.17

1869 non Scutella subrotunda Lamarck; Tournouer, p.278-82

1878 non Scutella subrotunda Lamarck; Dames, p.23

1882 Scutella ammonis Fuchs, p.30, pl.9, f.1-4

Scutella rostrata Fuchs, p.30, pl.12, f.4-6

1884 non Scutella subrotunda Lamarck; Bittner, p.— (fide Airaghi, 1902, p.375)

1891 Scutella striatula de Serres (partim); Gregory, p.597-8

1898 non Scutella subrotunda Lamarck; Nicholson, f.238 (fide Durham, 1953)

1901 non Scutella subrotunda Lamarck;Airaghi,p.186,

1902 Scutella melitensis Airaghi, (partim) p.377-8n, pl.15, f.1

non Scutella subrotunda Lamarck; Airaghi, p.375

1905 non Scutella subrotunda Lamarck; Fallot, p.9, pl.1, f.2

1908 Scutella melitensis Airaghi; (partim) Stefanini, p.447-50

1912 Scutella subrotunda(Leske); Lambert, p.57-62, f.1

1912 Scutella Scillae (Klein); (partim) Lambert, p.62-3

1913 non Scutella subrotunda Lamarck; Zittel, p.405

1914 Scutella melitensis Airaghi; (partim) Cottreau, p.87-91; non pl.4, f.7,7a

1914 Scutella Scillae (Klein); (partim) Lambert and Thièry, p.318

1914 Scutella subrotunda (Leske); Lambert and Thièry, p.318

1948 Scutella subrotunda (Leske); Mortensen, pp.2,4,361-2

1953 Scutella subrotunda (Leske); Durham, p.349-50, pl.47

1953 non Scutella rotundata , H.&G.Termier in Piveteau, p.13, f.3

1955 Scutella subrotunda (Leske); Durham, p.150-1, f.3c, 14c, 18a

non Scutella Subrotunda, Hyde, f.8

Diagnosis;

Thin-edged scutellids, very low conical upper surface, near circular outline with slightly indented margin, especially at ends of rear ambulacra but not of rear interambulacrum; petals a little under half corresponding radius; flat oral surface, central mouth with anus removed from it between 0.38 and 0.56 of the mouth to margin distance, located between first pair of post-basicoronal rear interambulacral plates; interamb columns just reach basicoronals, not touching ambulacral ones.

Description:

The test is flat, thin-edged and is large when fully-grown. The upper surface is gently conical, highest slightly to the rear of the apical disc; while the lower surface is flat. It has a nearly circular outline, slightly longer than wide and sinuous with indentations of varying extent which are not always symmetrically developed, (e.g. neotype-BM.E 16593). These are formed at the ends of the central amb and interamb sutures, especially those of the rear paired ambs.

The apical disc is central, up to 4mm. across, with genital plates fused to form a central, pentagonal madreporite with a finely irregular surface perforated by numerous small pores (60/sq.mm. in Gz 691). There are four genital pores at the corners of the madreporite, the rear corner lacks one, and five very small ocular pores.

The ambulacral petals are flush with the test surface, or are very slightly depressed relative to the interambs (e.g.Gz 620) and extend, on average, 0.45 of the distance from the ocular pores to the margin, the front petal often further than the others but none ever more than halfway. The length of the paired petals is twice their width, the unpaired one is longer, usually narrower and also tapers less distally.

Dot-dash pore-pairs are formed. The inner pores are oval and nearly constant in size except near the oculars: the outer pores are the same near the oculars but rapidly become slit-shaped and up to about 1.5mm. long (Gz 619) three-quarters of the distance from the oculars and then contract to the end. They are deepest on the outer side and are occasionally seen to be joined to the inner pores by a fine groove, but are usually apparently non-conjugate (rare with dot-dash pore-pairs). The shape of petal-ends varies within and between species but is always less tapered than the proximal ends, often with outer pores that have become irregular (e.g. Gz 619, text-fig. 5,1). Sometimes the outer pores suddenly shorten to resemble the end of a pipette (e.g. Gz 38), occasionally the inner pores remain further apart than usual (e.g. Gz 42). The plates within each petal are simple, bent to contain one pore-pair (text-fig. 5,2), and there are from 50 to 90 in each column within the petals.

Outside the petals the ambulacra quadruple in width to the margin with seven (e.g. Gz 623) or eight (e.g. Gz 1009) plates to a column, each hexagonal and wider than long. The first plate outside a petal is irregular, sometimes with the development of a minor plate (e.g. Gz 625).

The interambulacral areas are double along their entire length and widen rapidly outwards within the petal area, with the plates bending back near the petals(text-fig. 5,3); beyond the petal area the interambs widen slightly. There are five plates in each column, they have no kink, are smaller and narrower than the equivalent ambulacrals, and are narrower at the margin, forming a thin, rounded edge.

The upper surface, apart from the apical disc, is covered by small, tubercular spine-bases. The oral surface contains the mouth which is central, circular to subpentagonal, not sunken, and has a diameter of up to 6mm.

The basicoronal plates, which are not easily detected (for example, they are not visible on Durham's neotype, BM E 16593), form round the mouth with five pairs of ambulacrals and five single interambulacrals, fifteen in all, radially arranged. The ambulacrals are in symmetrical pairs, longest at their junction: up to 8.4mm. long, 0.17 of radius in Gz 627, and shaped as in text-fig. 5,5. The interambulacral ones are longer: 9.6mm. in Gz 627, 0.19 of the radius. They are wider at their widest part and each outer end has a double inflection in one side (text-fig. 5,5).

The ambulacral columns touch the sides of the interamb basicoronals and consist of six plates in each column. The first post-basicoronal plates are nearly straight-sided, their length twice the width, and the succeding plates are nearly equilateral hexagons which widen to the margin where their width is twice the length.

The interambulacral columns taper orally, reaching the tip of their basicoronals but not extending down to touch the ambulacral ones. The first post-basicoronals are wedge-shaped with one of the pair bigger than the other (on Gz 627, 1b, 2a, 3b, 4a, 5a are bigger), whilst sometimes one of the pair may be occluded (e.g. Gz 610, text-fig. 5,4).

The anus is circular, small and not sunken but sometimes has a shallow triangular depressed area distally. It is always located between the rear pair of first post-basicoronal interambulacral plates, but at a variable distance along them: half-way in Gz 614, two-thirds from the oral end in Gz 627, very nearer the outer end in Gz 604. The distance from the mouth ranges between 0.38 and 0.56 of the mouth to margin length; in the neotype it is 0.51 of the distance (text-fig. 6). Succeeding interambulacral plates are more regularly hexagonal, widening to the margin, and larger than the equivalent ambulacrals with five in each column.

Food grooves run out from the mouth along the lines of paired ambulacrals and bifurcate at about 30° immediately beyond them with the two branches keeping along the centre of their plate-columns. Secondary branching is variable; some form half-way along at right-angles and pass into the ambulacral columns and then bend to the margin; others slant off more gradually; all become dendritic and have died out at the penultimate marginal plates.

Dimensions:	length:	58 to 113mm.
	width:	57 to 109mm.
	thickness:	4.6 to 9.2mm.

Horizon and Material:

All the specimens measured come from one level, the Scutella Bed between the Lower Coralline Limestone and the Globigerina Limestone. The species has a greater range, described earlier, pages 15-18. The scutellids are usually found with the apical disc upwards and the mouth buried in matrix; some, about one in eight, are upside down, facilitating a study of the adoral plate structure which is otherwise difficult to examine. About thirty individuals were collected, twenty of these in good enough condition to be measured. All the specimens are cracked and the coelom area is frequently crushed, owing to the very delicate test. The marginal areas of the oral surface are sometimes bored by parasites. Small, broken fragments, closely packed together, are common in certain areas, an indication of shallow water re-sorting. The best collecting areas are those where this close packing has not occurred and individual specimens can be extracted. Most specimens came from round Dwejra (273897), Torri ta Xlendi (293873) and Ix-Xatt L'Ahmar (355862).

Type specimen:

Leske's original type has long since disappeared. The specimen figured by Scilla (1670, no.35, pl.8,f.1), has, however, been preserved in the Woodwardian Collection at the Sedgwick Museum , Cambridge (drawer E24, no.35). Since the description and figuring of this specimen was pre-Linnean it cannot, unfortunately, be used. Durham (1953, p.349-50, pl.47) selected a neotype from the British Museum Collection. It is registered as BM E 16593.

Remarks:

The synonymy of Scutella subrotunda reveals the uncertainty that has existed in the past. Much of this has been caused by descriptions restricted to the upper surface of the test from which, at first glance, all scutellids look alike. Features thus missed are the position of the anus, the basicoronal plate pattern and the pattern of the food-grooves, all important for specific distinctions. Lambert (1912, p.57-61) summarised the history of the name and Durham (1953, p.349-50, pl.47) figured and described a neotype which is slightly untypical of the subrotunda specimens examined as far as its more pronounced marginal indentations are concerned.

Scutella ammonis is included partly because the figures and description agree with subrotunda and also since unpublished attempts have been made to identify the Maltese scutellids with this form. Scutella rostrata has been recognised as a variant of ammonis by previous workers, (e.g. Cottreau, 1914, p.53-4), and is also included although specimens of neither species have been examined personally.

Scutella sp. nov.

plate 7, text-figs. 5,6 and 7.

1891 Scutella striatula de Serres, (partim); Gregory, p.597-8

1902 Scutella melitensis Airaghi, (partim), non pl.15, f.1

1908 Scutella melitensis Airaghi, (partim); Stefanini, p.447-50

1912 Scutella Scillae (Klein), (partim); Lambert, p.62-3

1914 Scutella melitensis Airaghi, (partim); Cottreau, p.87-91, pl.4, f.7,7a.

1914 Scutella Scillae (Klein), (partim); Lambert and Thiéry, p.318

1955 Parmulechinus [Scutella] cf. subtetragona Grateloup; Durham, p.152

Diagnosis:

Small scutellids of variable thickness; very low, conical to convex upper surface; subtriangular outline, widest behind the central apical disc; margin slightly indented at ends of rear ambulacra, rear interambulacrum usually not indented; petals a little under half length of corresponding radius; lower surface flat, mouth central with anus removed from it between 0.66 and 0.78 of mouth to margin distance, located between the second pair of rear interambulacral post-basicoronal plates; food grooves shallow and indistinct; tubercles relatively large and distinct.

Description:

The upper surface of the test is flat and usually thin-edged but is occasionally thicker (e.g. Gz 13, 1002, 1008), being raised in the petal area to produce a conical to convex surface. The lower surface is flat and frequently crushed in the coelom area; the outline is subtriangular, slightly longer than wide and widest behind the apical disc. The margin is indented at the ends of the central ambulacral and interamb sutures, particularly of the rear paired ambulacra. There is no rear notch, except for an eccentric one in Gz 1008 (which is possibly caused by damage during growth).

The apical disc is central, up to 2.5mm. across, with a fused madreporite and four genital pores as in subrotunda.

The petals are flush with the test surface, extending between 0.44 and 0.54 of the distance to the margin, and are thus apparently more variable than in subrotunda. In small specimens the petal length is twice the width and is more in larger ones. The front petal is often slightly the longest and in large specimens is the slimmest.

The pore-pairs are conjugate with a dot-dash pattern. The outer pore is only slightly slit-shaped in small forms and otherwise is very similar to subrotunda. The number of pores to a column ranges from 25 (Gz 1005) to 50 (Gz 960).

The ambulacra beyond the petals treble in width by the margin and contain seven plates in each column. The interambulacra are like those of subrotunda but no kinking is detectable in plates near the disc. The upper surface is covered by small tubercular spine-bases which are relatively larger and more marked than in subrotunda.

The mouth is central on the lower surface. It is circular, not sunken and up to 2mm. in diameter. The basicoronal plates are the same as in subrotunda, though the paired nature of the ten ambulacrals is difficult to establish. The ambulacral columns touch the sides of the interambulacral basicoronals as well as the ambulacral ones. Six post-basicoronal plates are seen on the ambs of Gz 975 with shapes that are similar to those of subrotunda.

The interambulacral columns taper mouthwards with the wedge-shaped first post-basicoronals touching the tips of the interambulacral basicoronals. The others are more regular hexagons and the outer ones are larger than the corresponding ambulacral plates.

The anus is circular, small, not sunken and is sited between the second pair of rear interambulacral post-basicoronal plates (e.g. Gz 1002, text-fig.5,5). Its distance from the mouth relative to the mouth to margin length varies from 0.66 to 0.78.

The food grooves are less prominent than in subrotunda, running along the centres of ambulacral basicoronals and splitting immediately beyond, at an angle of about 30°. They become much shallower and very indistinct towards the margin.

Dimensions:	length:	19 to 56mm.
	width:	17 to 54mm.
	thickness:	2.8 to 4.5mm.

Type specimen and material:

Gz 12 (pl.7) is figured as the type specimen. The oral surface is identical to that of Gz 1002 (text-fig.5,5). A dozen specimens have been collected from the Scutella Bed in the same localities as for subrotunda.

Remarks:

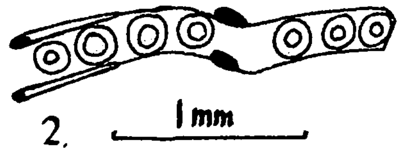
At first this form was considered to be simply the earlier growth-stages of Scutella subrotunda, both because it occurs at the same level, though not so widely, and also on account of the continuous range in the size of the scutellids (as shown in text-fig.6). Cottreau, in the only published figure of the species, (1914, pl.4,f.7,7a), considered it as the young form of Scutella melitensis Airaghi, which he equated correctly with Scutella subrotunda. The difference in outline,in thickness, and in prominence of the tubercles on the apical surface might all be accounted for within the variation of one species. The reason why the two forms must be separated lies in the relation of the anus to the plate structure of the lower surface and, mainly in consequence of this, in its distance from the margin. The former is rarely seen in normal preservation, the latter is easier to examine. Text-fig.6 shows the result of plotting the relative position of the anus against the absolute size, expressed by the length of the rear interamb. It is clear that there are two distinct positions for the anus and these warrant specific separation. The generic position of the small scutellid is not clear. The criteria drawn up by Durham (1953, p.351) do not help. In all but details of the anal position the species fits Scutella. For the anus Abertella or possibly Parascutella has the same relation to the post-basicoronal plates but a different distance from the margin. This has suggested that a revision of the generic characters is needed, as attempted above.

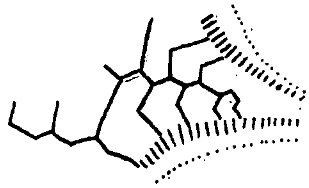
The synonymy shows the earlier suspicion that there was more than one species of scutellid in Malta, but it provides no name for the second form. Lambert's suggested Scutella scillae is invalid because it is pre-Linnean and, more importantly, because the differences between Scilla's figure and that of Leske are simply those of inaccurate drawing. The specimen figured by Scilla and preserved in Cambridge, referred to above, is definitely an example of subrotunda. Durham's tentative comparison with Scutella subtetragona Grateloup is invalidated by the clear differences in general shape, in the position of the anus, in the type of food grooves, and in the details of the plate structure and column widths.

TEXT - FIG. 5

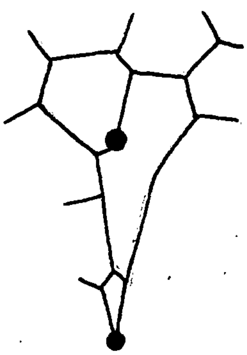
1.

2.





3. ×1



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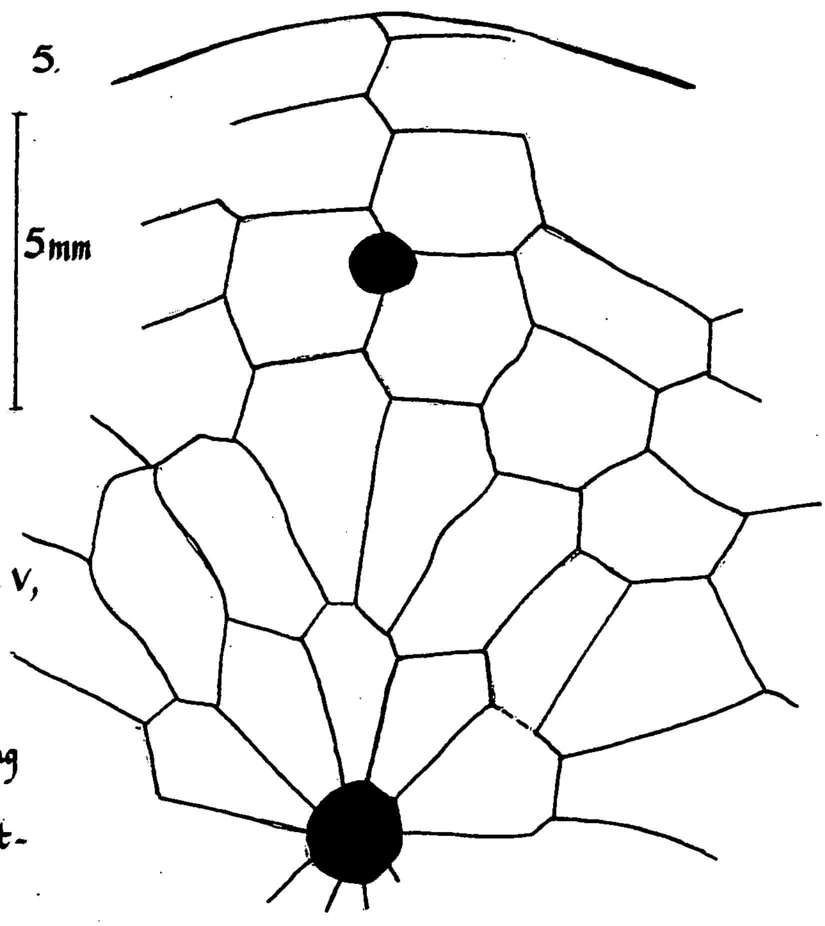


PLATE DETAILS IN Scutella

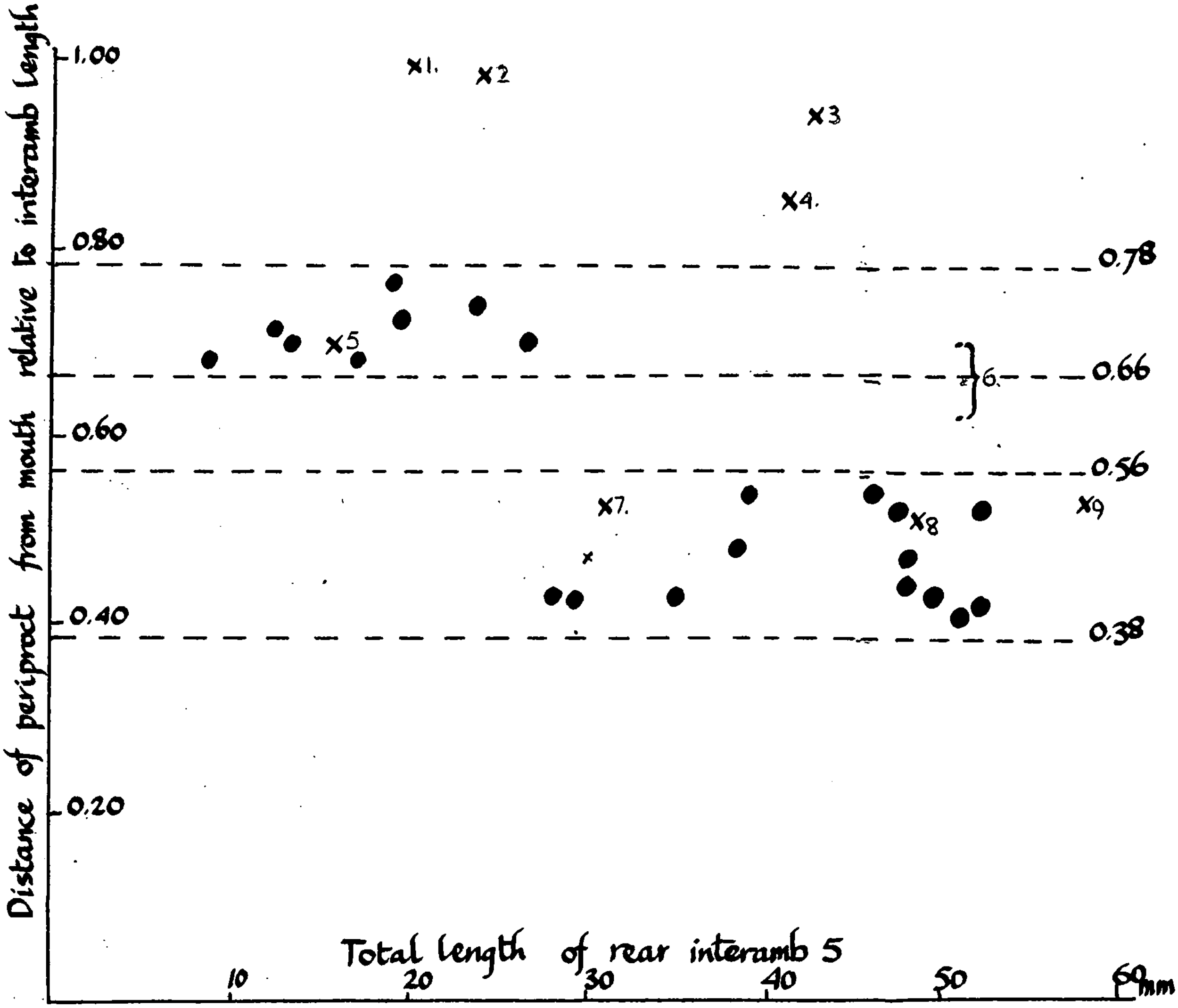
Scutella subrotunda

1. Gz 619 - distal end of petal V, showing pore-pair irregularity.
2. Gz 619 - detail of a plate and pore-pairs of petal IVb.
3. Gz 701 - interamb 4, showing kink developed in plates.
4. Gz 610 - occlusion of a post-basicoronal plate on interamb 5.

Scutella sp. nov.

5. Gz 1002 - plate boundaries on oral surface.

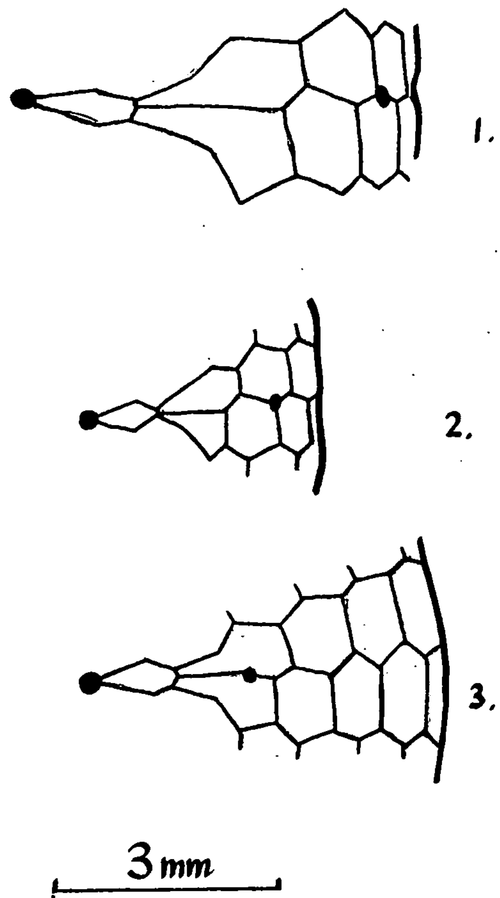
TEXT-FIG. 6



POSITION OF PERIPROCT IN *Scutella*

1 & 2. specimens of *S. subtetragona* in Sorbonne
3. specimen of *Parascutella* [*S.*] *leognanensis* in Sorbonne
4. figure of *P.* [*S.*] *leognanensis*
5. figure of *S. melitensis* in Cottreau 1914
6. approx. position of type of *S. melitensis*
7. type of *S. ammonis*
8. neotype of *S. subrotunda*
9. example of *S. melitensis* in Cottreau 1914

TEXT-FIG. 7



DIFFERENT PERIPROCT POSITIONS
IN THREE SCUTELLID SPECIES

1. *Parascutella* [*Scutella*] *leognanensis* (Lambert)
2. *Scutella* sp. nov.
3. *Scutella subrotunda* (Leske)

PLATE FIVE

Scutella subrotunda (Leske)

Gz 38 x 2/3

Scutella Bed,

N of Dwejra, 272897

Scutella sp.nov.

Gz 12 x 3

Scutella Bed,

Ix-Xatt L-Ahmar, 356862

Scutella subrotunda (Leske)

Gz 627 x 2

Scutella Bed,

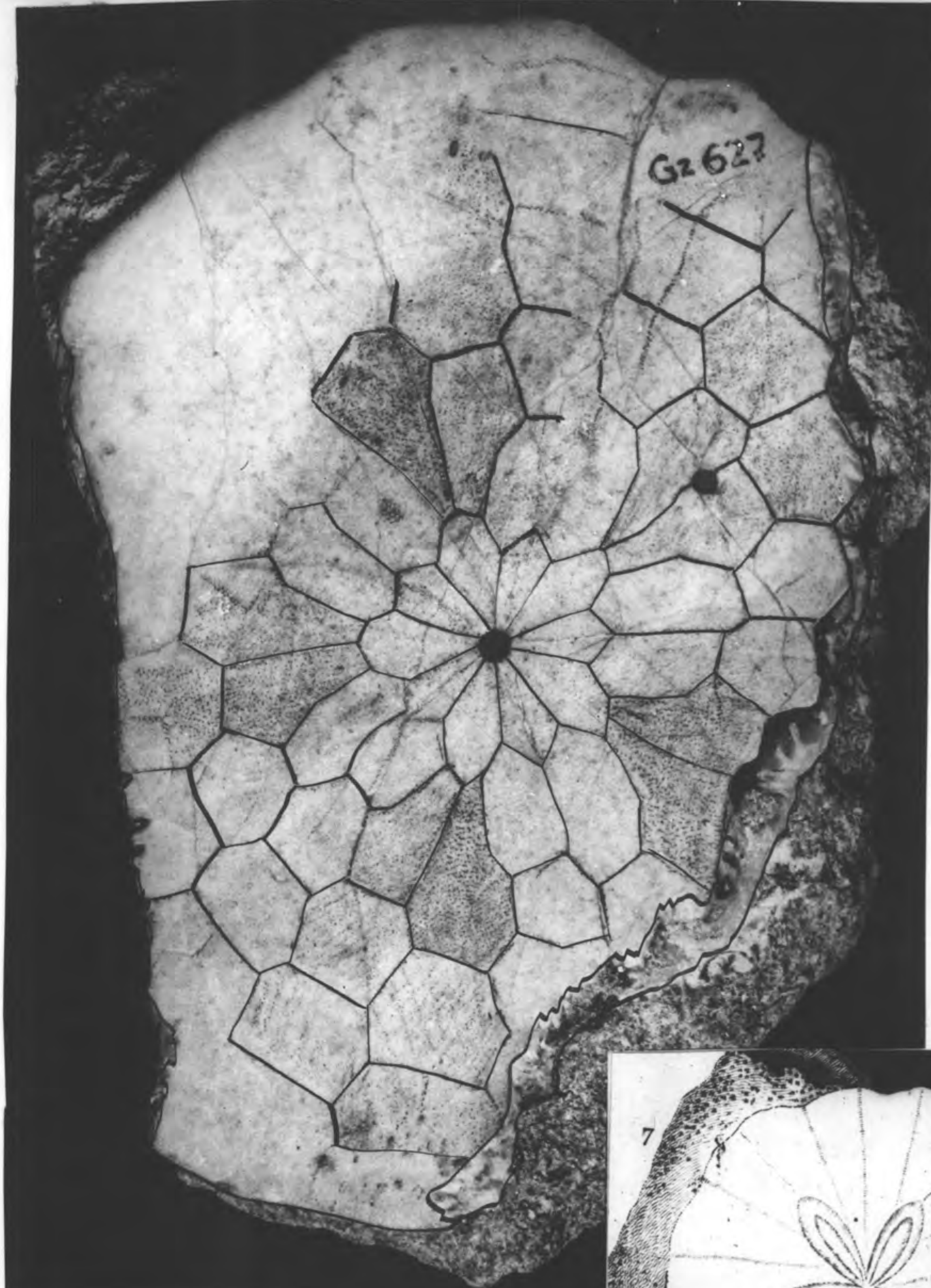
Ix-Xatt L'Ahmar, 356862

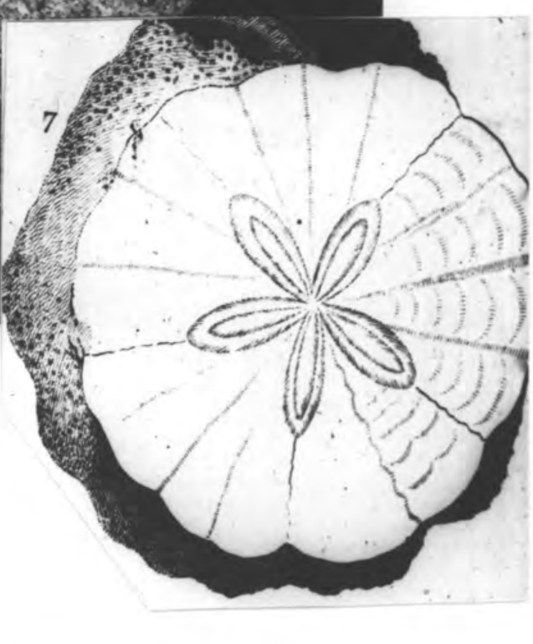
Leske's type figure

Addit. ad Kleinii &c, 1778

pl.47, fig.7 x 1

PLATE SIX





7

PLATE SEVEN

Scutella subrotunda (Leske)

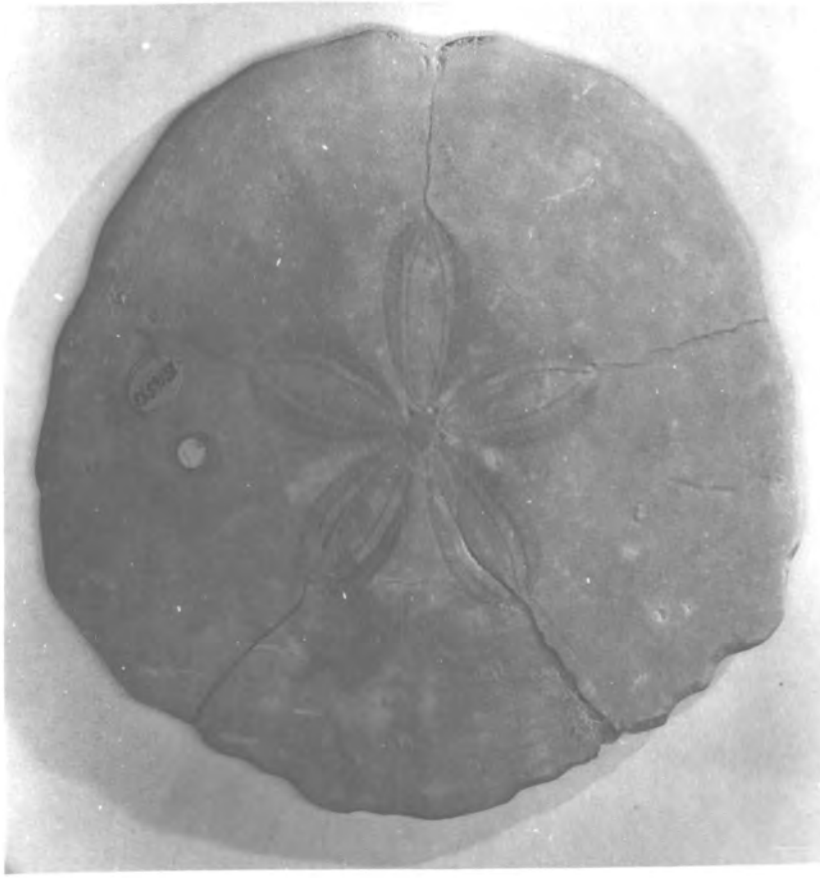
neotype

BM E 16593 x 1

Scutella Bed, Malta

note inflation of petals

and indentations on interamb la



Order	CASSIDULOIDA	Claus 1880 emend.
Suborder	CASSIDULINA	Claus 1880 emend.
Family	ECHINOLAMPADIDAE	Gray 1851
Genus	Echinolampas	Gray 1825

Type species Echinolampas oviformis (Gmelin)

Diagnosis: (from Kier 1962, p.106):

Medium to large forms, often with high test, elongate to circular, apical system monobasal, petals moderately developed, sometimes lanceolate, open or closing distally, pore-zones usually unequal, inter-pore zones wide, single pores in ambulacral plates beyond petals; periproct close to margin, transverse; peristome transverse, pentagonal; bourrelets well developed; phyllodes single pored, usually moderately developed, with from two to three series of pores at each side; buccal plates present; tubercles adorally same size as adapically; usually narrow, naked granular zone in interambulacrum 5.

At least 11 separate species of Echinolampas have been recorded from Gozo and Malta. Discussion and description is confined to the distinctive species common in the Greensand. Other reliably recorded species are listed at the end of the descriptions.

Echinolampas lucae (Desor)

plate 8

1847 Conoclypus lucae Desor; Agassiz and Desor, p.168

1855 Conoclypus plagiosomus Agassiz; Wright, p.125-7

1891 Heteroclypeus hemisphaericus Gregory, p.598-9, pl.1, f.11

Heteroclypeus subpentagonalis Gregory, p.599-600

1908 Echinolampas Pignatarii (Airaghi); Stefanini, p.456-462

1911 Hypsoclypeus hemisphericus (Gregory); Gregory, p.671-673

1921 Heteroclypeus melitensis Lambert and Thiéry, p.377

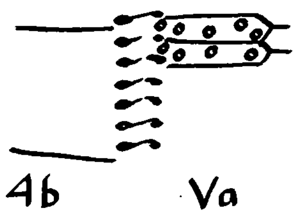
Diagnosis;

Large, subcircular, domed cassiduloid echinoids; apical disc small with very small ocular plates; ambulacra have open-ended, near-parallel pore zones extending almost to ambitus; flat lower surface with mouth slightly to front of centre, sunken, pentagonal, and transversely elongate, surrounded by prominent bourrelets and fainter phyllode; anus close to rear margin, not sunken and transversely elongate.

Description of Maltese specimens:

Upper Surface. The striking upper surface contains a prominent Apical Disc, sited at the highest point of the test, slightly to the rear of centre. It consists of an irregular, conical knob, a few millimetres high, covered with small spine-bases and fine perforations which extend to the interambulacral column-heads, forming a central pentagonal madreporite which has four genital pores round it, column 5 lacking one. The ocular pores are not distinguishable.

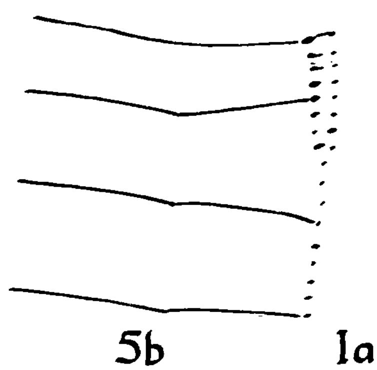
Ambulacral Columns. The ambs extend from the apical disc to the ambitus with little expansion. At the ambitus, where their width is greatest, they are little over a quarter of the interambulacral width. The pore-zones are made up of about 20 pore-pairs. Each outer pore is elongated laterally and connected to the circular, more deeply impressed inner pore by a faint groove (see text-fig. 8a). They gradually diverge from the apical disc and become parallel between half and two-thirds along their length, i.e. about 50mm. from the disc. Some 20mm. from the ambitus they are replaced by faint, single pores which form slightly divergent lines towards the ambitus (text-fig. 8b). The open-ended petals are not quite symmetrical: IIb and IVa, the columns nearer the front, are noticeably straighter than IIa and IVb; Ia and Vb are straighter than Ib and Va. The sutures of the ambulacral plates are indistinct as a result of the even covering of small spine-bases, but an apparently simple suture runs along the line of the pore-pairs.



35mm from ambitus

M(t 321 x 2

Text-figure 8a



20mm from ambitus

M(t 321 x $1\frac{1}{2}$

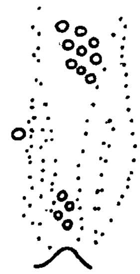
Text-figure 8b

Interambulacral Columns. The wider interambs are raised slightly above the level of the ambs, except along the main sutures, which are a little sunken and, around the ambitus in particular, are thickened. The plates are large and have curved boundaries (see text-fig. 8b). They form two simple columns between the ambs and are uniformly covered by small, tubercular spine-bases, except at the sutures. There are about twenty plates in each column with the largest a little above the ambitus. At the ambitus the last plate in columns 1a, 2a, 4b, and 5b widens towards the pore-zones to produce wedge-shaped plates. All the interamb plates have a slight inflexion half-way across and this is related to the two straight, radial ridges which run out along each interamb (seen best on interamb 5 of plate 8a).

Ambitus. The ambitus is evenly rounded and level, except for zones on either side of the rear. From interamb 4b round to 1a, the margin is raised, presumeably to aid in the dispersal of waste products.

Oral Surface. The lower surface is slightly concave, particularly between the mouth and anus, and, to a lesser degree, along the ambulacra.

Text-figure 9
Mlt 321
Phyllode on amb IV
×2



Ambulacral Columns. Each amb has two faint lines of pores along its edges. These converge on the mouth and become more pronounced some two-thirds of the distance from the ambitus, forming a phyllode, (see text-fig. 9 and compare Kier 1962, fig.93). On each amb this has two, then three lines of pores on either side of a band of spine-bases which extend to the mouth.

Interambulacral Columns. The interambs terminate at the mouth as raised bourrelets. These are five vertically-walled butresses forming the sides of the mouth. Each of the five is covered with fine spine-bases and has rounded shoulders above, covered with larger spine-bases. The bourrelets on interambs 1 and 4 are narrower and that on interamb 5 is wider as a consequence of the elongated shape of the mouth.

Mouth. The mouth is a little to the front of a central position and has a transversely elongated pentagonal shape. It is deeply sunken with steep sides, covered by fine spine bases which directly abut the phyllode and bourrelets.

Anus. The rear interamb contains the anus at the ambitus, on a slightly raised area with no sunken walls like the mouth. The anus has a transversely elongated shape.

Dimensions:

The best preserved specimen, Mlt 321 which is typical in size, has the following dimensions (in millimetres, with those of Gregory's type (1891, p.590) given in parenthesis where comparable):

Length 126.5(155), width 121(150), height 66.5(64), maximum width of pore zone 2(3), of inter-pore zone 12.5(17), distance of apical disc from front 61(72), distance of mouth from front 61(72); mouth -width 12, -length 7; anus -width 13(14), -length 6.5(7).

Remarks:

The synonomy shows the uncertainty that has existed over the name of this very distinctive fossil. Gregory gave the fullest description and figure in 1891 but subsequently decided that he had placed it in the wrong genus, an opinion restated by Mortensen (1948, p.315-6) who considered Heteroclypeus to be a synonym of Hypsoclypus. Kier(1962, p.111-2) opined that Hypsoclypus was indistinguishable from Echinolampas, though he exaggerated Mortensen's underestimation of the phyllodes in Hypsoclypus. Kier's opinion is adopted here. An examination of the various criteria adopted in distinguishing the genera in the synonomy reveals their arbitrary nature (eg. Agassiz and Desor, 1847, p.167-8; Wright, 1855, p.125; Pomel, 1869, p.25 and 1883, p.62; Cotteau, 1891, p.104 and 1895, p.30-1; Gregory 1891, p.598-600 and 1911, p.671-673; Airaghi, 1900, p.174-5; Lambert 1907, p.54-5; Stefanini 1908, p.456-462; Lambert and Thiéry on Heteroclypeus) and an examination of the Paris collections confirms the great similarity of appearance. Apart from names, the frequent presence of a raised madreporite, as described above, is interesting since it receives no mention in the descriptions mentioned. It is considered that Wright's original identification should stand and since it is agreed that this is conspecific with Echinolampas lucae the latter is listed from Malta for the first time. Kier's plates (1962, pl.31, f.1 and pl. 32, f.1) confirm this identification.

PLATE EIGHT

Echinolampas lucae (Desor)

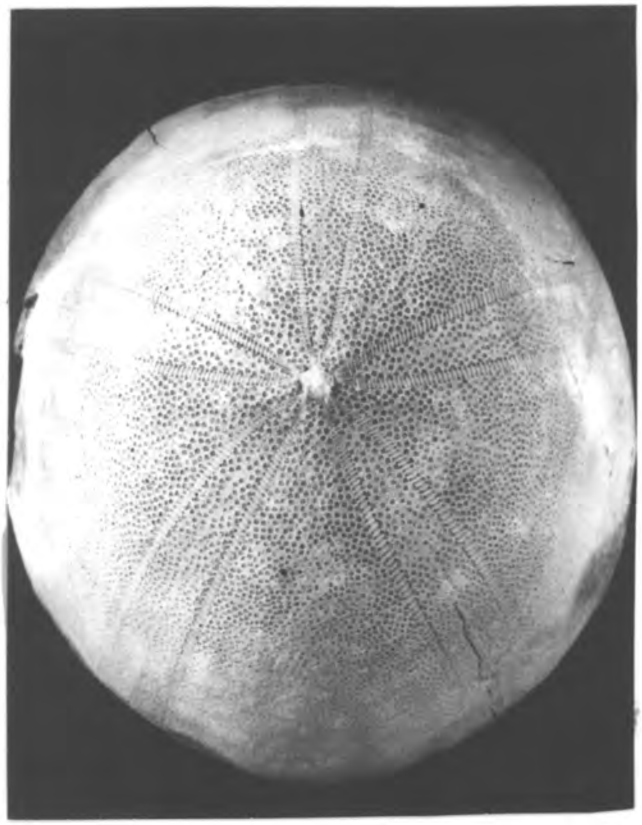
Mlt 321 x 2/3

Greensand; Dingli, Malta ÷ 438678

"Heteroclypeus melitensis" Lambert and Thièry

Lambert Collection, Sorbonne x 1

Gebel Geneffe, Egypt.



Order SPATANGOIDA Claus 1876

Family SCHIZASTERIDAE Lambert 1905

Genus _Schizaster_ L. Agassiz 1836

Type species _Schizaster studeri_ Agassiz 1836

Diagnosis:

Typical spatangoid, with general heart-shaped appearance, apical system posterior to centre, marked front groove, sunken paired petals, rear ones half length of front pair, peripetalous and lateral fascioles, latter passing beneath anus, mouth close to front with slight labrum and plastron to rear, anus in vertical rear surface.

Discussion:

In the past this genus has been much subdivided, more recently a two-fold division has been proposed, based mainly on the number of genital pores. Mortensen (1951, pp. 216, 297, 299), Kier (1956, p.881) and Cooke (1958, p.71) consider the significance of the genital pore number. The type species, _Schizaster studeri_ was described by Agassiz as having two genital pores, but it is still uncertain whether there are two or four in this species. Pomel in 1869 established the genus _Paraster_ with _Schizaster gibberulus_ Agassiz and Desor, a Recent form, as type species. This definitely has four genital pores. Mortensen recognised the two genera, Kier regarded _Paraster_ as a sub-genus for four-pored schizasters. All the Maltese specimens that have undamaged apical systems, that is, about a quarter, possess four genital pores (with two doubtful cases). In the face of uncertainty about the pores of S. studeri and the generic value of the pore numbers in general, all the Maltese forms have been placed in the genus Schizaster.

Specimens of Schizaster are among the most abundant Maltese echinoids in most collections. Seven species of Schizaster have been listed from the Maltese islands. These are;

S. canaliferus (Lamarck)1814

S. desori Wright 1855

S. eurynotus Agassiz 1843

S. melitensis Stefanini 1903

S. parkinsoni (Defrance)1827

S. sardiniensis Cotteau 1895

S. scillae (Desmoulins)1837

The specimens collected, together with those in the British Museum, have been allocated to two of these species:- S. eurynotus and S. parkinsoni, These are described below and separated on the basis of both morphology and horizon.

Schizaster eurynotus Agassiz

Plate 12, text-figure 11.

1778 Spatangus lacunosus (partim); Leske, p.227

1814 Spatangus canaliferous (partim); Lamarck, p.327

1836 Spatangus canaliferous (partim); Lamarck; Grateloup, p.67

1837 Spatangus Scillae; Desmoulins, p.392

1843 Schizaster eurynotus; Agassiz (in Sismonda), p.31, pl.2, fig.2 & 3

1843 Schizaster canaliferous (Lamarck); Agassiz (in Sismonda)(partim).

1847 Schizaster eurynotus (Lamarck); Agassiz and Desor (partim), p.127

1855 Schizaster eurynotus (Lamarck); Wright, p.262-4

1856 Schizaster scillae Desmoulins; Cotteau

1864 Schizaster Scillae (Desmoulins); Wright, p.484

1891 Schizaster scillae (Desmoulins); Gregory, p.617-8

1906 Schizaster eurynotus Agassiz; Lambert, p.114-8

1908 non Schizaster eurynotus Agassiz; Stefanini, pp.476, 8 & 9, pl.17, fig. 13

1914 Schizaster eurynotus Agassiz (in Sismonda); Cottreau, p.114-5, pl. 14, figs. 1-6.

Diagnosis:

Medium-sized spatangoid echinoids, oval in outline, notched in front, tapered to rear; apical disc with four genital pores, between three-tenths and four-tenths of the total length from the rear; unpaired front ambulacrum in a deep and broad, U-shaped groove; angle between front amb and adjoining paired ones between 35^{o} and 40^{o}; lateral and peripetalous fascioles; mouth on lower surface, a quarter of the length from the front, with labrum and phyllode; large plastron; anus near top of rear truncated surface.

Description:

Upper Surface. The adapical surface is raised to a height of nearly two-thirds of the length, greatest close to the rear which overhangs near the top and contains the anus. The outline is oval, slightly longer than wide, indented at the front and tapered to the rear.

Apical disc. The disc is small with four genital pores; the rear pair are larger and farther apart. The madreporite extends back between oculars I and V, cutting out the rear genital plate, and links forwards to genital 2. The disc is situated between three-tenths and four-tenths of the total test length from the rear.

Paired ambulacra. These form deeply sunken petals, the front pair of which extend nearly seven-eighths of the distance to the margin and are proximally flexed forwards strongly and then a little recurved at the extreme ends. The front pair are widest close to their ends and are quite blunt-ended. Their angle of divergence from the long axis of the test is between 35° and 40°. The pore-pairs are conjugate with the inner ones oval and the outer ones more elongate. The inter-pore zones are nearly as wide as the pore-zones. The rear pair of petals are short, less than half the length of the front pair, and are leaf-shaped with tapered ends. The pore-pairs resemble those of the front pair but are closer spaced.

Unpaired ambulacrum. The front amb is partly petalloid, in a wide and deep furrow with a U-shaped cross-profile which is widest two-thirds of the distance from the apical disc to the front. The furrow notches the front margin and continues on the lower surface. There are a single series of of pore-pairs on both edges of the base of the furrow. These extend three-quarters of the distance to the margin, with pores about half the size of those in the paired petals, circular in shape and close together with an irregular tubercular spine-base between each inner and outer pore. Shallow grooves run from close to each outer pore up the side of the furrow, at right angles to its length. These are longer than comparable ones on S. parkinsoni (cf. Gz 919 and Gz 307, pl. 12). The inter-pore zone is about seven times the width of the pore zone. The furrow narrows from near the end of the pore-zones up to the margin.

Interambulacra. The interambs are raised relative to the ambs and are covered with a regular pattern of tubercular spine-bases which are larger around the margin, close to the disc and along the edge of the front furrow. The front pair are very narrow between the petaloid ambs but widen rapidly outside them. The suture between the two columns is closer to the front of the test. The rear pair widen more rapidly. Both pairs have series of nodes developed on them (see on Gz 919, pl. 12). The rear interamb is strongly ridged and is often crushed along the central suture.

Fascioles. There are two fascioles. The peripetalous one is fairly distinct. It crosses the front amb immediately beyond the pore-zone as a broad band (1.5mm. wide on Gz 912), then narrows and bends sharply back in columns 2b and 3a until reaching the central suture, where it rapidly widens across columns 2a and 3b and bends round the front paired petals; then it narrows and stays close to the rear edge of petals II and IV before bending out a little where the lateral fasciole branches off, then it crosses the interambs 1 and 4 close to the apical disc, bends round the ends of the rear petals, narrows and bends forward a little in crossing the rear interamb. Most of its path can be traced on Gz 919 (pl. 12). The lateral fasciole is narrower and less prominent. It branches off the peripetalous one at nodes on interambs 1b and 4a and then runs to the rear and the margin in a straight line until near the anus, where it drops vertically down the truncated surface and bends beneath the anus.

The anus is near the top of this truncated rear with a marked overhang above and a steep, flat area below. It is oval and elongated vertically.

Lower surface. The oral surface is somewhat convex, especially across the plastron and contains the mouth about a quarter of the test length from the front. The mouth is transversely elongated, crescentic in shape and has a labrum behind it with a thin lip and a fine groove to the rear. An area free of tubercles separates this from the plastron. The ambulacra form a phyllode round the mouth like that in *S. parkinsoni*. The front amb is in a shallow groove which links with the furrow on the upper surface. The front paired ambs extend from the mouth at right angles to the long axis of the test and narrow to the margin. The rear pair are horseshoe-shaped on either side of the plastron and are covered with fine spine-bases and a few larger ones at the rear. The interambulacra are covered with large, tubercular spine-bases, each with a boss and perforated mamelon. They are large and spaced out round the mouth (e.g. Gz 919, pl.12) and smaller, more closely packed towards the rear. There are small areas without spine-bases around the mouth, between the front and rear paired ambs, possibly serving to connect the phyllode ends.

Schizaster parkinsoni (Defrance)

Plates 9 - 13, text-figures 10, 11.

1811 Spatangus lacunosus Parkinson, p.29 (partim), pl.3, fig.4

1827 Spatangus Parkinsoni Defrance, p.96

1837 Spatangus Parkinsoni (Defrance; Desmoulins, p.240

1847 Schizaster Parkinsoni (Defrance); Agassiz and Desor, p.22

1855 Schizaster Desori Wright, p.264-6, pl.6, fig.3a-c

1855 Schizaster Parkinsoni (Defrance); Wright, p.266-8, pl.5, fig.3a-c

1858 Schizaster Desori Wright; Desor, p.391

1858 Schizaster Parkinsoni (Defrance); Desor, p.392

1864 Schizaster Desori Wright, p.485

1864 Schizaster Parkinsoni (Defrance); Wright, p.484-5

1891 Schizaster parkinsoni (Defrance); Gregory, p.616-7

1891 Schizaster desori Wright; Gregory, p.617

1906 Schizaster Desori Wright; Lambert, p.113

1908 Schizaster melitensis Stefanini, p.479-80

1908 Schizaster Parkinsoni (Defrance); Stefanini, p.476-9, pl.17, figs. 11 & 12

Diagnosis:

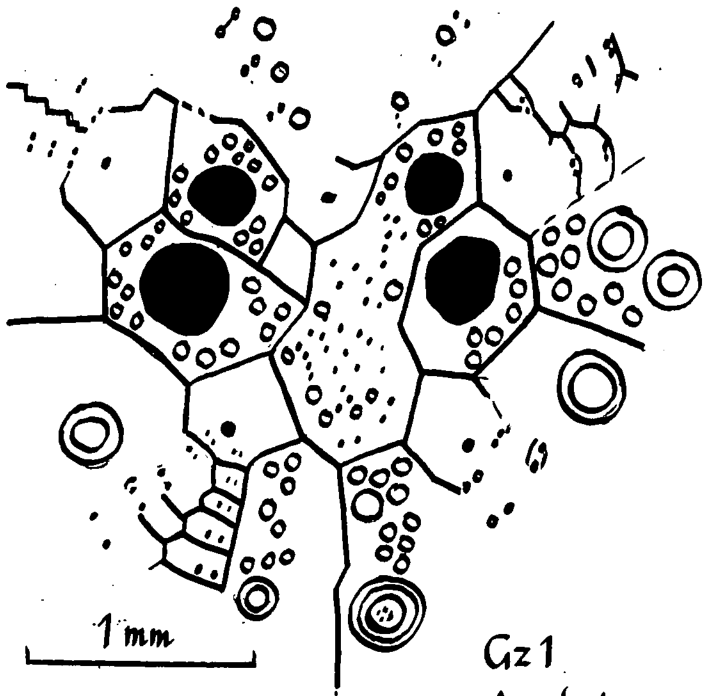
Medium to large spatangoid echinoids, oval in outline, notched in front, rounded to subangular at rear; apical disc with four genital pores, between four-tenths and half of the total length from the rear; unpaired front ambulacrum in a U-shaped groove, varying from narrow and deep to wide and shallow; angle between front amb and adjoining paired ones between 40° and 50°; lateral and peripetalous fascioles; mouth on lower surface, a quarter of length from the front, with labrum and phyllode; large plastron; anus near top of rear truncated surface.

Description.

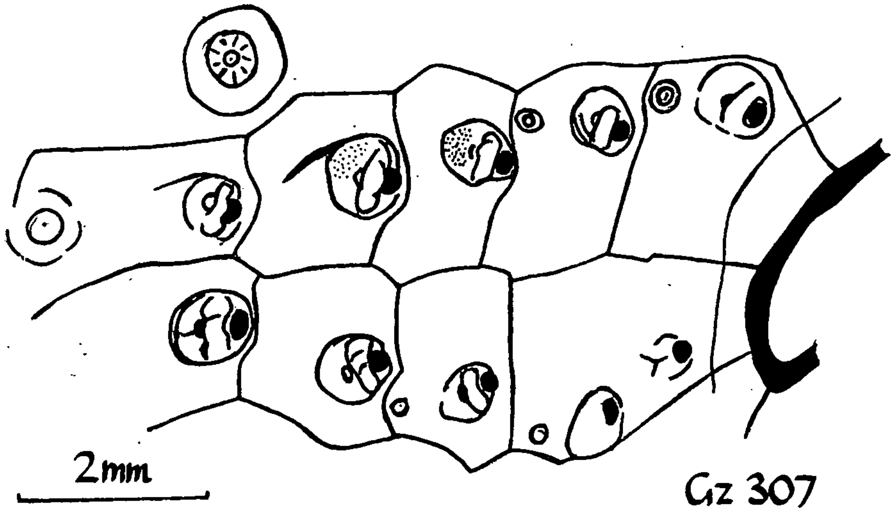
Upper surface. The apical surface has an oval outline, longer than wide, with a notch at the front and a round to subangular rear. The height varies considerably but is greatest behind the apical disc, along the rear interamb. The forward slope is gentle, that to the rear is steep, with a truncated vertical surface containing the anus near its top with a slight overhang above it.

Apical disc. The disc is small and frequently damaged. It has four genital pores; the rear pair being larger and farther apart; the smaller front pair not always being easily detected. The madreporite extends back between oculars I and V (e.g.Gz 1, text-fig. 10). The disc is situated half to four-tenths of the length of the test from the rear.

Paired ambulacra. The paired ambs form sunken petals which vary in depth from specimen to specimen (cf. Gz 30, pl.9 and Mlt 272a, pl.10). The front pair extend three-quarters of the distance to the margin and are slightly flexed forwards. They are blunt-ended and their width varies from a fifth



Gz 1
Apical disc



Gz 307
Phyllode on amb IV

PLATE DETAILS IN *Schizaster parkinsoni* to nearly a third of the petal length (cf. Gz 30 with petals distally wide and Mlt 278a with slimmer front petals). The angle of divergence from the long axis of the test is between 40° and 50°. The pore-pairs are conjugate; inner ones oval, outer ones pearshaped; the inter-pore zones are a little narrower than the pore zones. The rear pair of petals are short, about two-thirds the length of the front pair, an elongated oval in shape and blunt-ended. The pore-pairs resemble those of the front petals but are closer together.

Unpaired ambulacrum. The front amb is partly petaloid, in a deep U-shaped groove which passes from the apical disc to the mouth and is widest at or near the front margin (cf. Mlt 272a, pl.10 and Gz 30, pl.9, with Gz 307, pl.9). There are a single series of pore-pairs on both edges of the base of the groove. The pores are small, the inner and outer ones are close together, separated by an irregular, tubercular spine-base. Short, small grooves run from close to each outer pore up the side of the groove, at right angles to its length. They are shorter in length than those on S. eurynotus (cf. Gz 307 with Gz 919, pl.12). The wide inter-pore zone is gently concave in section. The pore zones extend two-thirds of the distance from the disc to the margin and immediately beyond them the groove narrows in some specimens (e.g. Mlt 278a), though not as strongly as in S. eurynotus .

Interambulacra. The interambs are raised relative to the ambs and are covered with an irregular pattern of tubercular spine-bases, which are larger towards the margin, around the apical disc and along the edges of the front groove. The front pair widen rapidly from the disc and their central sutures are closer to the front of the test, making columns 2a and 3b wider than 2b and 3a. The rear pair widen more rapidly. Both pairs have series of raised nodes on their surface (seen best on Gz 307, pl.9, and Mlt 278a, pl.10) which appear related to the fascioles. The rear interamb forms a low ridge which is frequently broken along the central suture as a result of post-depositional compaction.

Fascioles. There are two fascioles, a peripetalous one with a lateral fasciole branching from it. The peripetalous fasciole is distinct and variable in width, with the broadest sections around the ends of the petals and the narrow sections at the nodes within the interambs. Its path is very similar to that in *S. eurynotus*. The lateral fasciole is narrower. It branches from the peripetalous one at nodes on the interamb columns 1b and 4a (e.g.Mlt 278a, pl.10) and passes beneath the anus (e.g. Mlt 268c, pl.13).

The anus is near the top of the truncated rear surface with an angular overhang above. It is frequently crushed and has a steep, flat area below, made up of regular interamb plates. It is oval and vertically elongated (e.g.Mlt 268c, pl.13).

Lower surface. The oral surface is gently convex, particularly across the plastron. The mouth is about a quarter of the test length from the front margin. It is transversely elongated and crescent-shaped with a raised labrum behind and surrounded by a well developed phyllode (e.g. Gz 307, pl.13).

This is formed by the widening of the ambulacra towards the mouth, with a series of single pores, each with a ridge or saddle-shaped projection, a sunken rim and a remnant second pore, not unlike that observed on Eupatagus.(cf. Gz 307, text-fig.10 with text-fig. 17). The pores are arranged in V-shaped lines with one pore to a plate, except for those nearest the mouth in columns la, lla, lllb, lVa and Vb, which have two pores (agreeing with Nichols' observation on Echinocardium cordatum (1959, p.397). The unpaired amb is in a shallow groove which links with the deep furrow on the upper surface. The front paired ambs are at right angles to the long axis of the test and narrow to the test margin. The rear pair are horseshoe-shaped, extending on both sides of the plastron and widening a little at the margin. They are covered by fine spine-bases with a few larger ones at the rear. The interambulacra are covered by large, tubercular spine bases showing clearly developed bosses and small perforated mamelons. The tubercles are larger and more scattered around the mouth, with very small spine-bases between them and are smaller and more close-packed towards the rear and the upper surface.

Discussion:

Quite apart from the frequent distortion through burial, Schizaster parkinsoni shows considerable variation in shape and in the nature of the front paired petals and front furrow. The maximum width of specimens is approximately equal to their length but its position ranges from in front of the apical disc (Mlt 278a, pl.10, and Gz 168) to behind it (Gz 30, pl.9), whilst others have parallel sides from in front of to behind the disc (Gz 307, pl.9 & BM E 1621, the British Museum neotype of S. parkinsoni, pl.11). The front section of the margin varies from semi-circular (Mlt 278a and Scilla's example, pl.10,) to angular, forming the three sides of a rounded pentagon (Gz 307). The rear part may be blunt-ended (BM E 1621, pl.11 and BM E 1648, the type of S. desori, pl.10) or subangular (Gz 307 and Scilla's example, pl.10). The front paired petals vary from quite shallow and wide (Gz 30, pl.9) to narrow and deep (Mlt 278a and Mlt 272a, pl.10). Some petals flex back distally (Mlt 278a, pl.10 and BM E 1621, pl.11), others end as straight petals (Gz 307, pl.9 and Mlt 272a, pl.10); some widen gradually and are blunt-ended (Gz 30, pl.9), others are straight-sided along much of their length and have subangular ends (Mlt 272a and Mlt 278a, pl.10). The front groove can be relatively narrow and deep as in S. eurynotus (e.g. BM E 1648, pl.10) or wider and more shallow (Gz 30, pl.9), with intermediate examples (Gz 307, pl.10). The former type contract beyond the pore-zones, the latter widen gradually. The notch at the front of the margin can be marked (Gz 307, pl.9) or slight (Mlt 278a, pl.10).

These variations are clearly gradational, as can be seen on examination of the plates, and do not warrant separation into different species.

Differences between S. parkinsoni (P.) and S. eurynotus (E.)

Shape. E. is always tapered to an angular rear with a raised rear interamb; P. varies as described above.

Apical disc. In E. is to the rear of centre; in P. it ranges from central to a little to the rear (see text-fig.11). The very small overlap in this character makes it insufficient in isolation to separate the two species.

Front paired petals. The angle of divergence from the long axis is less and varies less in E. The divergence is produced by the forward flexing of the pore-zones immediately outside the apical disc and, though variable, is always greater in P. since the ambs are less flexed forwards.

Front groove. In E. this is wider and deeper, with a contraction beyond the pore-zones and a marked notch in front; in p. when the groove is deep, it is narrower and when wide, it is shallow with only slight notching of the margin.

Relative petal lengths. In E. the front pair are relatively longer than in P. and the latter show less variation.

Peripetalous fasciole. In E. this keeps close behind the front paired petals before swinging across to pass round the rear pair; in P. it is farther to the rear, away from the front petals.

Remarks:

The Maltese schizasters have been placed in two species on the basis of the above descriptions. Wright in his original work (1855, p.484-5) recognised three species, as did also Gregory (1891, p.616-8), whilst Stefanini limited them to two (1908, p.476-80) and Cottreau listed four (1913, p.24). Wright's S.desori and S.parkinsoni are shown on text-fig.11 and it is seen that they fall near the extremes of the variation of one group with continuous variation between. It is interesting to note Leith Adams' comment in his notes in Wright's 1864 paper (p.484). About S. parkinsoni, he says, "I have found it not easy to distinguish at all times between specimens of S. desori and this species." Stefanini's S. melitensis (1908, p.479-80, pl.117, fig.14), if it is from the Globigerina Limestone, is almost certainly in the parkinsoni group. On the other hand, Cottreau's record of S. sardiniensis (1913, p.24 and 120, pl.14, fig.8) is more problematic. His figure agrees with the type in the Sorbonne, figured by Lambert (1907, pl.4, fig.8), though Cottreau shows the front groove widening more, whilst Cotteau's original figure is smaller (1895, pl.5, fig.11). Over 60 identifiable schizasters have been collected from Gozo and Malta and none of these resembles Cottreau's single specimen. Either the form is very rare or is based on the misidentification of a Hemiaster. Cottreau's text-fig. (p.120, text-fig. 35) shows a lateral fasciole but it cannot be seen on the plate. Until there is more conclusive evidence the existence of S. sardiniensis on the Maltese islands will be regarded as not proven.

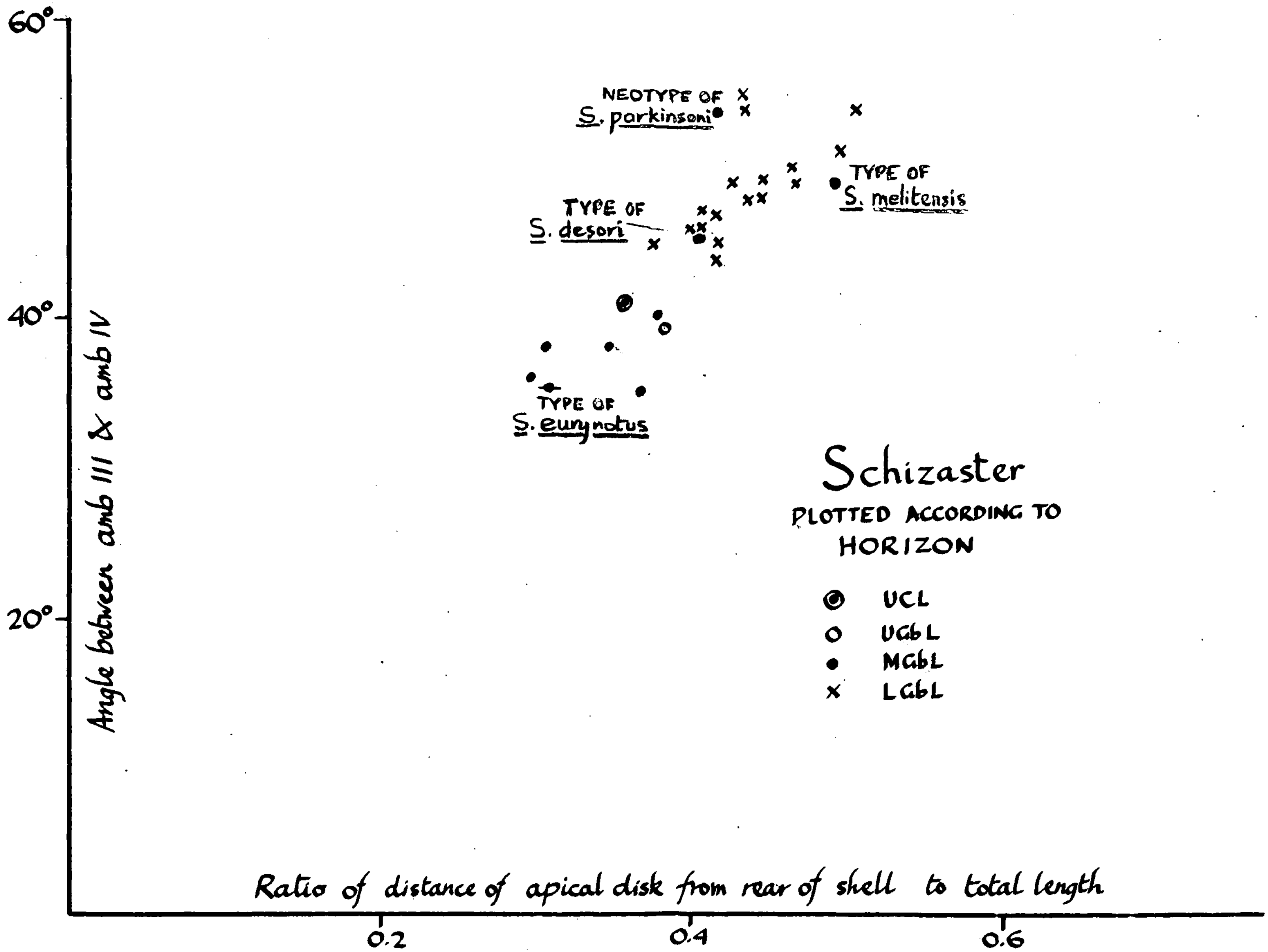
Mention must also be made of the Schizaster of Scilla, in the Woodward collection at the Sedgwick Museum (pl.10, very kindly photographed by Dr.Forbes of the Sedgwick Museum). This specimen was figured by Scilla (1747, pl.7, fig.1) as "Echinus Spatangus". This citation is pre-Linnéan but it is interesting to note that Scilla's specimen falls just within the S. parkinsoni group and not that of S. eurynotus, with which Wright included it (1855, p.262) and for which Desmoulins (1837, p.392) created the name "Spatangus Scillae".

The fact that S. eurynotus shows more limited variation than S. parkinsoni may be more apparent than real, both on account of its more restricted occurrences, involving less variation in environment, and more probably, because of its relative scarcity. The two are, however, clearly separable both morphologically and stratigraphically. Text-figure 11 shows that they appear to lie along a common line and this suggests that they are closely related. The deeper petals could indicate that S. eurynotus was a deeper burrowing form, if a valid analogy can be drawn with Nichols' work on Micraster and living spatangids (see Nichols, 1959 and 1960).

Horizons and Material;

Most of the Schizasters were collected from the Scutella Bed and the Lower Globigerina Limestone. These were all referable to S. parkinsoni. Some of the Scutella Bed specimens were noteworthy on account of their size, for example, Gz 845 is 87mm. long. Six specimens of S. eurynotus came from the local, yellow facies of the Middle Globigerina Limestone and isolated examples also came from the Upper Globigerina, the Blue Clay and the Upper Coralline Limestone. As noted in the stratigraphical section, the difference between the schizasters in the Lower and Middle Globigerina Limestone gives these divisions more significance than micropaleontological data has done.

TEXT-FIG. 11



Schizaster
PLOTTED ACCORDING TO HORIZON
UCL
UGbL
MGbL
LGbL
NEOTYPE OF S. parkinsoni
TYPE OF S. desori
TYPE OF S. eurynotus
TYPE OF S. melitensis
Angle between amb III & amb IV
60°
40°
20°
Ratio of distance of apical disk from rear of shell to total length
0.2
0.4
0.6

PLATE NINE

Schizaster parkinsoni (Defrance)

Gz 30 x 1.9

Lower Globigerina Limestone; Taċ-Ċawla 278924

Schizaster parkinsoni (Defrance)

Gz 307 x 1.9

Lower Globigerina Limestone; Dahlet Qorrot 389897

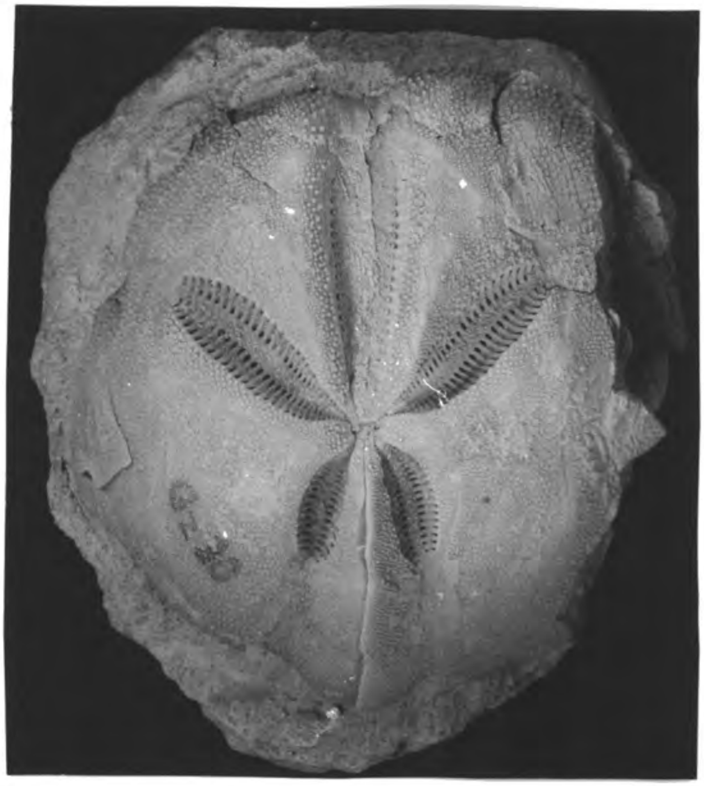


PLATE TEN

all Schizaster parkinsoni (Defrance)

Mlt 278a x 1.6

Lower Globigerina Limestone;

Ta' Klula, Gozo 288883

BM E1648 x 1

type of S. desori

Mlt 272a x 1.9

Lower Globigerina Limestone;

Ta 'Klula, Gozo 288883

E 24.1 Woodward Collection,

Cambridge x 1

specimen figured by Scilla

PLATE ELEVEN

Wright's figure of S.desori x 1

Ann. Mag. Nat. Hist. 1855, pl.6, fig. 3a-c

Wright's figure of S.parkinsoni x 1

Ann. Mag. Nat. Hist. 1855, pl.5, fig.3a-c

BM E1621 x 1

type of S.parkinsoni

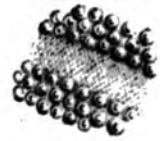
3b

3c

3a

3a

3b



3c

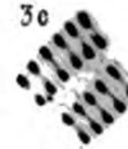


PLATE TWELVE

Schizaster eurynotus Agassiz

Gz 919 x 1.5

Middle Globigerina Limestone;

SW of Ghajn Abdul, 286893

Gz 919

front view x 0.9

Schizaster eurynotus Agassiz

BM E9272 x 1

labelled "*S.scillae*, Globigerina

Limestone, Kollya Baydha".

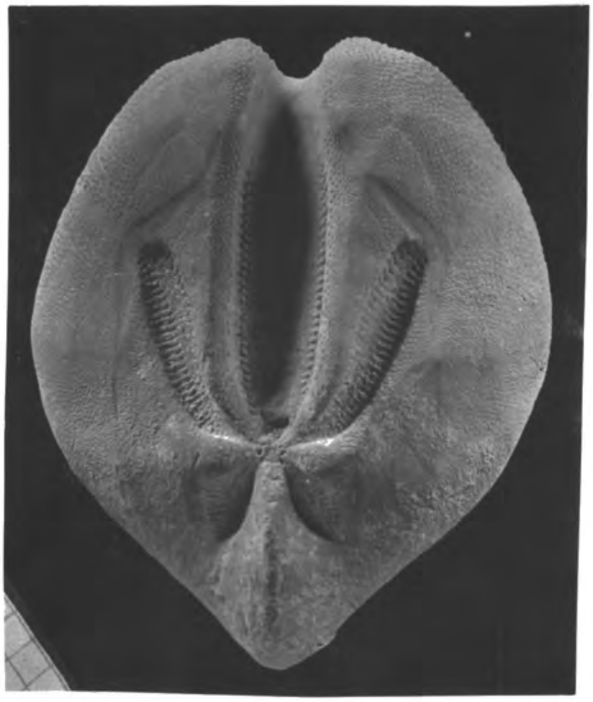
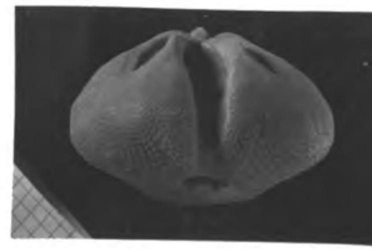
(i.e. Qolla I-Bajda, 325929)

detail of front amb III

in Gz 919 x 5

detail of front amb III

in Gz 307 x 5

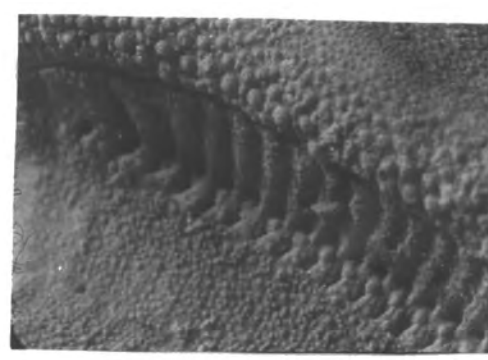
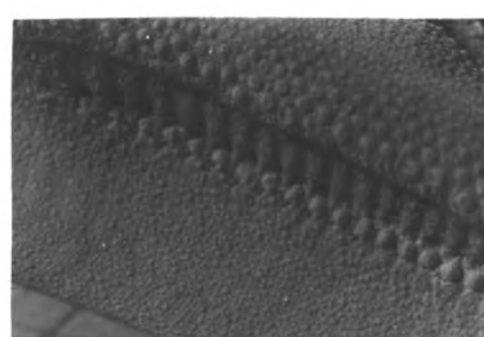



PLATE THIRTEEN

Schizaster parkinsoni (Defrance)

Gz 307 x 0.8

S.parkinsoni (Defrance)

Mlt 268c x 0.85

Torri Ta'Mgarr-ix-Xini

347861

S.parkinsoni (Defrance)

Gz 1 x 4

S.eurynotus Agassiz

BM 1958 x 1

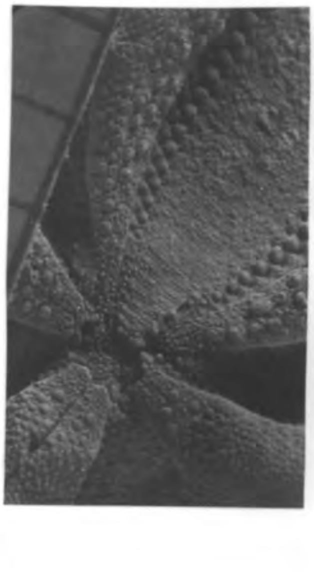
labelled "Upper Limestone ?"

S.parkinsoni (Defrance)

Gz 961 x 5

Lower Globigerina Limestone

N of Torri tal Qaura, 273897



Order SPATANGOIDA Claus 1876

Family HEMIASTERIDAE H.L.Clark 1917

Genus Hemiaster Desor 1847

Type species Spatangus bufo Brongniart

Diagnosis:

Fairly small spatangid echinoids, globular in shape and truncated to rear; one fasciole, surrounding short, sunken, petaloid ambulacra; front pair twice length of rear one, unpaired petal in groove extending beyond pore-zone a variable distance; apical disc small, normally ethmolysian but occasionally ethmophract, with one to four, but usually two or four, genital pores, and sited to rear of centre; mouth on lower surface, a quarter to a third of test length from front with phyllode and small labrum; large tuberculated plastron to rear; anus at top of rear, truncated face.

Discussion:

The above diagnosis is based on the original of Desor (1847, p.367-8) with two modifications. The first relates to the apical disc. Desor stated that it was small and had four genital pores. Subsequent workers have created separate genera for hemiasters with fewer genital pores and with differing madreporites. Mortensen (1950, p.380ff) recognised four genera as follows:

Hemiaster s.s. - ethmophract disc with four genital pores,

Trachyaster - ethmolytic disc with four genital pores,

Opissaster - ethmolytic disc with two genital pores,

and Ditremaster - as Opissaster but with shallow petals and different shape

Kier (1957, p.876) pointed out the artificiality of these distinctions, showing in particular the unreliability of genital pore number as a criterion. He separated Hemiaster and Opissaster with the former having an ethmophract disc and the latter an ethmolysian one, with deeper, more flexed petals than Hemiaster. The present material in part bears out his conclusions. Most specimens have two genital pores, some have four and an isolated specimen has only one. All the undamaged apical discs which were examined had ethmolysian madreporites, with a clear separation of the rear pair of genital plates (text-fig. 12 & 13). This even applies to the one example of Hemiaster cotteaui which has a definite hemiasterid appearance. It seems best to define Hemiaster widely, to take in all these variations, as was done by Lambert and Thièry (1925, p.498),(though they went on to subdivide in great detail). This is particularly advisable since detailed study of the apical disc is possible in only a few instances, giving rise to many contradictory descriptions in the past. It is interesting that Gregory describes all the Maltese hemiasters as having ethmophract discs (1891, p.610, 611 & 612), though in the case of H.scillae he stated that there was some doubt (p.611).

Desor also recognised two subgroups based on the relative lengths of front and rear petals, regarding those with unequal lengths as the true Hemiaster. The others have since been allocated to various genera so that unequal petal length is now essential to Hemiaster.

Hemiaster scillae Wright

Plates 14-18, text-figures 12, 13.

1827 non Spatangus crassissimus; Defrance, p.96

1837 Spatangus crassissimus Defrance; Desmoulins p.394

1855 Hemiaster Scillae; Wright, p.191-3, pl.7, fig.1a-f

1858 Hemiaster Scillae Wright; Desor, p.375

1864 Hemiaster Scillae Wright; Wright, p.483-4

1883 Opissaster Scillae (Wright); Pomel, p.38

1891 Hemiaster scillae Wright; Gregory, p.611

1891 Hemiaster vadosus; Gregory, p.611-3, pl.2, fig.6a-c

1905 Hemiaster Scillae Wright; Lambert, p.102

1907 Opissaster Scillae (Wright); Lambert, p.80-1

1907 Opissaster vadosus (Gregory); Lambert, p.81

1908 Opissaster Scillae (Wright); Stefanini, p.470-1, pl.17, fig.7

1908 Hemiaster vadosus Gregory; Stefanini, p.471

1911 Hemiaster scillae Wright; Gregory, p.673

1914 Opissaster Scillae (Wright); Cottreau, p.70

1914 Opissaster vadosus (Gregory); Cottreau, p.70

1925 Trachyaster (Opissaster) scillae (Wright); Lambert & Thièry, p.509

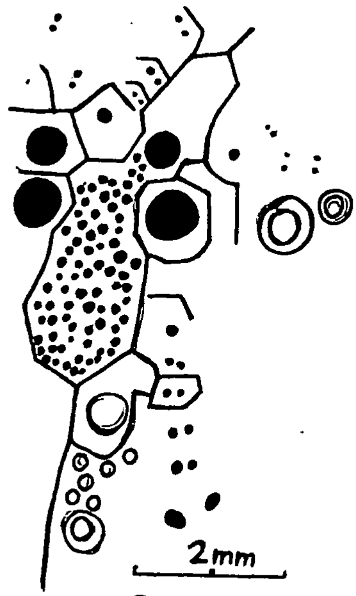
1925 Trachyaster (Opissaster) vadosus (Gregory); Lambert & Thièry, p.508

Diagnosis:

Small to medium spatangid echinoids, globular in shape and truncated to rear; one peripetalous fasciole; paired ambs forming sunken and flexed petals, front pair twice length of rear ones; unpaired petal in front groove extending to margin and indenting it a varying amount; ethmolysian apical disc with two, or occasionally four, genital pores, sited to rear of centre; concave lower surface; mouth close to front with phyllode and small labrum; broad plastron to rear; anus at top of truncated rear surface; whole test apart from petals evenly covered with small tubercles.

Description:

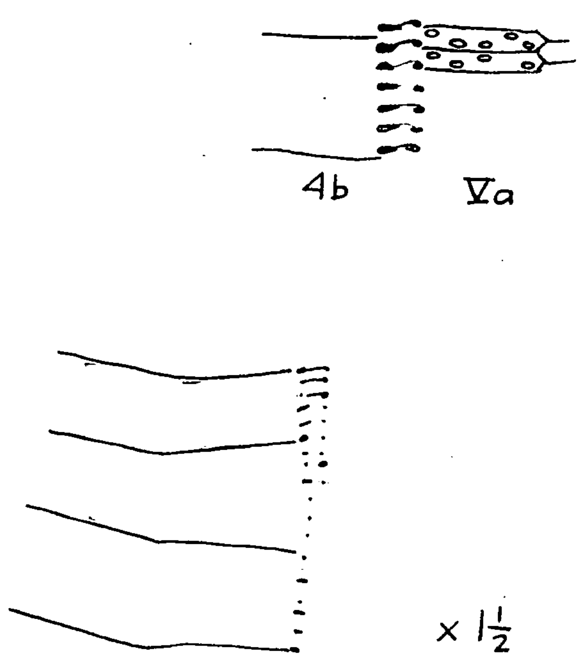
These are very small to medium-sized spatangid echinoids, globular in shape, with a truncated rear and flattened under-surface. Their width is normally a little less than the length and is greatest a little in front of the apical disc, though occasionally greatest across the disc (Mlt 269h, Mlt 283f). Their height is about three-quarters of the length (e.g.Gz 312), frequently reduced by crushing; and is greatest on the rear interamb near the apical disc. The apical disc is small, slightly sunken and ethmolysian with two (Gz 320a, pl.14, fig. 1) or, more rarely, four (Gz 320b) genital pores and depressed ocular plates which slightly resemble genital pores (Gz 320a, pl.14, Gz 381, pl.14, and Gz 336a, text-fig.12). It is sited to the rear of centre, between 0.55 and 0.70 of the total length from the front margin.



Gz 336a

Apical disc of <u>Hemiaster</u> <u>scillae</u>

Text-fig. 8 repeated in error



The paired ambulacra have sunken petals on the apical surface. The rear pair of petals are between 0.58 and 0.36 the length of the front pair, the ratio decreasing slightly with size. They are straight, diverging from the long axis of the test at between 35° and 45°; and pear-shaped, extending less than a quarter of the distance from the disc to the margin, widening up to two thirds of the petal length near the outer end, which is blunt against the peripetalous fasciole. Between 10(Gz 355 & 380) and 17 (Gz 191) pore pairs occur in each column. They are slit-shaped, except close to the ocular plates of the apical disc, and the outer row is slightly wider. The inter-pore zone has about the same width as each pore zone (e.g.Gz 381, pl.14). The ambulacra beyond the rear petals are somewhat sunken in their centre and continue narrow in width to the rounded ambitus. The front pair of petals flex forwards immediately beyond the disc and sometimes flex back at the rounded end (e.g.Gz 381 and Gz 329 -flexed; Gz 320a and Gz 346 -much less; Gz 330, Gz 191 and Gz 620a -in between; see plates 12 & 16). They diverge from the long axis of the test at an angle of between 45° and 50°. The petals are straight-sided along over half their length, with a width of about a half to a third of their length. Between 16(Gz 380) and 28(Gz 191) pore-pairs occur in each column and are slit-shaped with a shallow furrow between inner and outer pores. Ambulacra outside petals are sunken in a fairly narrow groove which dies out towards the margin and are composed of plates with a width twice their length and fewer tubercular spine-bases than adjoining interambulacral areas (e.g.Gz 329, pl.14). The front unpaired ambulacrum is in a deep groove, extending beyond the pore-zones, which reach about halfway to the front margin, as a shallower groove indenting the margin a variable extent, in general doing so more the larger the test (typical is Gz 330, while Gz 320 shows greater indentation and Gz 278 less, pl.14 & 15). Pore-zones are narrow, separated by a wide inter-pore zone, about eight times the width of a pore-zone, and widen a little outwards with a slight constriction of the furrow at the end of the pore-zones (e.g.Gz 320a, pl.14). Pores are small and circular; the inner and outer ones are separated by a minute irregular knob (e.g.Gz 320, pl.14). The pore pairs are closely spaced, aligned obliquely, sloping forwards and inwards and not at right angles to the length of the ambulacrum as in the paired petals.

The interambulacral areas are raised relative to the ambs with irregular ridges along their centres especially within the fasciole. They are covered with small but prominent tubercular spine-bases, which spread into the ambs where they are reduced in number. The size of the tubercles increases towards the margin and round the apical disc, each one showing a well developed areola with boss and perforate mamelon (see Gz 320a, pl.14); those round the disc form a double row on each interamb.

The petal areas are surrounded by a fasciole which is broad and fairly constant in width, running in a straight line between the ends of the petals, not bending in towards the disc, and crossing the front groove at right angles immediately beyond the pores.

The truncated rear surface contains at its top the anus which is oval and elongated vertically.

The oral surface is very similar to that of *Schizaster* (pl.17, cf. pl.13). The mouth lies near the front, between a quarter and a third of the length from the front margin, rather closer in the smaller specimens, e.g.Gz 342 and Gz 349, and has a markedly curved and continuous groove round from the apical disc. It is shaped like an orange segment, transversely elongated and surrounded by a thickened lip. The labrum forms the highest part of the lower face and produces a slight projection over the rear of the mouth (e.g.Gz 315 and Gz 312, pls.15 & 17). Crushing frequently occurs at right-angles to the length across the mouth, giving an appearance of greater overlap of the labrum (e.g.Gz 314, pl.17).

An indistinct phyllode round the mouth is produced by adoral widening of the ambs and is made of V-shaped lines of single pores, each with a raised ridge behind it and, on some, a small pit. Distal parts of the ambs are narrow and usually free of large tubercles until close to the ambitus. The front amb forms a shallow groove which slightly indents the front margin. The front paired ambs are perpendicular to the front unpaired amb (and at 180° to each other), the rear pair run either side of the plastron and at about 20° to the long axis of the test, curving into the centre a little, giving a caliper-like appearance.

The oral interambulacra are fairly flat apart from the labrum and a slightly raised part at the rear of the plastron (e.g. Gz 312, pl.17). They are covered with large tubercles, which increase in size towards the mouth, with their mamelons at the mouthward end of the tubercle. Patches with only small spine-bases occur behind the labrum and link the ends of the phyllodes (Gz 312). Some specimens are less thickly covered on the front four interambs (Gz 315) but the rear plastron is always covered in a concentric pattern of increasing size outward from the rear and the central raised part of the plastron.

Discussion:

Wright established two species of Hemiaster:- H.cotteaui and H.scillae (1855, p.190-3, pl.7, figs.1 & 2) and Gregory added a third, H.vadosus (1891, p.611-3, pl.2, fig.6). The type specimen of H.scillae could not be traced and some doubt is attached to the reliability of the type specimen of H.cotteaui. The type specimen of H.vadosus shows Gregory's figure to be accurate.

All but one of the specimens collected in the course of the present work appear to be conspecific, with differences which are gradational rather than discontinuous. For example, the height of the test of Maltese hemiasters ranges from equal to the length in many small specimens (e.g.Gz 278, pl.15) to under half the length in larger ones (e.g. Gz 185, pl.16). Apart from size, the nature of the matrix may have some relation to height. Specimens preserved in the hard, grey, phosphatic limestone of the nodule beds are much rounder and make up most of the H.vadosus group; those from the softer Lower Globigerina Limestone are frequently squashed (e.g.Gz 320a, pl.14) and undamaged specimens have a height of about three-quarters their length. Again, the unpaired front ambulacrum is in a fairly deep groove which extends a variable amount beyond the pore zones and the peripetalous fasciole. In general, the smaller the test the less the groove extends towards the margin. The types of H.vadosus and H.scillae represent the extremes of this variation. The type of the former has a length of 16.5mm., with the groove not reaching to the front margin. There is, in fact, an almost continuous variation in length from 13 to 44mm. Thirdly, there is a very slight decrease in the front to rear petal length ratio as the size of the test increases.

It is concluded that the bulk of the Maltese hemiasters are best referred to Wright's Hemiaster scillae and that Gregory's H.vadosus is a junior synonym of this species.

One specimen was collected which is referable to Hemiaster cotteaui. Stefanini appears to have been without specimens (1908, p.471) and in the British Museum collection there are only six specimens, one of which is certainly a Hemiaster scillae, whilst there are at least four times as many specimens of H.scillae. It has been concluded that H.cotteaui is a rare large form occuring in the Lower Globigerina Limestone far less often than H.scillae from which it is clearly separable (see description below).

Hemiaster cotteaui Wright

Plate 18, text-fig.13

1855 Hemiaster Cotteaui Wright, p.190-1, pl.7, fig.2a-d

1858 Hemiaster Cotteaui Wright; Desor, p.375

1864 Hemiaster Cotteaui Wright; Wright, p.483

1883 Opissaster Cotteaui (Wright); Pomel, p.38

1891 Hemiaster cotteaui Wright; Gregory, p.610-11

1907 Opissaster Cotteaui (Wright); Stefanini, p.471

1914 Opissaster Cotteaui (Wright); Cottreau, p.70

1925 Trachyaster (Opissaster) cotteaui (Wright); Lambert and Thièry, p.508

Type specimen; BM E 1584 (see plate 18).

Comparisons:

H.cotteaui is clearly separable from H.scillae in the following respects:

a. the front pair of petals are longer in relation to the size of the test. (cf. BM E 3777 with Gz 185, pl.16).

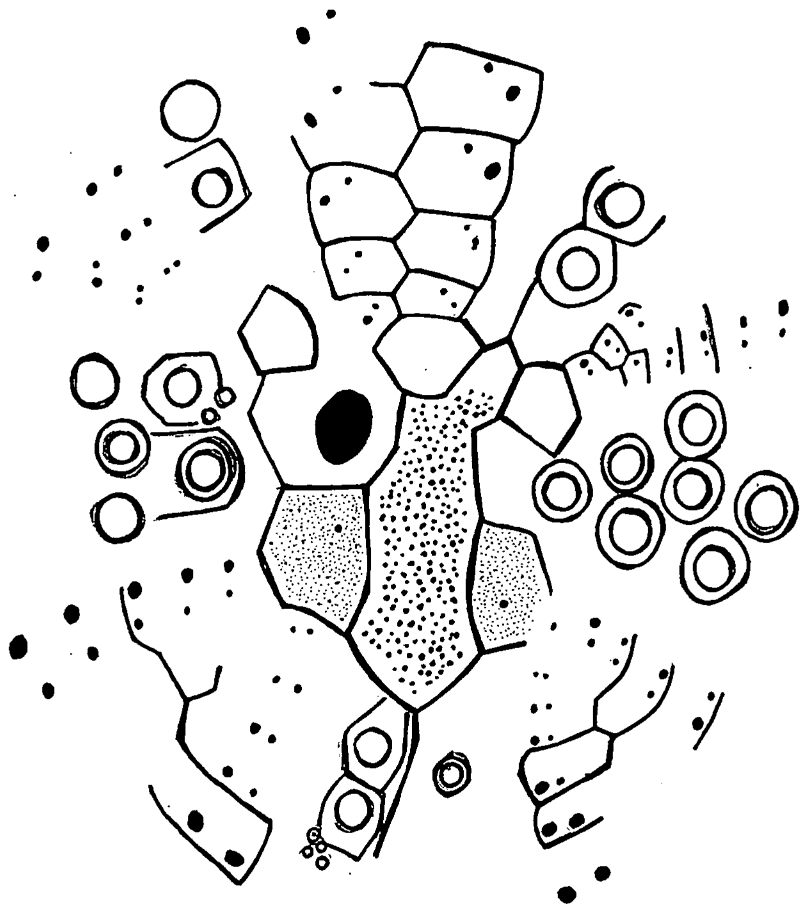
b. the front pair of petals are inclined at a more obtuse angle to the unpaired amb (cf. as above).

c. the front pair of petals are usually inflated distally and slightly reflexed (cf. BM E 34620, pl.16 and Gz 320, pl.14).

d. the rear pair of petals are far longer, relative both to the front pair and to the size of the test (cf. BM E 1584, pl.18 with Gz 381, pl.14).

e. the apical disc appears to have to have four genital pores usually. The single specimen collected, Mlt 307, has only one (see text-fig.13)

f. the peripetalous fasciole resembles a Schizaster in its adapical inflexion across the interambs (cf. Wright's type figures of H.scillae and H.cotteaui and also BM E 34620, pl.16 with Gz 330, pl.14).



2 mm

Mlt 307

APICAL DISC OF *Hemiaster cotteaui*

g. the tubercles are much less prominent on the surface, despite Wright's type figures.

h. the test is in general much broader and lower.

For all these reasons H.cotteaui is considered as a distinct species from H.scillae.

A comparison of the three British Museum specimens, with Gregory's type figure of Pericosmus coranguinum is interesting. BM E 3777 (pl.16) has a very similar appearance to Gregory's type, BM E 3405 (1891, pl.2, fig.3). It is possible that these form one group of hemiasteroid echinoids which have more variable petal lengths than is usual. Lambert (1907, p. 59-61) created a sub-genus, Gregoryaster, for P.coranguinum since its lack of a marginal fasciole and presence of four genital pores distinguished it from Pericosmus. Cottreau (1914, p.67) raised this to generic status. If H.cotteaui and P.coranguinum are conspecific they should be named Gregoryaster cotteaui (Wright). Unfortunately insufficient material was collected to decide this question (see also under Gregoryaster).

PLATE FOURTEEN

Hemiaster scillae Wright

Lower Globigerina Limestone,

Dahlet Qorrot 389897

Gz 320 x 1

Gz 320a x 1

Gz 381 x 1

Gz 329 x 4

Gz 330 x 1.9





PLATE FIFETEEN

Hemiaster scillae Wright

Gz 278 x 5

Upper Globigerina Limestone

SW of Dahlet Qorrot 385896

Gz 315 x 3

Lower Globigerina Limestone

Dahlet Qorrot 389897

Gz 278 x 5

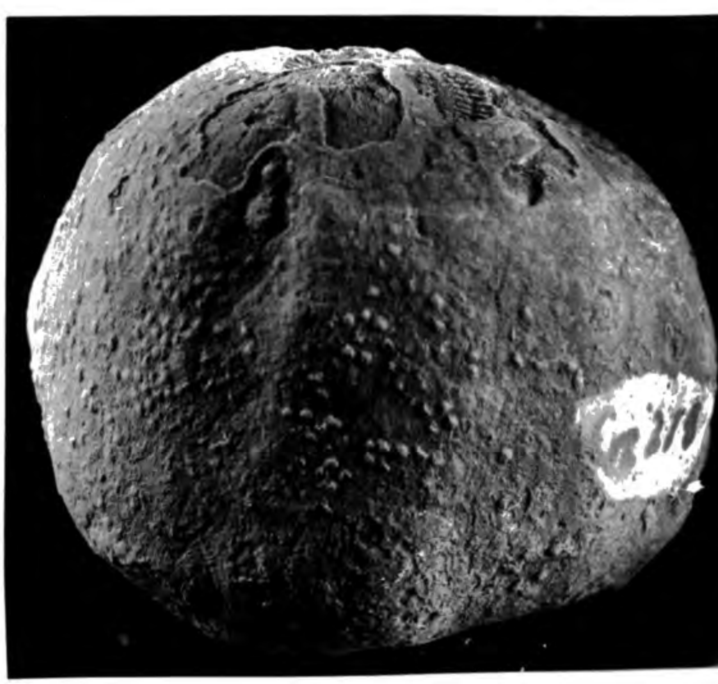


PLATE SIXTEEN

Hemiaster cotteaui Wright

BM E 34620 x 1

'Globigerina Limestone'

H.scillae Wright

Gz 185 x 1

Lower Globigerina Limestone

W of San Lawrenz 274904

H.cotteaui Wright

BM E 3777 x 1

'Miocene, Malta'

H.scillae Wright

Gz 320a x 3

PLATE SEVENTEEN

Hemiaster scillae Wright

Lower Globigerina Limestone

Dahlet Qorrot 389897

Gz 312 x 2.5

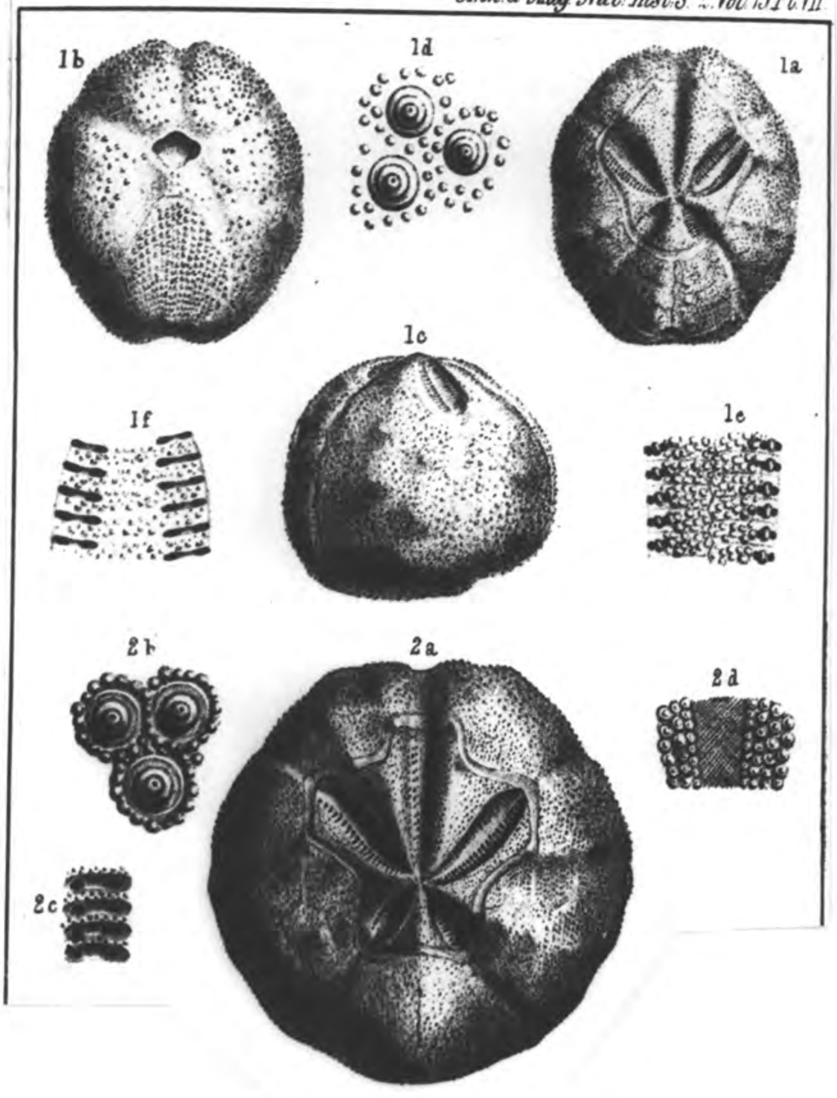
Gz 314 x 2.5

PLATE EIGHTEEN

Wright's type figures
of *Hemiaster scillae*
and *Hemiaster cotteaui* x 1
Ann. Mag. Nat. Hist. 1855, plate 7
fig. 1 & 2

Gregory's type figures
of *Hemiaster vadosus* x 2
Trans. Roy. Soc. Edin. 1891,
plate 2, fig. 6

Type specimen of
Hemiaster cotteaui
BM E 1584 x 1
Globigerina Limestone




6.^{a}


6.^{b}


6.^{c}


6.^{d}

Genus *Gregoryaster* Lambert 1907

Type species *Pericosmus coranguinum* Gregory

Diagnosis:

Small to medium sized spatangoid echinoids; sub-circular in outline; highest at centre; upper surface evenly tuberculate; unpaired amb in shallow groove indenting the front margin a little; paired petals long, fairly narrow and sunken, straight-sided or slightly curved, rear pair a little shorter than front pair; apical disc ethmolysian with four genital pores; a single, fairly broad peripetalous fasciole; oral surface gently convex; mouth near front with small labrum and tuberculated plastron to rear; anus near top of small, truncated rear surface.

Discussion:

This diagnosis follows the original given by Lambert (1907, p.57), modified with respect to the paired petals which he stated to be slightly and evenly curved. This is the case with *Gregoryaster coranguinum* but *Gregoryaster lorioli* has straight-sided paired petals and has been included in the genus for reasons given below.

In the discussion of *Hemiaster cotteaui* it has been suggested that *H. cotteaui* and *G. coranguinum* are closely related and could possibly be conspecific. If additional material confirmed this, then the diagnosis of *Gregoryaster* would have to be widened to recognise the variation in rear petal length and the type species would become Hemiaster cotteaui.

Gregoryaster lorioli (Stefanini)

Plate 19d, 19e

1855 Hemiaster Grateloupi (Sismonda); Wright, p.189-90 (pars).

1864 Brissopsis Grateloupi (Sismonda); Wright, p.484 (pars)

1908 Dictyaster** Lorioli; Stefanini, p.472-3, pl.17, fig.8

1914 Holcopneustes Lorioli (Stefanini); Cottreau, p.66

1924 Trachyaster Lorioli (Stefanini); Lambert and Thièry, p.486

**non Dictyaster Alcock and Wood-Mason 1896 -order Asteroidea.

Diagnosis:

Small spatangoid echinoids; sub-cordate in outline with a gentle frontal indentation; low conical upper surface evenly covered with fairly large tubercular spine-bases except on petals; widely divergent paired ambs, long, petaloid, straight-sided, and sunken with slit-shaped pores; rear paired petals nearly as long as front ones; unpaired amb in shallow groove, widening to margin; apical disc ethmolysian with four genital pores; interambs raised a little above ambs, sunken along central sutures; no rear ridge; single, peripetalous fasciole, broad and constant in width, running straight across interambs; lower surface gently convex; mouth near front with small labrum; plastron broad and tuberculate; anus near top of small, truncated rear surface.

Brief Description of Single Specimen (Gz 972, pl.19, figs.d & e):

Upper Surface. This forms a low cone, highest round the small, sunken apical disc which has four large genital pores (one of which is half broken off) and a large ethmolysian madreporite. The paired ambulacra form narrow, straight-sided, smooth-surfaced petals, each in a shallow groove extending three-quarters of the distance to the margin and resembling Pericosmus latus in their divergence from the long axis of the test. The pores are slit-shaped and fairly large with the inter-pore zone a little wider than the pore-zone. The unpaired amb forms a shallow and evenly widening groove, which indents the margin very slightly. The pore-pairs are circular and very small, forming two indistinct lines. The interambulacra are slightly raised above the ambs, except along the central sutures. They are evenly covered with fairly large tubercular spine-bases, each surrounded by a line of very small spine-bases (pl.19, fig.e), and these extend to the front, unpaired amb and over the paired ambulacra beyond the petals. The peripetalous fasciole forms a broad, finely granular band touching the ends of the petals and going straight across the interambs. The anus is damaged but is clearly on the small rear truncation. The lower surface is obscured, as was the case with Stefanini's specimen (1908, p.472-3), but can be assumed to be typically spatangoid, with the mouth near the front, possessing a phyllode and small labrum, with a tuberculated plastron to the rear.

Discussion:

The specimen closely resembles _Pericosmus latus_, particularly since genital pore 2 is almost broken away. It is clearly separable for the following reasons: there are four genital pores; there is no marginal fasciole; the peripetalous fasciole is broader and much more regular; the spine-bases are relatively large; and the front groove is shallower.

The specimen has been identified as belonging to Stefanini's species on the basis of the latter's description and admittedly poor photograph. From these it hardly appears to differ except in the nature of the rock matrix. Stefanini's specimen comes from the (?Lower) Nodule Bed (1908, p.476), whilst Gz 972 is from the middle of the Lower Globigerina Limestone. Several Maltese echinoids occur at both horizons, so there is no difficulty in that respect.

The generic position of Stefanini's species has altered three times already. Stefanini unfortunately started this by creating a homonym of the starfish genus _Dictyaster_. He enumerates (1908, p.474) the features distinguishing his _Dictyaster_ from other spatangoids as follows. The ethmolysian apical disc separated it from _Hemiaster_ as he understood that genus and suggested an affinity with _Trachyaster_. Lambert and Thièry, and Mortensen in fact later classed it under this genus but Stefanini ruled it out because of _Trachyaster's_ deep and narrow front groove and its schizasterid tuberculation. The single fasciole distinguished it from _Schizaster_, _Paraster_, _Linthia_ and _Pericosmus_, though he included in the new genus two other species previously classed as pericosmids, which indicates its similarity to Pericosmus. This fits in with the present allocation of the species to Gregoryaster, with which Stefanini did not compare his specimen although aware of its existence (1908, p.481-2).

Lambert (1907, p.59-61) separated Gregory's Pericosmus coranguinum from the genus Pericosmus on criteria very similar to those which distinguish Gregoryaster lorioli from Pericosmus latus: the four genital pores, the absence of a marginal fasciole, the nature of the peripetalous fasciole, the shallow front groove, and the larger spine-bases. G.lorioli differs from G.coranguinum (Gregory, 1891, p.615-6, pl.2, figs.3 and 4a,b) in the straightness of its paired petals, the greater width of the front groove and its smaller size. These are thought to be specific rather than generic differences. It ought to be added that no specimens were collected that were definitely referable to G.coranguinum.

Under the discussion of Hemiaster (p.87-8) it was maintained that Mortensen's discrimination of Trachyaster and the allied species is artificial; G.lorioli adds weight to this. The four-pored, ethmolysian apical disc and single, peripetalous fasciole would place it with Trachyaster but the similarity in length of front and rear petals makes it distinct from the Hemiaster group.

In the synonomy it has been suggested that specimens of G.lorioli may have been included in Wright's understanding of Brissopsis grateloupi (Sismonda), since Sismonda's original figure and description (1842, p.25, pl.2, figs.1 & 2) resemble G.lorioli in most respects apart from size.

Family PERICOSMIDAE Lambert 1908

Genus Pericosmus Agassiz and Desor 1847

Type species Micraster latus Agassiz

Diagnosis:

Medium to large echinoids, varying in shape from broader than long, heart-shaped to almost cylindrical; fairly high, sub-conical to egg-shaped; petals well developed, usually distinctly sunken; front ambulacrum usually a little sunken, forming a prominent groove and indenting the front margin, with small pores arranged in straight rows; apical disc with three or, on some fossils, four genital pores; peripetalous and marginal fascioles present; former normally bending adapically in the interambs, irregular in path and sometimes splitting into two or more branches across the front amb; latter continuous round ambitus, passing below the anus; no sub-anal fasciole; oral side flattened or convex with rounded edges; mouth close to front with short labrum and tuberculated plastron to rear.

Discussion:

The diagnosis is based on that of Mortensen (1951, p.169-70) who states that "in the recent species there may be considerable variation in the shape of the test, so that identification by characters of the test alone may be very difficult" (p.172). This warns against drawing too narrow limits for the fossil species. All the Maltese specimens can be placed in the type species.

Pericosmus latus (Agassiz)

Plates 19a-c, f and 20; text-figure 14

1840 *Micraster latus*; Agassiz, p.2

1842 *Schizaster grateloupi*; Sismonda, p.25, pl.2, figs. 1 & 2

1847 *Hemiaster (Pericosmus) latus* (Agassiz); Agassiz and Desor, p.19, pl. 16, fig. 1

1855 *Pericosmus latus* Desor; Wright, p. 193-5

1864 *Pericosmus latus* (Agassiz); Wright, p.487

1891 *Pericosmus latus* (Agassiz); Gregory, p.613-5

1906a *Pericosmus latus* (Agassiz); Lambert, p.104

1906b *Pericosmus latus* (Agassiz); Lambert, p.43, pl.2, fig.3, pl.9, fig.1

1908 *Pericosmus latus* (Agassiz); Stefanini, p.481-2

1914 *Pericosmus latus* (Agassiz); Cottreau, p.120-2, pl.15, fig.5, 6.

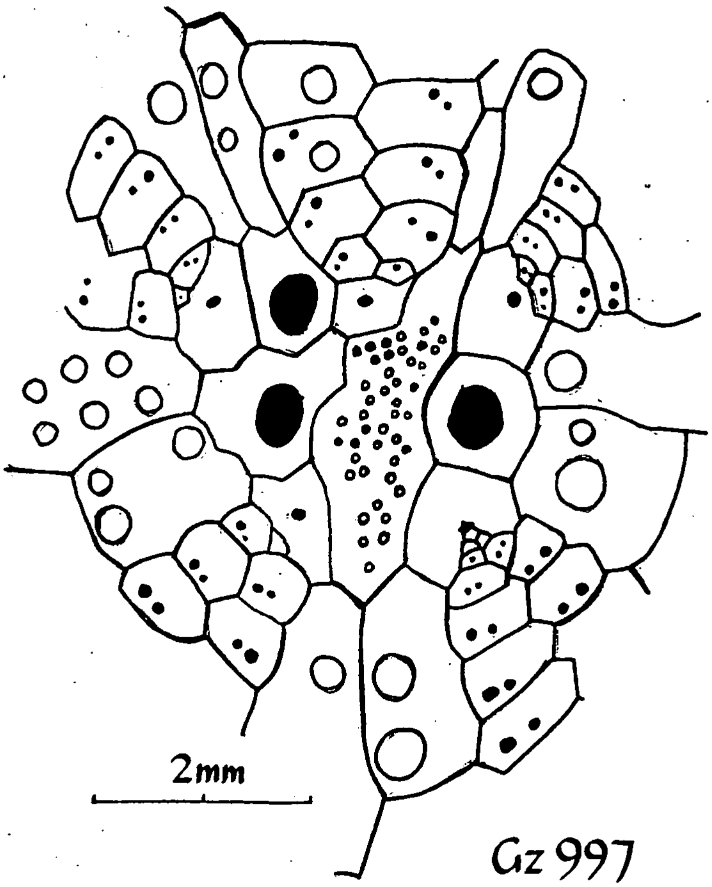
Diagnosis:

Medium-sized spatangoid echinoids; sub-circular outline indented at front; width a little greater than length; low, conical upper surface; long, narrow, straight petaloid ambulacra in moderate grooves, rear pair nearly as long as front ones, diverging half as much from the long axis of the test; unpaired amb in groove widening to indented front margin; central ethmolysian apical disc with three genital pores; peripetalous and marginal fascioles, former variable in path and branched over front amb, latter indistinct; lower surface gently concave; mouth close to front with small labrum; anus at rear in small vertical surface.

Description:

Upper surface. The apical surface has a rounded, conical shape with a central slightly sunken apical disc and five straight, sunken petals, the front, unpaired one forming a groove which reaches and indents the front margin. Apart from the disc and petals, the surface is covered with fine tubercular spine-bases. The apical disc is distinguished by having three genital pores (text-fig.14 and plate 19, fig.a & b). The column heads of interambs 2 and 5 directly abut the elongated madreporite, producing an ethmolysian apical disc; those of 1, 3 and 4 have distinct genital plates, each with a large pore. (Desor, 1847, p.19 and Wright, 1855, p.194, both describe only two genital pores, possibly the result of damaged specimens, most writers mention the typical three-pored disc.) Five ocular or terminal plates, each with a very small pore, head the ambulacral columns. Ocular plate III on Gz 997 (text-fig.14) is not in contact with the last-formed interambulacral plates of columns 2b and 3a which they would normally touch (cf. the other interamb column heads). This confirms the observations made by Kier (1956, p.971-4) though he recognised this feature in old specimens, whilst Gz 997 appears to be a fairly young example to judge by its size.

Ambulacral columns. The straight-sided, paired petals are in rounded, fairly



APICAL DISC OF Pericosmus latus

shallow grooves; the unpaired one widens gradually to the front margin which it slightly indents to a varying extent (cf. Mlt 266m with Gz 997, pl.19). The pore-pairs remain circular, non-conjugate and small; about 15 pairs are present and they die out beyond the peripetalous fasciole. The paired petals almost form a "St. Andrew's cross" (the term used by Wright, 1855, p.194) but the front pair incline a little farther out from the long axis of the test. The pore-pairs are faintly conjugate; both the inner and outer ones are slit-shaped, the former being a little deeper. The inter-pore zone is about one and a half times the width of the distance separating the inner and outer pores. The rear pair of petals are between eight-tenths and nine-tenths of the length of the front pair and each contains some 25 pore-pairs, compared to about 30 in the front pair. Both pairs of petals extend about half-way to the margin; beyond them the ambulacra form steep-sloping, widening, double columns of plates (e.g.Mlt 420a, pl.19, fig.f).

The interambulacra are higher than the ambs but are a little depressed along their central sutures. The rear interamb lacks a central ridge and is as low as the other ones. This is another feature distinguishing this form from the Maltese schizaster and, to a lesser extent, the hemiasters. Two fascioles are present on the upper surface of Pericosmus latus. The peripetalous one is the clearer but is narrow and difficult to trace. It has a variable path across the interambs, particularly over the rear one (cf. the three examples on pl.19), closely follows the outer edges of the petals and is irregular and indistinct across the front amb, where it splits into two or three branches. This was not mentioned or shown by Agassiz and Desor in the original description (1847, p.19 and pl.16, fig.1 & 1a) but Wright observed it (1855, p.194), as did Cottreau (1914, p.121-2, text-fig.36), who failed to note Wright's comment but considered the feature at length. The marginal fasciole is difficult to detect around the ambitus, to which it keeps very close. Agassiz and Desor (1847, pl.16, fig.1a) show it passing beneath the anus. Wright (1855, p.194) could not check this in either of his specimens and in the four specimens studied in the present work the rear area was crushed. The Corsican specimens, examined in Paris, do however confirm the fact.

Lower Surface. None of the specimens has a well-preserved under surface. By comparison with the British Museum specimens (esp. BM E 11683) and those in Paris, together with Wright's description, it can be presumed to have a gently curved oral surface. The mouth is close to the front and has a small labrum and a phyllode similar to that of the hemiasters and schizasters. A large tuberculated plastron forms the rear of the surface and the anus occurs at the top of the small, vertical, rear surface.

Discussion:

Specimens similar to those from Malta have been examined from Bonifacio in southern Corsica and from northern Egypt. Pericosmus latus has also been recorded from the Balearic Islands, Sardinia and Central Italy (Stefanini, 1908, p.482 and Cottreau, 1914, p.71 -who also lists the Maritime Alps). Gregory (1891, p.614) mentions in addition Ottnang, in Austria, and Madeira.

The Corsican and Egyptian specimens are mostly larger than the Maltese, and Agassiz's type (cast T40, pl.20) has cheaper petals. Cottreau (1914, p.121, pl.15, fig.6) established a varietal form _P.latus_ var. _minor_ for the smaller forms but this appears to be unnecessary. Agassiz and Desor's figure (1847, pl.16, fig, 1 & 1a) shows a small example (though this may be misleading if the drawing has been reduced and inaccurately stated to be natural size), and, bearing in mind the present-day variability within the genus (Mortensen, op.cit.supra), it appears best to keep them all within the one species, _Pericosmus latus_.

PLATE NINETEEN

a. <u>Pericosmus</u> <u>latus</u> (Agassiz)

Mlt 266m x 1 *

Scutella Bed,

Ix-Xatt L-Ahmar, 358862

b. <u>P.latus</u> (Agassiz)

Gz 997 x 1 *

Scutella Bed,

Torri ta Xlendi, 292873

c. Gz 997 x 1 *

view of unpaired amb.

* fascioles on these specimens darkened for emphasis.

d. <u>Gregoryaster</u> <u>lorioli</u> (Stefanini)

Gz 972 x 2

Lower Globigerina Limestone

N of Torri tal Qaura, 273897

e. Gz 972 x 4

f. <u>P.latus</u> (Agassiz)

Mlt 402a x 1 *

Scutella Bed,

near Marfa, Malta.

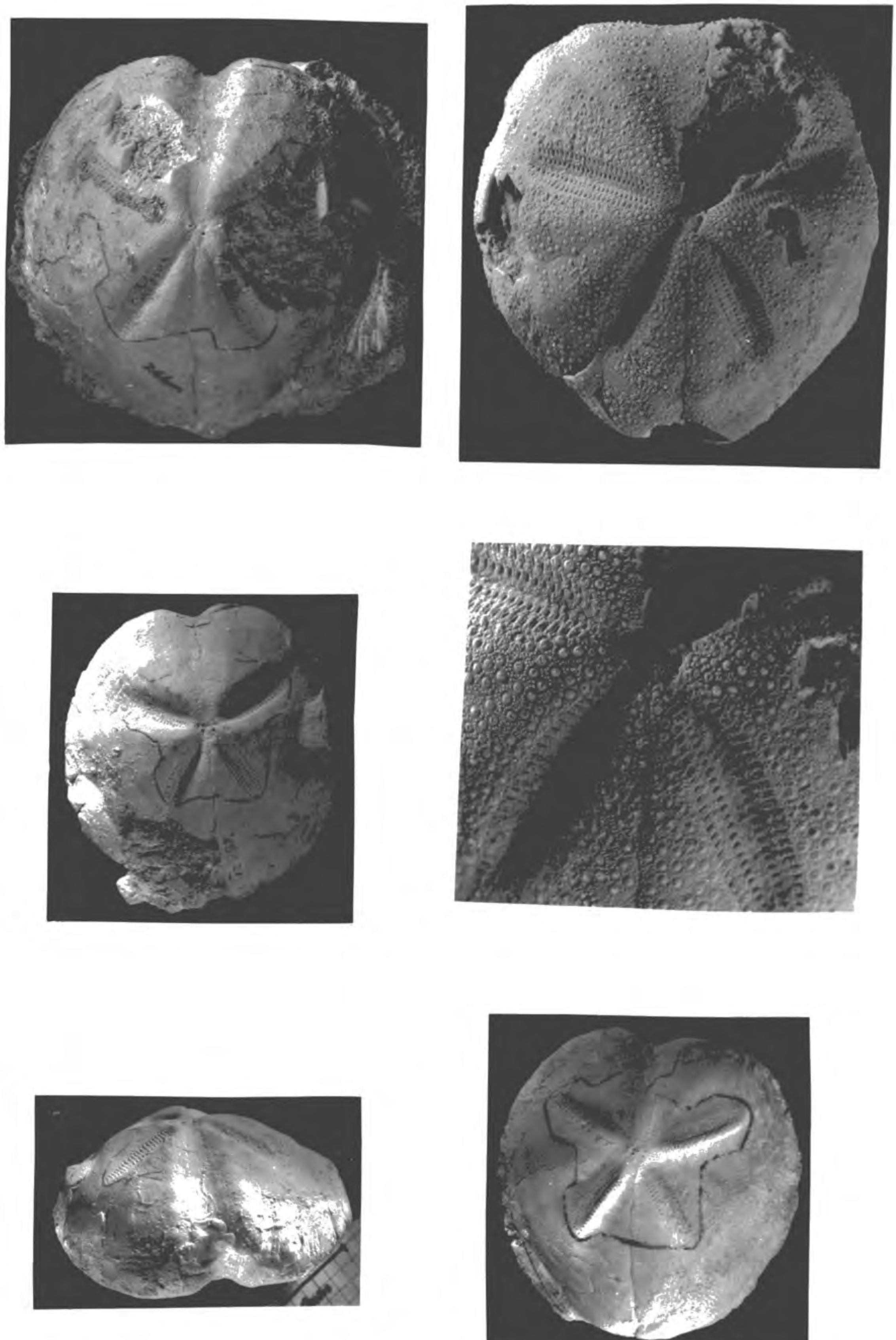


PLATE TWENTY

Pericosmus _latus_ (Agassiz)

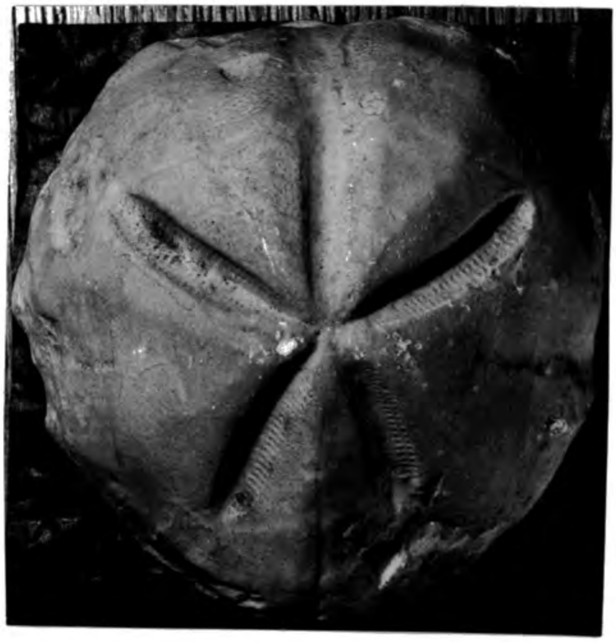
Agassiz's mould T40 x 1

Musée Nationale

Specimen from Bonifacio, Corsica x 1

No. 505, Drawer B2, Lambert Collection;

Sorbonne.



Family BRISSIDAE Gray 1885

Genus Eupatagus L. Agassiz 1847

Type species Eupatagus valenciennesi Agassiz

Diagnosis:

Spatangoid echinoids with test of moderate size, oval and usually low in outline with slight keel and truncated rear surface. Apical disc small and to the front, with four genital pores. Unpaired ambulacra not petaloid, a little sunken. Paired ambs petaloid, not sunken, closed with wide interpore zones; front pair widely divergent. Narrow peripetalous fasciole enclosing primary tubercles on some or all interambulacra and not bending in on the latter. Sub-anal fasciole broad and shield-shaped. Mouth slightly sunken with inconspicuous phyllode; long, narrow labrum and raised tuberculate plastron to rear.

(Modified from Kier 1957, p.806 and Mortensen 1951, p.457-8)

Eupatagus dekonincki (Wright)

Plates 21-26, text-figures 15-17

1855 Spatangus De Koninckii Wright; p.178-181

1855 Eupatagus De Koninckii Wright; Wright, p.274

1858 Euspatangus De Konincki Wright; Desor, p.415

1864 Eupatagus Konincki Wright; Wright, p.487, pl.22, fig.5a-c

1891 Metalia melitensis; Gregory, p.621-2, pl.2, fig.5a-c

1891 Euspatangus de konincki (Wright); Gregory, p.624

1908 Eupatagus melitensis (Gregory); Stefanini, p.464-70, pl.17, fig.6

1909 Brissoides Konincki (Wright); Lambert, p.135

1909 Brissoides melitensis (Gregory); Lambert, p.135

1914 Euspatangus Konincki Wright; Cottreau, p.24

1914 Euspatangus melitensis (Gregory); Cottreau, p.24, 123-4, pl.9, fig.9

1914 Melita melitensis (Gregory); Fourtau, p.68

1951 Eupatagus melitensis (Gregory); Mortensen, p.459

Diagnosis:

Medium sized spatangoid echinoids, oval outline, small apical disc two-fifths of total length from the front, with four relatively large genital pores. Unpaired ambulacrum narrow and slightly sunken. Paired ambulacra not sunken; front ones slightly shorter with their front pore-zones flexed out then back, with acute petal ends, diverging from long axis of the test at about 70°; rear pair with more symmetrical pore-zones and blunter ends, diverging at about 30°.

Two separate fascioles: a narrow peripetalous one enclosing an area of large tubercular spine bases on the paired interambs but not on the rear one; and a sub-anal fasciole with two sets of four pore-pairs within it.

Flat oral surface with mouth between a quarter and a third of the total length from the front, with an inconspicuous phyllode. Front three ambulacra narrow, rear pair broad. Long narrow labrum and a spade-shaped, raised plastron. Anus in rear truncated surface.

Description:

These are medium sized spatangoid echinoids with an oval outline, a little longer than wide. The width is between four-fifths(Gz 19) and nine-tenths(Gz 10) of the length, the front margin is rounded and the rear margin is tapered to a varying extent. It has a small truncated area containing the anus. The test is highest on the rear interamb, about a third to half of the distance to the margin. The height is between a third and half the length but is frequently altered by crushing.

Upper surface. The apical disc is small, a little over two-fifths of the total length from the front, the actual value ranging from 0.40 (Gregory's type) to 0.54(Gz 20b). It is of typical spatangid pattern having four genital plates, each with a relatively large pore, with the one at the head of the right-hand front interamb (2 on Lovén's nomenclature) forming the madreporite and extending between the rear pair of oculars to touch the head of the rear interamb column; and with five small triangular ocular plates (text-fig. 16).

The paired ambulacra are petaloid with fairly sunken pore-zones. The front pair are slightly the shorter (between 0.82 -in Gz 621- and 0.94 -in Gz713- of the rear petal length) and extend to two-thirds of the corresponding radius, with the front pore zone of each petal flexed forwards and then back to a variable extent. Gz 10 shows a slight development of this whilst Gz 713 shows a greater flexing (plate 23). The rear pore zone is more evenly

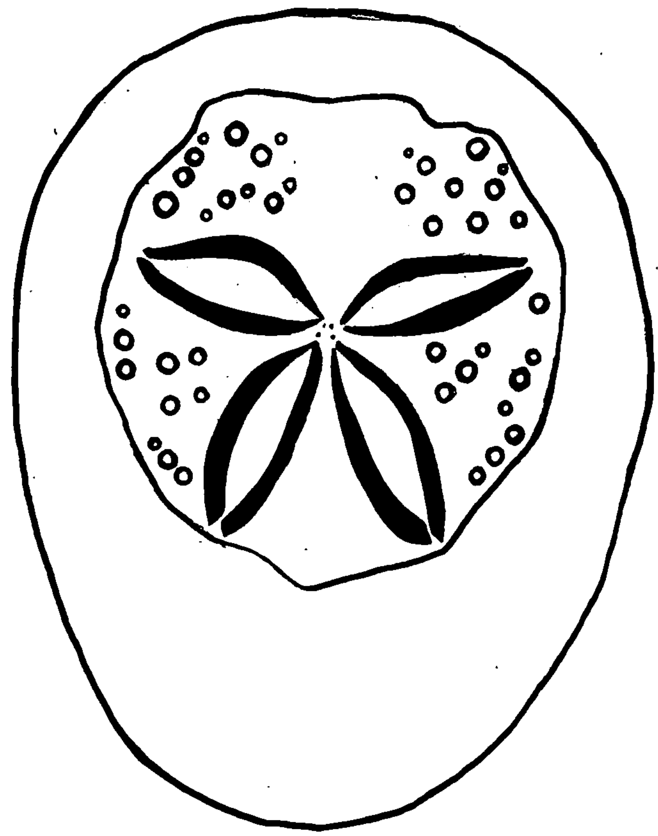
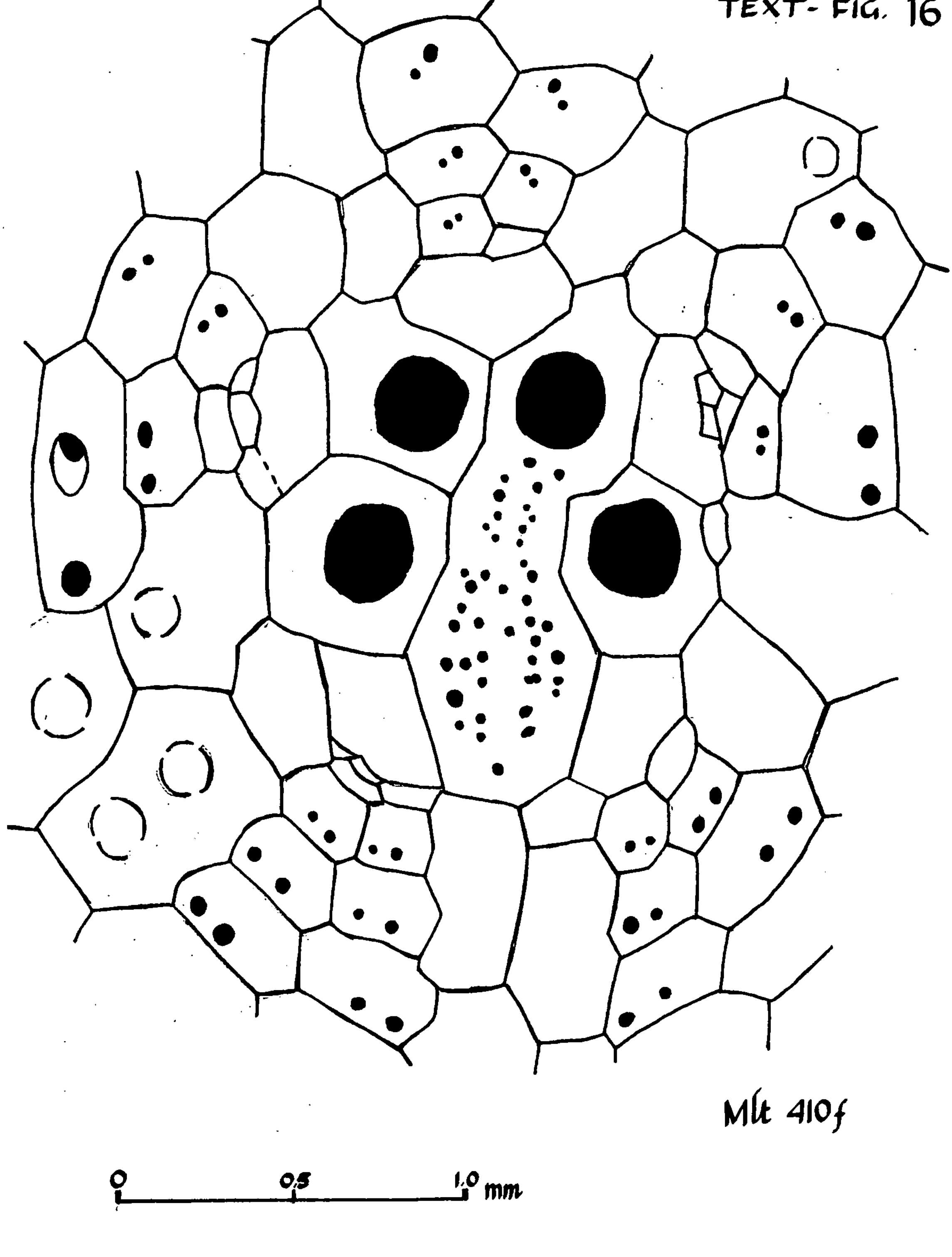


Diagram showing the primary tubercles and peripetalous fasciole of *Eupatagus dekonincki*.



Apical details of Eupatagus dekonincki.

curved and has conjugate pore-pairs with deep grooves. There are between 18 pore-pairs, in younger specimens (e.g.Gz 621), and 25 in larger ones (e.g.Gz 998). The outer pores are slightly slit-shaped and the inner ones are circular. The inter-pore zone is flush with the interambulacra. It widens to twice the equivalent pore zone width at a third of the distance from the ocular and then narrows to the ends, which are usually closed but are sometimes a little open (e.g.Gz 10, plate 23). The front pair of petals diverge at an angle of about 70^o from the unpaired amb. The rear pair extend only half the corresponding radius (e.g.Gz 602 -petal length 15mm., ocular to ambitus distance 32mm.). Their pore zones are more symmetrical, those adjoining the rear interamb form even curves widening until near the distal end. The front pore zones, adjoining interambs 1 and 4, are similarly curved but widen sooner and on some specimens bend out farther (e.g.Gz 713 compared to Gz 998 and Mlt 266a, see plates 21 and 22). The pore-pairs are conjugate with deep connecting grooves. There are between 22(Gz 621) and 27(Gz 998) pore-pairs, always about three more than in the front paired petals. The outer pores are slightly slit-shaped and the inner ones are circular. The inter-pore zones are one and a half times the width of the pore-zones at their maximum width, usually half way along the petal but nearer the ocular in some (e.g.Gz 713). The petal ends are closed with pore zones Ia and Vb sometimes projecting in front of the inner ones (e.g.Mlt 266a, pl.21). The rear pair of petals diverge at an angle of between 25^o and 30^o from the long axis of the test.

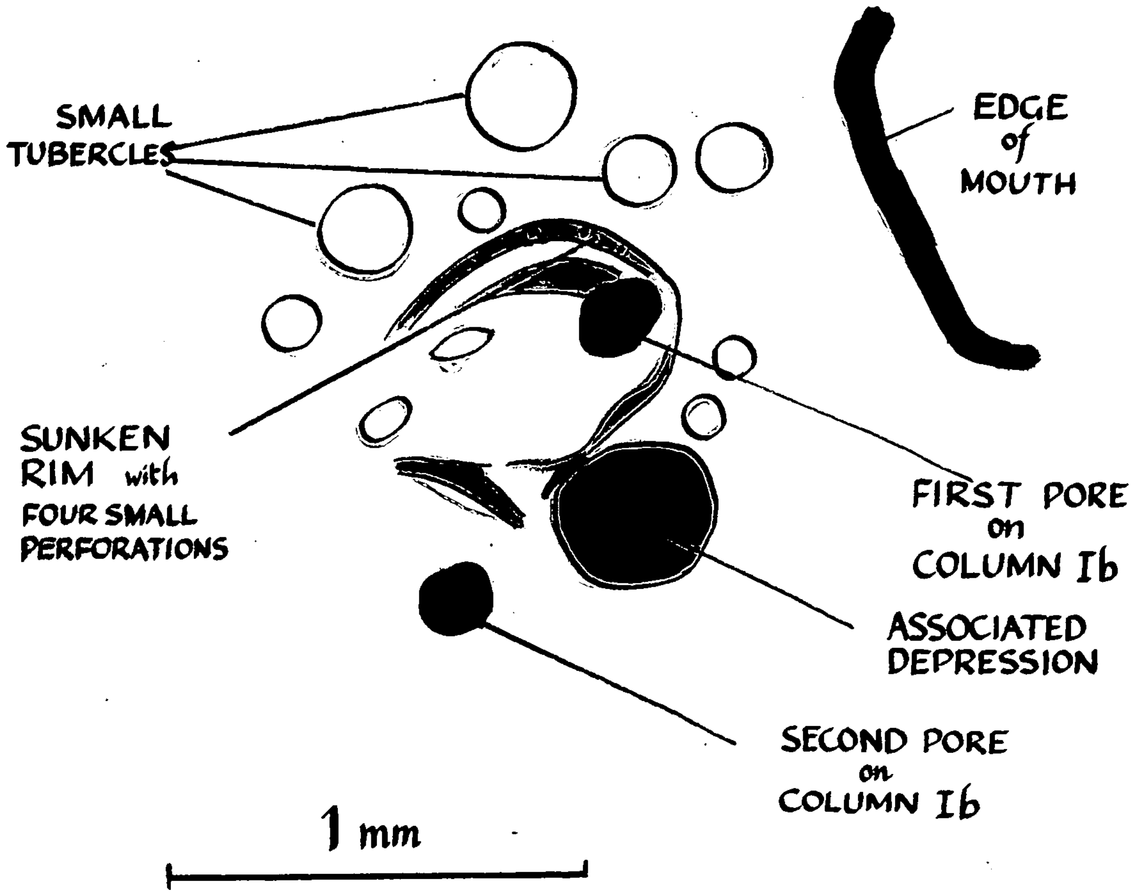
The ambulacra beyond the petals form a double column of plates, wider than long and increasing in width towards the margin with about four plates in each column of the front pair and about eight in the rear pair.

The unpaired ambulacrum is slightly sunken and straight sided and has pore zones which diverge at a constant angle of about 6-8°. Two columns of simple plates run from the ocular to the margin with around 25 plates in each (e.g.Gz 998: Gz 10, a smaller immature specimen has 20), increasing in size at a constant rate. The pore-pairs are very small, non-conjugate and aligned parallel to the column not across it as in the petaloid ambulacra. The inter-pore zone is wide and faintly concave in section.

The interambulacra are wider than the ambulacra, except for the rear one, and are covered with tubercles of various sizes. The primary tubercles follow only a general pattern but vary in details (see text-fig.15 for the generalised pattern and plates 21 and 22 for individuals). Each has a perforate mamelon with a relatively deeply sunken scrobicular area. They are restricted to the area within the peripetalous fasciole and are aligned partly parallel to it and partly across it. Their number is usually greatest on large specimens but not always (e.g.on interamb 1: Gz 713 - 9 tubercles; Gz 10 - 6; Gz 998 - 5). Primary tubercles are not found on the rear interamb. Secondary tubercles occur along the inner edge of the fasciole of the rear paired interambs (1 and 4) and along the borders with the unpaired ambulacra of the front interambulacra, in groups of about six in a regular pattern. Low ridges, varying in width, run across the interambulacra. A broad one runs down the centre of the rear interamb and produces a low, blunt keel; narrow ones form on the rear pair at approximately a third and two-thirds across the width; and narrow ones occur on either side of the front, unpaired ambulacrum, sometimes with a branch down the centre of the front interambulacra.

A peripetalous fasciole exists on the upper surface. It is narrow and is not always distinct, especially across the front ambulacrum (cf.Wright 1855, p.274:"the peripetal fasciole is rather broad"). It is fairly straight with kinks of varying extent along the edge of the front amb (see text-fig. 15 for a diagrammatic sketch) and passes a little distance from the front pair of petals but closer to the rear pair and then irregularly crosses the rear interamb, sometimes with a backward bend in the rear left-hand column (5a), (Gz 713, plate 21 and Mlt 404b), or in the right-hand one(5b), (e.g.Mlt 407b). (Cottreau (1914, p.124, pl.9, fig.9) draws attention to an example of kinking in this fasciole and it is clearly prone to irregularities.)

The lower surface contains the mouth, between a quarter and a third of the total length distant from the front,(0.26 in Gz 608 to 0.33 in Gz 621). This is shaped like an orange segment, convex to the front and transversely elongate with a width of about 1¾ times the length and a narrow lip, surrounded by a phyllode consisting of two near parallel lines of pores in each ambulacrum. There is a single pore to each plate except for one of the pair closest to the mouth, with the following pattern of plates with no pores -1a, 2a, 3b, 4a, 5b. This is the same pattern as that which occurs on Schizaster and may be typical of the spatangoids. Each pore is surrounded by an oval, sunken rim and, in most cases, apart from the pores most



Detail of part of a phyllode pore-zone on *Eupatagus dekonincki*.

distant from the mouth, with a small circular pit behind the actual pore, which sometimes has a double or slit-shaped opening, (see text-fig.17 for a detailed sketch of one pore showing structures presumably related to the musculature of the tube feet, by comparison with the structures discussed by Nichols, 1959, p.397-8, fig.28).

The front three ambulacra are narrow. The unpaired one lies in a slight groove running along the length of the test in front of the mouth. The paired ones are perpendicular to it and are only sunken in the phyllode area.

Discussion:

All the specimens of Eupatagus collected from the Scutella Bed and the Lower Globigerina Limestone can be allocated to this one species. The figures and descriptions of Wright's "Spatangus dekonincki" and Gregory's "Metalia melitensis", taken together with the material collected, show that only a single slightly variable species occurs. No actual comparisons were made between Wright's and Gregory's species, partly because Gregory placed them in a separate genera, until Stefanini attempted it (1908, p.469-70). He only listed possible differences on the basis of the published figures and his own figure of "Eupatagus melitensis" shows a poor specimen (pl.17, fig.6). He stated that E.melitensis was heart-shaped rather than oval, did not taper to the rear, had more large tubercles, and had wider petals than E.dekonincki.

Plate 26 allows a comparison of Wright's type and figure with Gregory's figure (Gregory's type could not be traced but the other types suggest that Gregory's published figures are accurate, which cannot always be said for Wright) and shows that there is little difference. Wright's type is more rounded in front and more tapered to the rear but the tubercles and petals are similar and have not been figured accurately. Plates 21 and 22 show that there is considerable variation in the details of the tubercles and, to a lesser extent, in shape, added to which, subsequent crushing often distorts the outline.

Wright originally recorded Eupatagus dekonincki from both Blue Clay and Globigerina Limestone (1855, p.181) but later ignored the former. All the present material is from the Scutella Bed, where Scutella subrotunda and E.dekonincki are often associated, and from the Lower Globigerina Limestone.

PLATE TWENTY-ONE

Eupatagus dekonincki (Wright)

Gz 713 x 2

Lower Globigerina Limestone

Ix-Xatt L-Ahmar, 356862

Mlt 536 x 2.5

Lower Globigerina Limestone

Rdum Qammieh, Malta

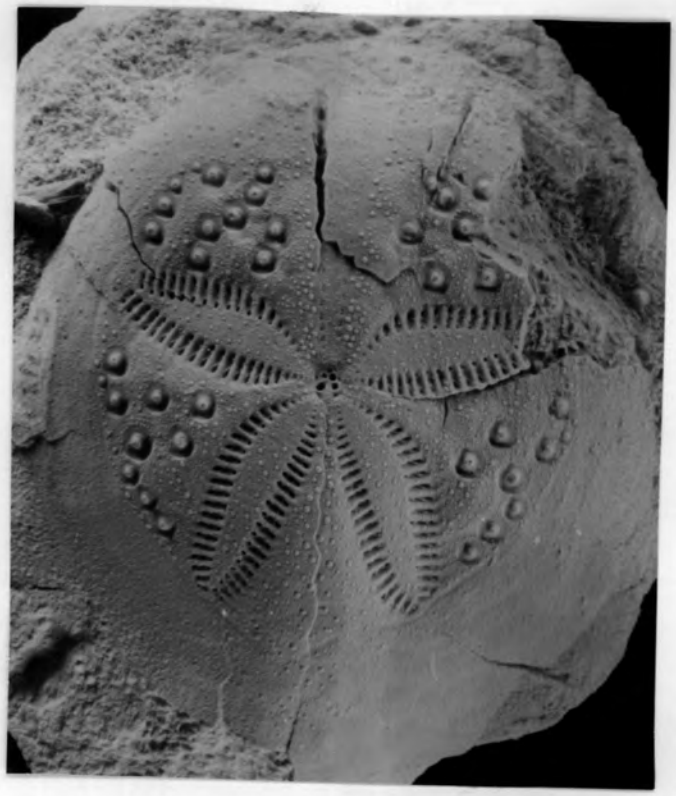
808400

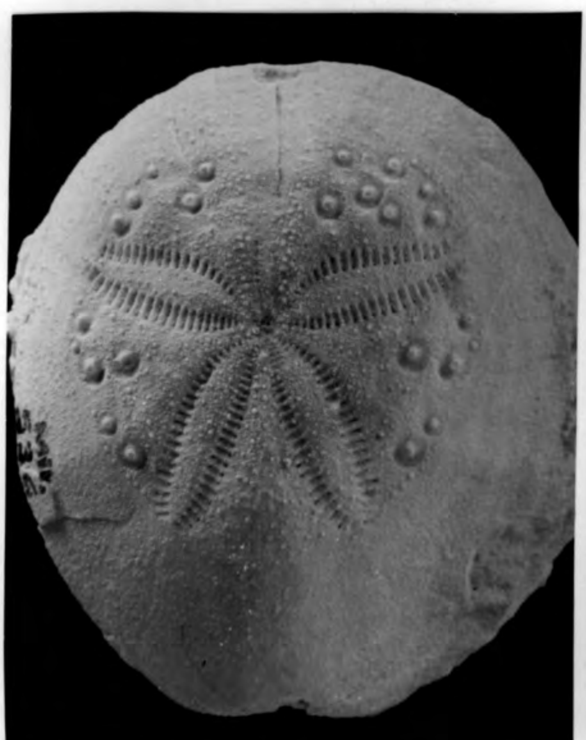
Mlt 266a x 2

Scutella Bed

Ix-Xatt L-Ahmar

356862






2662

PLATE TWENTY-TWO

Eupatagus dekonincki (Wright)

Scutella Bed,

Torri ta Xlendi, 293872

Gz 998 x 2

Gz 998 x 4

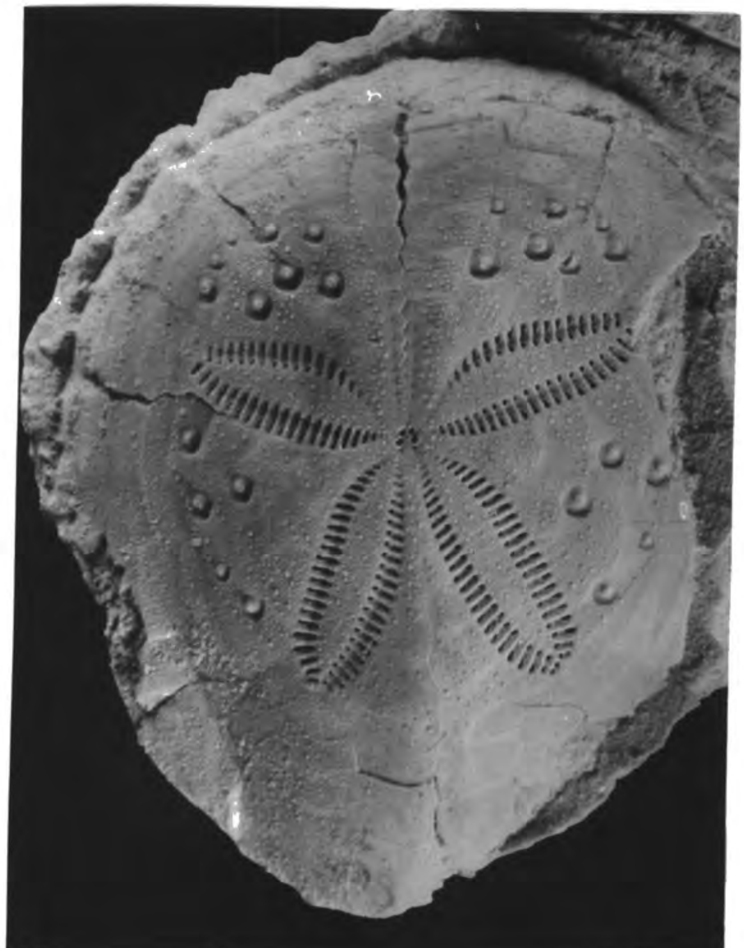


PLATE TWENTY-THREE

Eupatagus dekonincki (Wright)

details of the apical region

Gz 10 x 4

Lower Coralline Limestone,

Ix-Xatt L-Ahmar, 356862

Gz 998 x 4

Scutella Bed,

Torri ta Xlendi, 293872

Gz 713 x 4

Lower Globigerina Limestone,

Ix-Xatt L-Ahmar, 356862

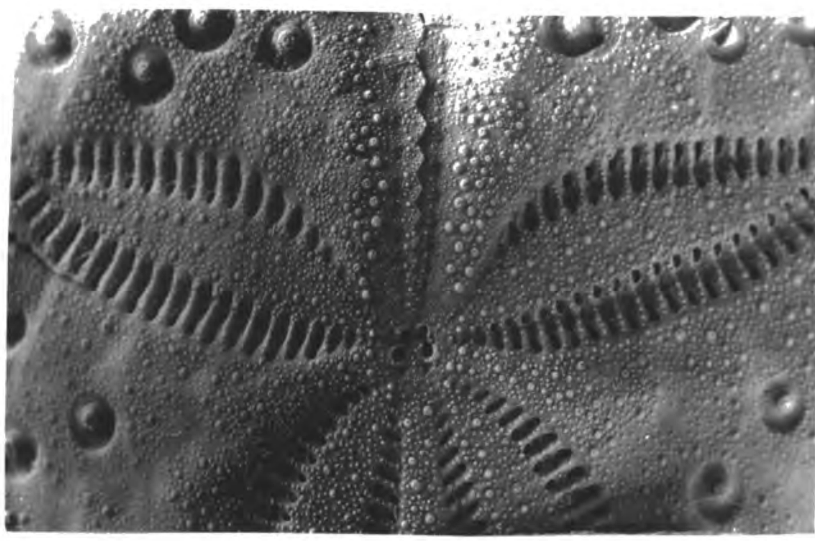




PLATE TWENTY - FOUR

Eupatagus dekonincki (Wright)

Mlt 402

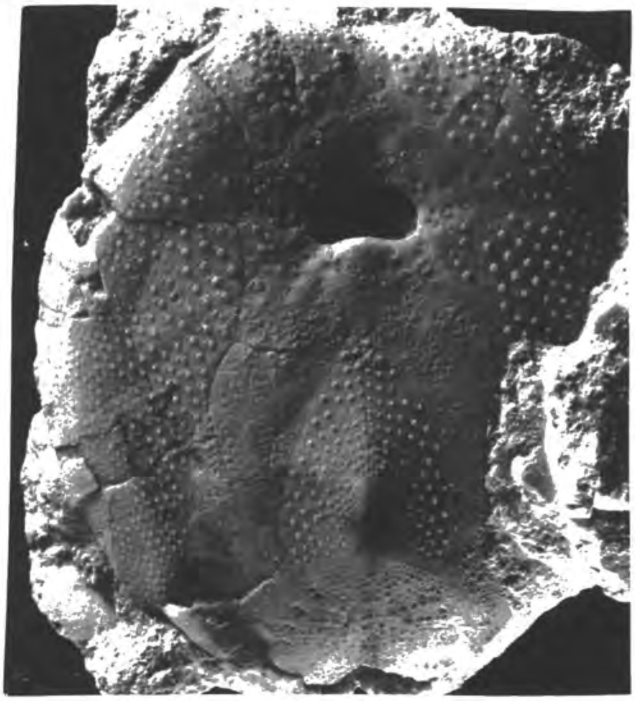
Scutella Bed,

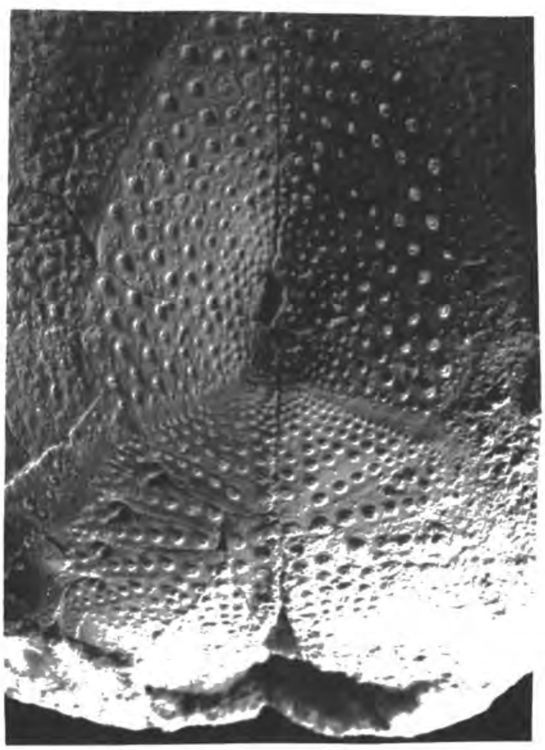
near Marfa, Malta

General Adoral View x 2

Details of the Plastron and Sub-anal Fasciole

x 4 x 4





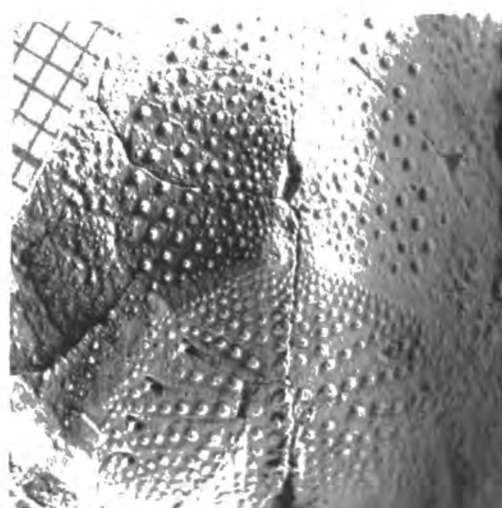


PLATE TWENTY-FIVE

Eupatagus dekonincki (Wright)

Gz 712 x 2

Lower Globigerina Limestone,

Ix-Xatt L-Ahmar, 356862

Gz 712 x 4

details of pores round mouth

Gz 710 x 2

Lower Globigerina Limestone

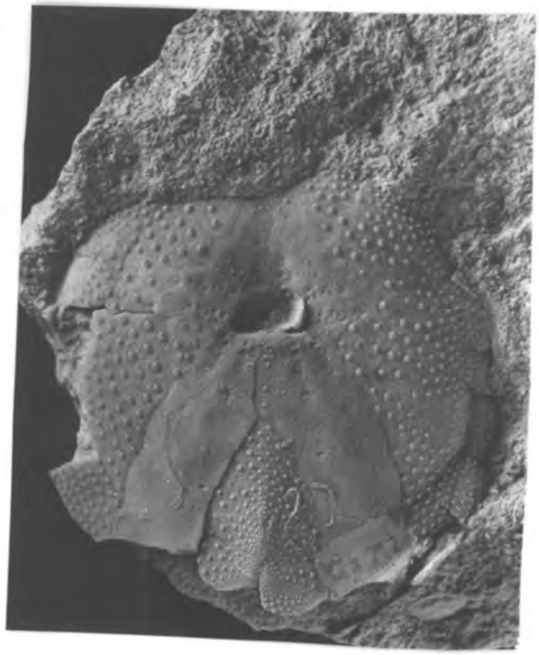
Ix-Xatt L-Ahmar, 356862

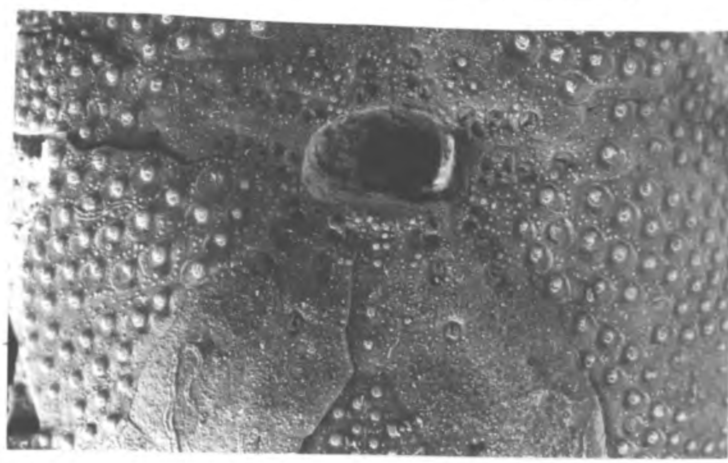
Gz 613 x 2

Scutella Bed,

Ix-Xatt L-Ahmar

plate boundaries darkened





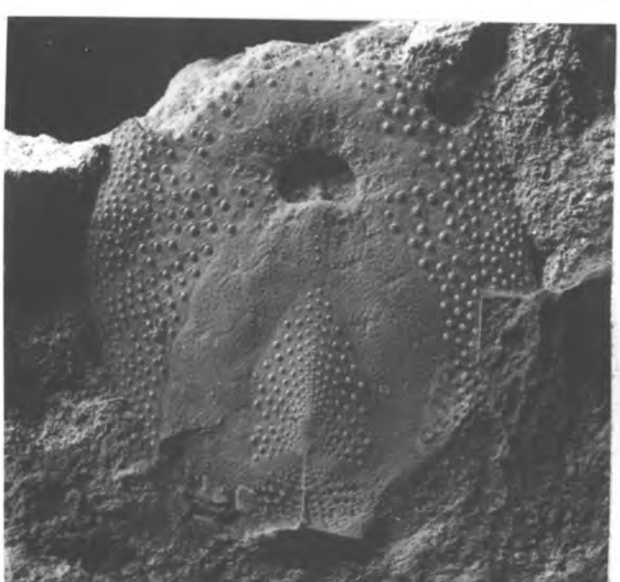


PLATE TWENTY-SIX

Eupatagus dekonincki (Wright)

Wright's type figures

Q.J.G.S., 1864, pl.22, fig.5

Type specimen

BM 1582 x 1

Globigerina Limestone

Gregory's type figures of

E. melitensis

Trans. Roy. Soc. Edin., 1891, pl.2, fig.5

5a

5b

5c

5.a

5.b

5.c

ECHINOID CORRELATION

Since the present work has been concerned with the stratigraphy and echinoid paleontology of Malta and Gozo questions of correlation with other areas have not fallen within the scope of the study and would require a similar personal aquaintance with the Tertiary rocks of the rest of the Mediterrenean coast. However, certain observations can be made.

First, it has been clear throughout the examination of the echinoids that the multiplication of specific and occasionally of generic names has served often to obscure similarities and even identities. Examples of this are Echinolampas lucae and Schizaster eurynotus both of which occur widely and have been given a variety of names. Occasional false identifications have produced the opposite result, for example, Gregory's misidentification of Scutella subrotunda as an Eocene form. It is hoped that the partial simplification of the faunal list will serve to make future correlations easier.

Secondly, examination of museum collections has provided some information almost impossible to derive from the literature. None of the scutellids seen, which have been collected from the Mediterranean Miocene, bear a close resemblance to Scutella subrotunda or to the newly recognised Scutella, although as earlier indicated, Scutella ammonis and Scutella rostrata (Fuchs, 1882, p.30) from the Miocene of Libya appear from the figures to be identical to Scutella subrotunda. Also, the lexique Stratigraphique Internationale (1956, p.81-2) records this species accompanied by Clypeaster marginatus and Schizaster eurynotus from Otranto on the heel of Italy. In the case of Clypeaster, not studied in detail, it is clear that there is a great deal of variation in form even from one locality. All the collections bear this out but especially that at the École des Mines in Paris where Corsican specimens show a clear variation in shape. This has given rise to a large number of specific names of doubtful validity and has obscured a true recognition of the wide distribution of Clypeaster altus during the Burdigalian. Specimens have been examined from Corsica and Egypt and according to Cottreau (1914, p.56-62) it has an even wider distribution (a recent reference to its occurrence in Spain is Alnela and Sanz 1958). Stefanini (1924, p.837-840 and p,845-6) discusses briefly the wider ranges of the genera. Of the spatangids, Pericosmus latus, Schizaster eurynotus and Schizaster parkinsoni have been collected from a wide area. No fresh information has been obtained on the dubious record of Schizaster parkinsoni from the West Indies (Stefanini, 1924 p.845). Echinolampas lucae is a distinctive cassidulid echinoid and can be recognised from a wide area.

In general, as would be expected, the Maltese echinoids have close affinities with those found in Southern Italy and the Libyan coast.

The following table lists echinoids recorded from the Tertiary rocks of Malta and Gozo. Those discussed in detail in the present work are shown as follows: C -common, O -occasional, R -rare. Those collected and provisionally identified but not discussed above are shown as follows:

c -common, o -occasional and r -rare. Those seen in Museums and considered to come from the Maltese Islands are marked with a -. In the case of the Globigerina Limestone, where it is not possible to be certain from which subdivision they derive, all three are marked - - -.

Synonyms and unreliable records which have been discussed previously are omitted. Other records that are considered to be dubious or to be synonyms of listed species are grouped together at the end of the list.

Where the most useful reference to the species is not that of the original author, this is given immediately after the author's name.

Table of Echinoid Distribution

	LCL	ScB	LGb	MGb	UGb	BC	Gs	UCL
Cidaris avenionensis Desmoulins; Gregory 1891			r					
C. melitensis Wright 1855								o
C. oligocenus Gregory 1891	o							
Arbacina piae Lovisato; Cottreau 1914		-	?-					
Schizechinus duciei (Wright); Stefanini 1908								o
Psammechinus tongrianus (Gregory) 1891	-							
P. tortonicus Gregory 1891								-
Echinocyamus stellatus Capeder; Cottreau 1914					-			
Clypeaster altus (Leske); Cottreau 1914							c	o
C. marginatus Lamarck; Cottreau 1914							c	o
Scutella subrotunda (Leske); Durham 1955	C	C						
Scutella sp. nov.	R	O						

	LCL	ScB	LGb	MGb	UGb	BC	Gs	UCL
<u>Echinolampas equizonatus</u> (Gregory) 1891		-	-	-				
<u>E.hemisphaericus</u>(Lamarck); Gregory 1891								-
<u>E.lucae</u>(Desor); Kier 1962							C	
<u>E.scutiformis</u>(Leske); Cottreau 1914			-	-	-			
<u>E.wrighti</u> Gregory 1891							-	
<u>E.tagliaferroi</u> Cottreau 1914			-	-	-			
<u>E.posterolatus</u> Gregory 1891		-						
<u>Schizaster eurynotus</u> Agassiz; Cottreau 1914				O		R		O
<u>S.parkinsoni</u> (Defrance); Stefanini 1908		C	C					
<u>Heterobrissus excentricus</u> (Wright); Cottreau 1914								-
<u>Brissus gregoryi</u> Stefanini 1908								-
<u>B.imbricatus</u> Wright 1864								-
<u>B.latus</u> Wright 1864								-
<u>B.oblongus</u> Wright 1855								-
<u>Trachypatagus tuberculatus</u> (Wright); Mortensen 1951								-
<u>Brissopsis crescenticus</u> Wright 1855			o					

	LCL	ScB	LGb	MGb	UGb	BC	Gs	UCL
<u>Echinoneus melitensis</u> (Wright); Brighton 1926								r
<u>Pliolampas vassalli</u> (Wright); Kier 1962			o					
<u>Studeria spratti</u> (Wright); Cottreau 1914			c	c				
<u>Hemiaster cotteaui</u> Wright 1855			R					
<u>H.scillae</u> Wright; Stefanini 1908			C	C	O			
<u>Gregoryaster coranguinum</u>(Gregory); Lambert 1907			R					
<u>G.lorioli</u> (Stefanini) 1908			R					
<u>Pericosmus latus</u> (Agassiz); Cottreau 1914		O	O					
<u>Spatangus delphinus</u> Defrance; Wright 1864							-	-
<u>S.marmorae</u>(Desor); Cottreau 1914			-	-	-			
<u>Eupatagus dekonincki</u> (Wright); Mortensen 1951	O	C	C					
?<u>Maretia</u> [<u>Lovenia</u>] <u>anteroalta</u> (Gregory) 1891					-			
<u>M.duncani</u> (Gregory) 1891			-	-	-			

Dubious Records

Cidaris adamsi Wright 1864: C.scillae Wright 1864: C.sismondai Mayer; Cottreau 1914.

Echinus hungaricus Laube; Cottreau 1914

Echinocyamus studeri (Sismonda); Cottreau 1914

Clypeaster melitensis Michelin 1867: C.latirostris Agassiz; Cottreau 1914: C.gibbosus (Risso)1826; Gregory 1891: C.reidi Wright 1855: C.portentosus Desmoulins; Smedile 1958: C.brevior Sequenza; Smedile 1958: C.folium Michelin; Smedile 1958: C.tauricus Desor; Smedile 1958.

Echinolampas angulatus Mérian; Cottreau 1914: E.doma Pomel; Cottreau 1914: E.manzoni Gregory 1891: E.hayesianus Agassiz and Desor; Gregory 1891: E.kleini (Goldfuss); Wright 1855: E.pignatarii (Airaghi); Roman 1955:

Brissus cordieri Agassiz and Desor; Desor 1858: B.depressus Gregory 1891.

Brissopsis duciei Wright 1855: B.grateloupi (Sismonda); Cottreau 1914.

Breynella equizonata Gregory 1891;

Spatangus ocellatus Defrance; Gregory 1891: S.pustulosus Wright 1864.

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A SIX INCH TO THE MILE
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