IV. *The Evolution of the Cretaceous Asteroidea.*

By W. K. Spencer, *B.A.*, *F.G.S.*

Communicated by A. Smith Woodward, *F.R.S.*

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[Plates 10–16.]

Contents.

Section I.—Introduction.

It was possible to show, in a recent monograph,* that the isolated ossicles of Asteroidea, which are so frequently found by the field worker, could be identified by means of their shape and ornament. During the last four years large quantities of such material have passed through my hands. In consequence there is now sufficient evidence to trace the evolution of the great majority of Chalk Asteroidea through the whole of the zones of the chalk, and even in some cases to refer them to Jurassic ancestors.

The importance of the investigation of chalk forms has been shown by Rowe (40, 41), who has pointed out (41 (v), p. 325) that "It is only in a deep-sea deposit like the Chalk, with slow, placid, and uninterrupted sedimentation taking place over vast periods of time, that we can reasonably hope to follow out every stage in the unbroken continuity of the evolution of a genus . . . ."

The discovery by Mr. Dibley† of the exact horizon of the chalk quarries near Bromley, Kent, enables us to confirm a suspicion long held that the majority of the specimens described from the white chalk, in the previous monograph, were from one zone only, namely that of *Micraster cor-anguinum.* The collection of Dr. Blackmore alone of those previously known to me contained material in any quantity from zones higher than this. In consequence a wealth of species from other horizons and localities remained still to be described. Collections have been lent from the following Continental museums and collectors :—

* Sladen and Spencer (45).

† Dibley, 'Geol. Mag.,' December, 1911, vol 8, p. 96.

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Belgium, Brussels, Musée Royal d'Histoire Naturelle de Belgique.
Denmark, Copenhagen, Universitetets Mineralogiske og Geologiske Museum.
,, ,, Dr. BRÜNNICH NIELSEN.
Egypt, M. FOURTAU.
France, Beauvais, Oise, M. JANET.
,, Ste. Colombe-les-Sens, Yonne, Dom VALETTE.
,, Vendôme, M. FILLIOZAT.
,, Poitiers, Prof. J. WELSCH.
Germany, Berlin, Kgl. Geologisch-palæontologisches Institut und Museum.
,, ,, Kgl. Geologische Landesanstalt.
,, Bonn, Geologisches Institut der Universität.
,, Munich, Palæontologisches Institut, Alte Akademie.
Sweden, Lund, Universitets Geologisk-Mineralogiska Institut.

I am greatly indebted to the courtesy of the various individuals who have kindly forwarded this foreign material. It has been possible in consequence to compare at first hand both English and Continental species, and to avoid any of those misconceptions which may follow from trusting to mere descriptions or imperfect identifications.

In addition the British Museum (Nat. Hist.) has purchased a large collection made by Frau AGNES LAUR by washing the "*mucronata*-chalk" of the Isle of Rügen. Indeed, it was when examining this collection that I discovered that there remains a large Asteroid fauna as yet undescribed.

Foremost amongst English collectors to whom I owe the greatest possible thanks are Mr. BRYDONE* and Dr. ROWE. They have been indefatigable in their pains to supply me with material. Dr. BLACKMORE has also kindly sent me further material from his collections. Messrs. CHATWIN and WITHERS have often helped me considerably by their knowledge of the English Chalk. I must also thank Messrs. BOWER, CARTER, DIBLEY, FABER, and FARMERY, and the Curators of the Norwich Museum for the loan of ossicles and material from various localities.

Prof. KARL PEARSON made some valuable critical suggestions as to the statistical evidence given.

Dr. HINDE has kindly assisted me with the Swedish and Danish literature, and Herr Dr. SCHÖNDORF was good enough to send me a list of German collections. Messrs. W. D. LANG and C. D. SHERBORN have also given me assistance from time to time.

It would have been impossible for me to have undertaken this work but for the great assistance rendered by Dr. BATHER.

Lastly, I must express my gratitude to Mr. LITTLE, who has, voluntarily, taken great pains to secure the excellent photographs which are reproduced in the plates. There can be no personal bias in the description afforded by a clear photograph. It is felt that the plates assist greatly the writer's arguments.

Mr. SEARLE has provided some supplementary drawings executed with his usual care.

* Mr. BRYDONE has sent me several thousand ossicles from upwards of 350 pits in Hampshire alone.

This paper endeavours to show :

A. As to Method—

(1) That isolated ossicles can be named by the collector with confidence. It is but rarely that uncertainty arises. Many thousands have passed through my hands.

(2) That it is possible, not only to separate the ossicles according to species, but also to reconstruct new forms.

B. As to Evolution—

(1) That Cretaceous Asteroidea belong only exceptionally to modern genera. The fauna is Mesozoic and has no general relationship with the Tertiary forms. In consequence the opportunity has been taken to revise the generic nomenclature in order to leave no misconception on this point.

(2) That the starfish may be separated into lineages ("species series") which preserve unbroken continuity during their life-history.

(3) That if the variation of individual characters in a lineage be considered they are—

(*a*) Usually of a continuous type.

(*b*) Frequently independent of each other.

(4) That the types of variation which arise in each lineage are predetermined and limited by innate causes.

(5) That environment affects the course of variation since the evolution of a lineage in the depths of the main Chalk seas differs from that nearer the shores.

(6) That each zone or group of zones has its own distinct fauna. In this connection it is possible to show that the stages of evolution in the Upper Cretaceous rocks fall into three periods of time :

(*a*) A "low-zonal" period, up to and including the lower quarter of the zone of *Micraster cor-anguinum.* Generally the forms are depressed and in certain genera (*Pycinaster* and *Metopaster*) small as compared with later forms. The marginalia bear well-marked spine pits.

(*b*) A "mid-zonal" period, up to and including the lower third of the zone of *Actinocamax quadratus* (sub-zone of *Offaster pilula*). Generally the forms are of medium to large size. The spine pits on the marginalia tend to become obscured by rugosities which make the plates appear to be highly ornamented.

(*c*) A "high-zonal" period, above (*b*) and including the Danian. A large proportion of the ossicles are large, high and not infrequently massive. Both spine pits and rugosities often disappear, leaving smooth plates.

It must be understood that the line of demarcation between these groups of species is never sharp. The parallelism which makes the above classification possible

is apparently due to the fact that a number of lineages make their first appearance simultaneously at the beginning of the Cenomanian and pass through corresponding approximately synchronous stages.

C. As to Stratigraphy—

(1) That ossicles of Asteroidea can be used by the field worker for zonal determinations.

(2) That the Asteroid fauna can be made the basis of a zonal classification.

An attempt is made in this paper to give in detail the evolution of only one characteristic Chalk genus, namely Metopaster, Sladen. It was felt that to describe *in extenso* the whole of the new species discovered would overweight the paper. The remaining genera are therefore only dealt with on broad general lines and in relation to the evolution of this one genus.

The Classification and General Characteristics of the Asteroidea.

Two classifications of recent Asteroidea are now in use. The first, established by SLADEN, divides the Asteroidea into two distinct orders: the Phanerozonia and the Cryptozonia. The Phanerozonia, as their name implies, are distinguished by the large size of their marginal plates and by the restriction of papulæ (specialised breathing organs) to the abactinal surface. The Cryptozonia have less distinct marginal plates and a wider distribution of the papulæ.

The second classification, established by PERRIER, takes account of five orders: the Forcipulata, the Spinulosa, the Velata, the Paxillosa, and the Valvata or Granulosa. Each of the orders has characteristics which suggest descent along distinct lines. It further cuts across the classification of SLADEN inasmuch as some of the orders include both Phanerozonate and Cryptozonate forms.

Against the first classification it is urged that both palæontological and embryological evidence shows that a sharp division of the Asteroidea into Phanerozonia and Cryptozonia is not warranted. The Cryptozonia are really later specialised forms which have arisen from various Phanerozonate roots. All young starfish have large marginalia. Similarly large marginalia are characteristic of early (pre-Tertiary) fossil forms. The reduction in the size of the marginalia in both later life and racial history appears to be correlated with an extension of the area devoted to papulæ.

The classification of PERRIER is followed in this paper. Apparently three of his orders are represented in the Cretaceous rocks, the Valvata, the Paxillosa, and the Spinulosa.

The Valvata or Granulosa.—This order, as the names suggest, has two main characteristics: (1) the frequent presence of small granular spines upon the plates, (2) the general valvular form of the pedicellaria.

The modern genera belonging to the order are divided into five families: the Pentagonasteridæ, the Gymnasteridæ, the Pentacerotidæ, the Antheneidæ, and the

Linckiidæ. The first four families include Phanerozonate forms, the fifth Cryptozonate forms. Throughout each family one can trace the gradual reduction of the plates to afford room for the protrusion of papulæ and a marked tendency for the surface of the plates to be raised into projections which are often surmounted by spines. The majority of Cretaceous genera belong to this order.

The Paxillosa.—This group is characterised by the possession of grouped prominent spines (paxillæ) on the abactinal plates of the disc. Very few genera belonging to the order are found in the Mesozoic seas of North Europe. Practically all the forms which do occur are nearly related to the modern genus Astropecten.

The Spinulosa.—The Chalk genus Tholaster (see pp. 137, 138) appears to have some relationships with the modern genus Asterina.

Asterina is classified by PERRIER with the Spinulosa. The pedicellaria of this order are formed by the clustering of non-specialised spines.

Specific and Generic Nomenclature.—An attempt has been made to study the facies of the Asteroid fauna as a whole and to carve out, as suggested by ROWE (40, p. 498), broad zoological groups which are upon the same line of descent. These zoological groups are termed "species series." Varietal, specific, and generic names within the series are used almost exclusively with the dual purpose of providing shortened descriptive terms and of marking zonal changes for forms within a lineage. Other questions of nomenclature have been entirely subordinated to these.

Variation in the "Species Series."—The ossicles of Cretaceous Asteroidea undergo changes in shape and ornament which are parallel in the various "species series." These changes have been carefully studied, and it is useful at this stage to state the general results of this study, as the descriptions of the genera and species given below are thereby rendered more readily intelligible.

We may consider first of all changes due to the raising of the surface of the plate. These may be classified under three heads :—

(1) A general swelling of certain plates which may, as *e.g.* in Stauranderaster (see Plate 13, figs. 9 and 16), be characteristic of the genus.

(2) A fortuitous production of prominent projections which may arise independently in the different species of a genus or even as variations in individuals as, *e.g.*, in species and varieties of Metopaster (*Cp.* figs. 2 and 3, Plate 10).

(3) A production of small swellings or rugosities during a well-defined period in the life-history of the series.

Alterations in the structure of the plate due to this last cause are to be especially noted in "species series" belonging to the genera Metopaster, Crateraster and Stauranderaster. In these "series" we notice that, as a rule, the primitive species have plates covered with small, uniformly distributed, granular spine pits (Plate 13, fig. 3). Later, these spine pits tend to disappear. Usually, before the spines have disappeared, granular eminences appear on the plates between the spine pits, and thus give the plates a rugose appearance (see, *e.g.*, Plate 13, figs. 5 and 7).

Besides this series of changes from a primitive spinous to a secondary smooth or rugose condition we also find serial alterations in the size and height of the plates. The early species of a lineage are small and depressed. They later increase largely in size and height.

Quite frequently the inner edge of the supero-marginalia becomes tumid and the whole plate wedge-shaped. A curious parallelism in general form is thus produced (*Cp.* Plate 10, fig. 16 ; Plate 11, figs. 14–17 ; Plate 12, fig. 17, and Plate 13, fig. 29).

Certain species, after they have passed through the above stages, "stages of elaboration," are seen to undergo the same changes in a reverse order, "stages of regression."

Frequently, after a period of regression, new stages of elaboration may be observed. There thus arises in the "series" a type of variation which may be called "periodic." Periodic variation plays a particularly important part in the evolution of the Calliderma-Chomataster series and the Crateraster-Teichaster series (see pp. 121, 126).

If these general characteristics be kept in mind it is easy to follow the life-history of all the Cretaceous Asteroidea.

Zonal nomenclature.—It is convenient at this stage to give some account of the zonal nomenclature adopted.

High zones.	Danian. (Montian).	
	Zone of Belemnitella mucronata.	*Upper.*
	,, ,, ,,	*Middle.*
	,, ,, ,,	*Lower.*
	,, Actinocamax quadratus.	*Sub-zone of* A. quadratus.
Mid zones.	*Zone of* Actinocamax quadratus.	*Sub-zone of* Offaster pilula.
	,, Marsupites.	Marsupites band.
		Uintacrinus band.
	,, Micraster cor-anguinum.	*Upper three-quarters.*
Low zones.	*Zone of* Micraster cor-anguinum.	*Lower quarter.*
	,, Micraster cor-testudinarium.	
	,, Holaster planus.	
	,, Terebratulina lata.	
	,, Rhynchonella Cuvieri.	
	,, Holaster subglobosus.	
	,, Schloenbachia varians.	
	,, Pecten asper.	
Lower Cretaceous.	Albian.	
	Aptian.	
	Neocomian.	

I have followed the example of DE LAPPARENT and KAYSER in placing the Albian in the Lower Cretaceous.

The zoological break which is established for the Asteroidea at a point which is about the top of the lower quarter (or third) of the zone of *M. cor-anguinum* has previously been established for the Echinoidea by ROWE (40, p. 536). BRYDONE and GRIFFITH (9, p. 9) place this lower *cor-anguinum* chalk in the zone of *M. cor-testudinarium*, and it would serve to simplify our zonal records if this suggestion were adopted.

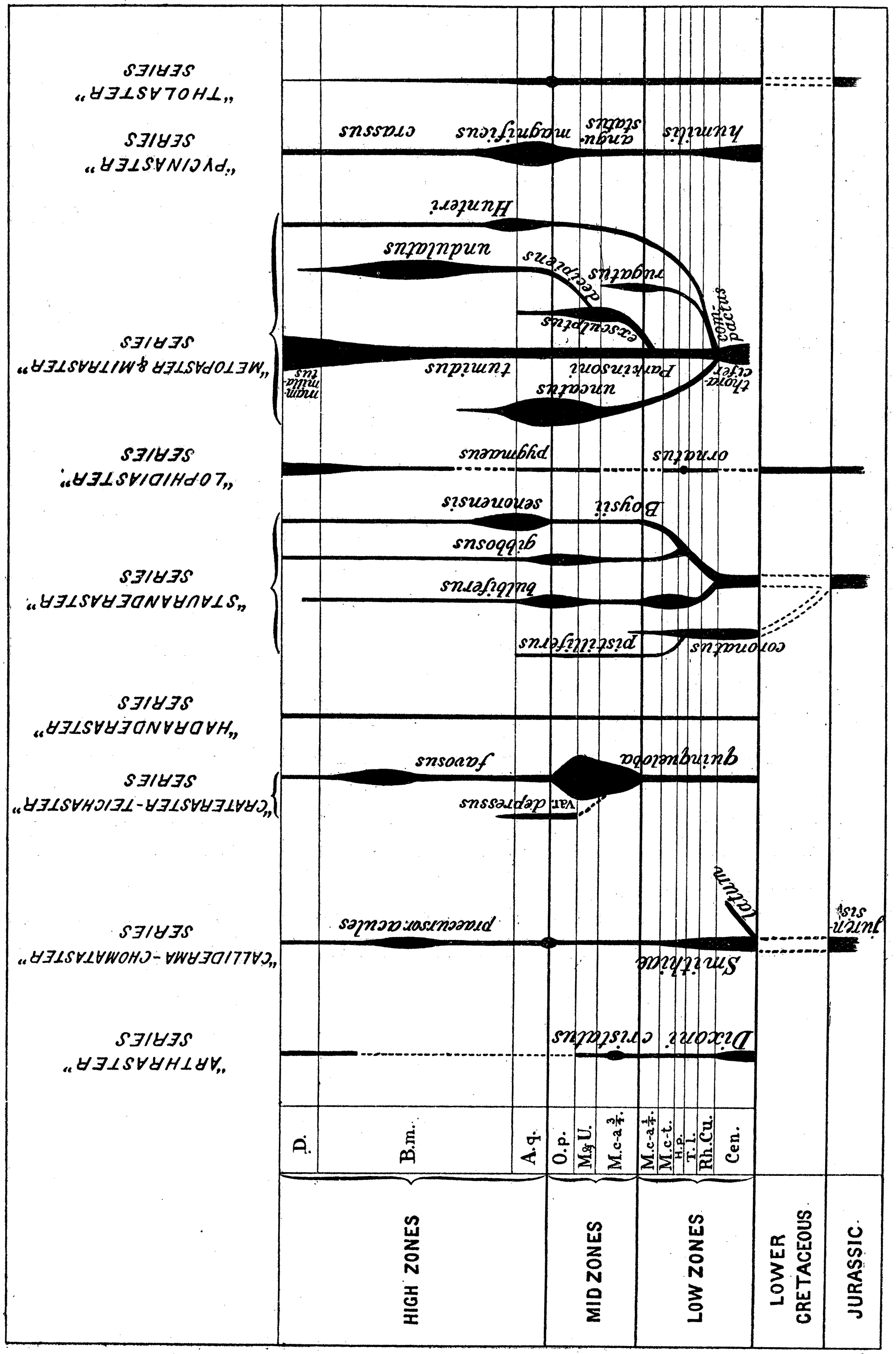
The classification adopted for the Chalk between the zones of Marsupites and *B. mucronata* requires some detailed explanation as it involves the sub-division of chalk, which until recently in England was always united in a single zone, into two distinct stages. This *quadratus* chalk has of late been carefully studied in the South of England by GRIFFITH and BRYDONE (9) and it has been established by their joint work, supplemented by the further work of BRYDONE* alone (8), that it is divisible in Hants, Sussex, and Wilts into two parts, the upper of which is herein called the sub-zone of *Actinocamax quadratus* and the lower the sub-zone of *Offaster pilula*.

JUKES-BROWNE (27) suggests that the new boundary line corresponds with a break in the old zone of *A. quadratus* of France and Germany and is not merely a zonal boundary but also the boundary between two stages which can be recognised in what has hitherto been regarded as a single ("Senonian") stage. These stages ("mid" and "high" zones) were clearly seen in a study of the Asteroids, and I had determined upon them before JUKES-BROWNE'S paper afforded a welcome confirmation of my own views.

In the paper it is assumed that the zones of *Offaster pilula* of France (both near Beauvais and in Yonne) and the *quadratus* zone of Yorkshire are roughly identical with the sub-zone of *O. pilula* of BRYDONE.

The classification which has been adopted for the sub-division of the zone of *Belemnitella mucronata* is explained in Section III of this paper.

* BRYDONE himself calls these two parts the restricted zone of *A. quadratus* and the zone of *O. pilula*.


"THOLASTER" SERIES
"PYCINASTER" SERIES
crassus
magnificus
angustatus
humilis
"METOPASTER & MITRASTER" SERIES
Hunteri
undulatus
decipiens
rugatus
exsculptus
compactus
tumidus
Parkinsoni
uncatus
thoraciferus
"LOPHIDIASTER" SERIES
pygmæus
ornatus
"STAURANDERASTER" SERIES
senonensis
Boysii
gibbosus
bulbiferus
pistilliferus
coronatus
"HADRANDERASTER" SERIES
"CRATERASTER-TEICHASTER" SERIES
favosus
quinqueloba
var. depressus
"CALLIDERMA-CHOMATASTER" SERIES
praecursor aculeus
latum
Smithiæ
"ARTHRASTER" SERIES
cristatus
Dixoni
D.
B.m.
A.q.
O.p.
M.g.U.
Cen.
HIGH ZONES
MID ZONES
LOW ZONES
LOWER CRETACEOUS
JURASSIC

TEXT-FIG. A.

Section II.—Description of "Species Series."

It is now possible to pass on to a detailed description of the various lineages.

A phylogenetic table is given opposite (text-fig. A). The dotted lines indicate that the lineage is probably existent, although its members have yet to be identified at those horizons.

The space between the horizontal lines suggests the thickness of the zones.

The thickness of the lines representing the lineages is intended to suggest the frequency of occurrence of the species in the main Chalk sea.

The table is designed merely to act as a general guide to the reader, for, in view of our ignorance of much of the Chalk, only an approximate rendering of the true facts can be given. A list of the genera described is given below.

Order—VALVATA *or* GRANULOSA, Perrier.

Family—PENTAGONASTERIDÆ, Perrier, 1884.

General Characters.—Body depressed. Arms often shortened so that the body is pentagonal in outline. Marginalia well developed, much larger than the adambulacralia, covered with granular or with scale-like, or, in certain cases, with isolated spines. Abactinal plates polygonal, rounded, or breast-plate shaped. If the latter isolated papulæ are present which protrude through the cut away angles of the plates.

The Cretaceous genera of Western Europe belonging to this family may be grouped as follows :—

(1) The "Metopaster" group, consisting of the genera Metopaster, Sladen, and Mitraster, Sladen.

(2) The genera Crateraster, nov. gen., and Teichaster, nov. gen.

(3) The genus Pycinaster, Sladen.

(4) The "Calliderma" group, consisting of the genera Calliderma, Gray ; Ophryaster, nov. gen. ; Chomataster, nov. gen. ; Comptonia, Gray ; and Trachyaster, nov. gen.

THE METOPASTER GROUP.

Genera—Metopaster, Sladen, and *Mitraster*, Sladen.

SLADEN and SPENCER (45), vol. 2, pp. 30 and 57.

Many of the species included in these genera have been already detailed in the above-mentioned monographs. They are amongst the most distinct of Chalk forms. The ornament on the marginalia shows considerable specialisation. There is a distinct but narrow border crowded with small hexagonal spine pits. The central area is always somewhat raised above this border. It may be smooth, rugose, or provided with circular, distinctly separated spine pits, the ornament affording a valuable guide as to the species (Plates 10 and 11).

Further specialisation is shown by the body form. Almost always this has a compact appearance due to the slight extension of the arms, and the fusion of the more distal supero-marginalia to form paired terminal plates characteristically "cheek shaped." In catagenetic varieties, however, the plates may be broken down into their primitive constituent ossicles and then the arms appear slightly produced (see Plate 14, fig. 3).

There is little distinction between the two genera. Mitraster is somewhat more compact than Metopaster, and its fused large terminal supero-marginalia are more equal to the other plates of the superior series.

A characteristic Metopaster is figured Plate 14, figs. 1 and 2.

For convenience in description the supero-marginalia other than the large terminal plates are called "median" supero-marginalia.

The species belonging to these two genera can be divided into four series indicative of distinct lines of descent.

(1) The *Metopaster Parkinsoni* series.
(2) The *Metopaster uncatus* series.
(3) The Mitraster series.
(4) The *Metopaster undulatus* series.

The general phylogeny of the series is figured p. 106, text-fig. A.

THE METOPASTER PARKINSONI SERIES.

This lineage is not only important in itself, but also probably formed the stock from which the other lineages of the "Metopaster" group descended. Ossicles of its constituent species are common at all horizons.

In general the species of the series fall into Low, Mid, and High-zonal groups.

The chief characteristics of the forms of the various groups are as follows :

Low-zonal forms. Terminal supero-marginalia flat and triangular, corresponding with the depressed body form. Surfaces of supero-marginalia often with prominent projections. Spine pits variable, either fine or coarse, but completely distributed over the whole of the central area.

Mid-zonal forms. Terminal supero-marginalia mitrate corresponding to a body form of medium height. Surface of supero-marginalia evenly swollen. Spine pits fine.

High-zonal forms. Terminal supero-marginalia when present often prominently tumid, corresponding to a high body form. Frequently the large terminalia are broken down into their constituent components. Surface of supero-marginalia often with prominent projections. Spine pits coarse, generally confined to a small portion of the plate. In the most advanced forms the spine pits are absent.

It will be noticed that the progress of evolution differs according to the character which is undergoing elaboration. There is, except for a comparatively short period (see p. 155), an increase throughout in body height (Plate 10, figs. 12–16). The variation in ornament follows a different course. Early forms have a variable ornament, there is then constancy for a prolonged period, followed again by marked variability.

Low-zonal Forms—

The series first becomes common in the Unter Pläner beds of Saxony. These beds correspond to the zones of *Schloenbachia varians* and *Holaster sub-globosus* of

the Cenomanian of England. Members of the series are very rare in England in beds lower than the Turonian. The ossicles when they first appear are universally low, but exhibit marked variability with respect to the form of their surface and its ornament. They may all be placed in the species *Metopaster thoracifer*, Geinitz.

Metopaster thoracifer, Geinitz.

Specific Characters.—Body depressed. Terminal supero-marginalia pointed, usually possessing one, two, or more horn-like protuberances. Median supero-marginalia usually with evenly swollen surface. Ornament varies from fine to coarse. Probably only two median supero-marginalia are present along each side of the disc.

GEINITZ (21, S. 89, Taf. 22, figs. 1–14) has described ossicles of this type under the name of *Oreaster thoracifer*, whilst a fairly complete specimen of the species was figured by SLADEN (45, p. 55, Plate 14, fig. 5), as *Metopaster cornutus*. The ossicle figured by GEINITZ (figs. 11*a* and *b*) is selected as the holotype.

I have been able to examine a collection from the Unter Pläner of Munich, as also large collections from Branscombe, Devon, where the species occurs in abundance.

Description.—Unfortunately, the specimen figured by SLADEN has been lost sight of, and it is impossible in consequence to determine with certainty the exact horizon from which it came. In my opinion, however, there is no doubt that it was found at the base of the Turonian. It is important, as it is the only well-preserved specimen, and shows only two median supero-marginalia along each side of the disc. This is the smallest number observed in any species of the genus Metopaster.

All the terminal supero-marginalia which I have examined are low, triangular, and are composed of three fused plates, as judged by the number of facets for the articulation of the infero-marginalia. The proximal facet is much larger than the remainder. We shall see that all these characters are also common to the earliest members of the *uncatus* series and Mitraster series. It therefore appears, since those forms are not differentiated until a later period, that the species *thoracifer* is a root stock for three of the main lineages of the genus.

There are nearly always horns on the terminal supero-marginalia. These vary greatly in number. In the Unter Pläner they are usually (Plate 10, fig. 1) in the form of irregular projections, whilst the Branscombe ossicles (Plate 10, fig. 2) have almost always one or two definite horns.

A few of the terminal supero-marginalia (Plate 10, fig. 3) from both localities are without protuberances of any kind. These must be regarded as merely fluctuations in the species. There is every transition from incipient swellings to prominent projections in the various ossicles discovered.

The median supero-marginalia from the Unter Pläner beds only occasionally present horn-like prominences (Plate 10, fig. 10). Sometimes their surface is evenly swollen, at other times again they possess an "uncatus" (*vide infra* p. 116)

profile. The infero-marginalia never possess protuberances. The spine pits on both sets of marginalia vary from fine to coarse.

The median supero-marginalia from Branscombe are evenly swollen and possess only fine spine pits. They represent a stage with respect to these characters intermediate between the variable Unter Pläner phase and the more constant phase found from the zone of *Terebratulina lata* to the zone of *B. mucronata.* In this latter zone we shall again find marked variability with respect to surface and ornament. That the transition, in the low zones, from the variable to the constant phase was not abrupt is shown by the occurrence of some very few ossicles also with horns on the terminal supero-marginalia in the zone of *T. lata* and by the coarseness about some of the spine pits found on members of the lineage in the zones of *Holaster planus* of Hampshire and Lincolnshire.

The evenly swollen ossicles found from the zone of *T. lata* upwards belong to the species *M. Parkinsoni,* Forbes. They remain low through the low zones. A fragmentary specimen in the possession of Mr. DIBLEY from the zone of *T. lata* of Wouldham shows that there were forms with at least four median supero-marginalia at this horizon (see also p. 153).

The terminal supero-marginalia found in the zone of *Micraster cor-testudinarium* at Seaford are abbreviate and strongly resemble the corresponding ossicles in the Mitraster series. It was probably from a somewhat similar form at present unknown but occurring at an earlier time (see p. 117) that the Mitrasters descended.

These Seaford ossicles are so constant in character that I feel it necessary to place them in a special variety, var. *abbreviatus* (Plate 10, figs. 4, 11).

Mid-zonal Forms—

The mid-zonal forms afford every stage in the natural transition from low-zonal to high-zonal forms. The ossicles of the species increase gradually both in size and height, but the ornament and surface shape remains constant in character. They all belong to the species *M. Parkinsoni,* Forbes.

If we take first the evolution of the main stock we find that many good examples of the species are found in the collection of the British Museum. Several of these are figured in the 'Mon. Brit. Cret. Aster.,' SLADEN and SPENCER (45). All of the figured specimens are from the chalk of Bromley, Kent, now shown to be of upper *cor-anguinum* age. Typical examples are figured Plate 11, figs. 1A, 2A; Plate 12, fig. 1A, of the monograph.

The terminal supero-marginalia are long and mitrate. Usually they are composed of at least five fused plates. The spine pits on the central areas of the plates are evenly distributed, and the outer surfaces of the supero-marginalia are evenly swollen.

Ossicles from the zone of *M. cor-anguinum* are figured Plate 10, figs. 5, 13.

Very large ossicles are found in the highest parts of the mid-zones (and at the base of the high zones). These ossicles are figured Plate 10, figs. 6, 14.

In the mid-zones a species diverges from the main stock, viz. :—

Metopaster exsculptus, n. sp.

Specific Characters.—Terminal supero-marginalia rounded. Ornament on central areas of both series of marginalia cut away at the edges.

Material.—The specimen figured as *M. Parkinsoni*, Plate 10, fig. 5A, of the 'Mon. Brit. Cret. Echin.' (45) is taken as the holotype.

Ossicles of the species are found so commonly in the zone of *M. cor-anguinum* of the South of England and so rarely outside the limits of this zone that they afford a valuable zonal guide in this area.

Description.—The terminal supero-marginalia (Plate 10, fig. 7) are short, rounded (not pointed as in *M. Parkinsoni*), and swollen at the junction of the abactinal and lateral faces. The central areas of the infero-marginalia are always cut away (Plate 10, fig. 17), sometimes to such an extent that the whole surface of the plate is occupied by the minute hexagonal spine pits which are on other forms confined to the margin. Occasionally (Plate 10, fig. 7), the central areas of the supero-marginalia are cut away in the same manner although never to the same extent as are those of the infero-marginalia. The species appears to remain as a prominent feature of the Asteroid fauna of the Marsupite and *quadratus* zones of Yorkshire.

High Zones.—

(1) *The Period of Regression.*—It has been seen that the top beds of the mid-zones contained large high forms of *M. Parkinsoni*. In the lower beds of the high zones there is a remarkable regression both in the size and shape of ossicles of this species. This regression appears not to have been a local phenomenon confined to the South of England but to have been widely spread. In France ("low" *mucronata* of Villers St. Lucien) the regression is so marked that one terminal supero-marginal was obtained which not only was low and triangular as are the low-zonal forms but was also horned as is *M. thoracifer*. The regression appears to have continued so far as the middle sub-zone of *B. mucronata*, after which advance again took place which resulted in the formation of the two further species *M. tumidus* and *M. mammillatus*.

(2) *The Period of Further Elaboration.*—In the zone of *Belemnitella mucronata* and in the Danian two new species appear which show greater elaboration than any of the species already described. These new species are—

Metopaster tumidus, characteristic of the zone of *B. mucronata*. In this species the marginalia show increase in height, the ornament coarsens and tends to disappear, and prominent tumidities appear on the supero-marginalia.

Metopaster mammillatus, characteristic of the Danian: The ornament is very coarse or absent and the plates are usually high and much swollen.

A feature in both species is the breaking down in the majority of the individuals of the terminal supero-marginalia. Forms in which this occurs lose their compact pentagonal outline and become "radiate" in appearance (Plate 14, fig. 3).

Metopaster tumidus, n. sp.

Specific Characters.—Body of medium height to high. Median supero-marginalia usually with a prominent tumidity or ridge. If large terminal supero-marginalia be present they possess a prominent abactinal swelling. Ornament, when present, frequently coarse.

The ossicle figured (Plate 15, fig. 1) is selected as the holotype of the species.

This form is one of the most widely distributed of all the Chalk Asteroids. It was found to be present in collections from the "mucronata" chalk of South and East England, France, Belgium, Denmark, Sweden, and North Germany.

Description.—There are two distinct facies of the species. The first, which we may designate as *M. tumidus* "proper," has large terminal supero-marginalia at the extremity of its arms. The second, which is called *M. tumidus,* var. *radiatus,* has extended arms ending in small plates.

The only set of associated ossicles of *M. tumidus* "proper" occurs as a portion of two rays in the possession of Prof. JAEKEL of Greifswald. Unfortunately these are not sufficiently well preserved to figure. Two views have therefore been reconstructed from the Rügen material (Plate 14, figs. 1 and 2).

The terminal supero-marginalia (Plate 10, fig. 8; Plate 14, figs. 1, 2; Plate 15, fig. 1), although variable as to length of ossicle and height of tumidity, present a very characteristic appearance and are especially easy to pick out when collections of ossicles are sorted.

The more median Supero-marginalia present interesting variations which are important as they serve to distinguish sub-zones or localities.

Those used in the construction are high and bear usually a tumidity which resembles a nipple. This type of ossicle is well represented in collections from Möen and Aalborg. Only a small proportion of the ossicles found at Rügen and none of those found at Trimingham are of this type, which is probably characteristic of the beds at the very top of the zone. The ornament is coarse, the spine pits being especially large on the nipple.

Var. *radiatus.*—The great majority of the supero-marginalia found in the collections from Rügen and Trimingham apparently belong to forms of *Metopaster tumidus* in which the terminal supero-marginalia are broken down into small ossicles. The extremity of the arm is thus straightened and the arm appears longer. A "radiate" appearance is thus given to the specimen (Plate 14, fig. 3).

Further, whereas the great majority of the supero-marginalia of *M. tumidus*

"proper" are apparently regularly uniform in height on the same specimen, the ossicles of these regressed forms gradually taper to the extremity and thus bring about an asymmetry in the articulating facets for neighbouring plates, an important distinctive character.

The Trimingham and Danish material suggests that the ossicles are frequently devoid of ornament on the central area. The great majority of the Rügen ossicles are punctate, although a few smooth forms may be met with.

The ossicles of the species from the Maestrichtian of Belgium differ somewhat from those already described. The median supero-marginalia are often as long as the largest ossicles from Germany and Denmark but they are never so high. Their abactinal surface is frequently swollen but the tumidity never assumes a teat-like shape.

Further the terminal supero-marginalia never appear to be broken down and in consequence there is no radiate variety in these beds.

We shall see later (pp. 154, 155) that the Rügen material contains median supero-marginalia of all heights from low to high. This variation in height is not conspicuously reflected in the terminal supero-marginalia from the same locality, for owing to the subordination of the true species to the radiate variety such ossicles are comparatively rare. The ossicles from Maestricht include numerous terminal supero-marginalia, and these show clearly variations in height corresponding to those of the median series. Low triangular terminals recalling the low-zonal forms are commingled with "mitrate" mid-zonal and typical "tumid" high-zonal forms. Usually, those terminal supero-marginalia which are small are low and triangular, those of medium size mitrate, and those large are tumid. These variations may to some extent correspond to the age at which individual Asteroids perished and be explained by recapitulation in descent.

Metopaster mammillatus, Gabb.

GABB (20, pp. 178, 179, fig. 2, 2*a*, 2*b*); CLARK (13, p. 32); SLADEN and SPENCER* (45, p. 110).

Specific Characters.—Body high. Supero-marginalia pronouncedly asymmetric, generally with a prominent tumidity which stretches well over the level of the abactinal surface of the disc and occupies the whole of the upper surface of the ossicle. Ornament coarse, that of the supero-marginalia often confined to the tumid portion of the plate.

* I wrongly ascribed this species to Pycinaster. The figures of GABB are quite clear as to details of ornament and show the undoubted relationship of the American species to the species from the Danian of Sweden and Denmark. The previous determination was based upon profile views. The resemblance of the profile views of the supero-marginalia of Pycinaster and Metopaster at this horizon is commented on (p. 123).

This species characterises the Danian beds of Denmark, Sweden, and North America. The tumidity on the supero-marginalia reaches its maximum development and enables the form to be readily recognised. The specimens figured are typical of the species.

Description.—The only associated ossicles which have come into my possession are those figured Plate 15, fig. 8. They come from the chalk of Saltholm, Denmark. A portion of one ray is fairly well preserved. It shows four supero- and four infero-marginalia in their original positions. The broad tumidity which characterises the species is clearly seen in side view, Plate 15, fig. 9.

The ornament on the plates figured is not so coarse as is usual in the species. The supero-marginalia are asymmetric, inasmuch as the articulatory face for the neighbouring supero-marginalia is pronouncedly smaller on one side than on the other.

The very many isolated median supero-marginalia which have been examined from both the Swedish and the Danish beds do not differ materially from the ossicles already described.

The paired terminal supero-marginalia differ widely in appearance according to the locality in which they are found. Specimens from Kagetrup (Denmark) closely resemble the corresponding plates of *M. tumidus.*

Other specimens from the same locality and also from Stevns Klint (Denmark) have the tumidity at the distal extremity of the plate (Plate 15, fig. 11). The terminal supero-marginalia from Annetorp (Sweden) and Rejstrup (Denmark) differ again, as they are high and narrow with a prominent abactinal tumidity (Plate 10, fig. 9).

It is probable that the great majority of the individuals had extended arms due to the breaking down of the large terminal supero-marginalia as has already been described in the case of the radiate variety of *M. tumidus.* In fact no large terminal supero-marginalia are found in the higher beds of the Danian (see p. 148).

THE METOPASTER UNCATUS SERIES.

We have seen that the study of the evolution of the *M. Parkinsoni* series shows lines of development which lead to—

(1) The loss of spine pits.
(2) An increase in height of the marginalia.
(3) Various changes in the shape of the surface of the supero-marginalia.
(4) A breaking down of the component plates which, when fused, constitute the characteristic paired ultimate supero-marginalia.

The *uncatus* series lose their spine pits almost as soon as they break off from the *Parkinsoni* stem, namely, in early low-zonal times. They acquire a hump on the exterior margin of the supero-marginalia and the forms remain low. In consequence

the profile view (Plate 11, figs. 9, 10) of the marginalia is very characteristic. The early breaking down of the terminal supero-marginalia which takes place as early as Marsupite times appears to prophesy a shorter life-history of the lineage as compared with that of the *Parkinsoni* series, and, in fact, the lineage itself disappears in the "middle *mucronata*."

Various forms of the lineage have been described by SLADEN and SPENCER (45).

Detailed Zonal History.—The members of the lineage can first be distinguished from those of the *Parkinsoni* series in the zone of *Terebratulina lata*. These early forms retain a few spine pits, the abactinal tumidity on the exterior margin of the supero-marginalia is low (Plate 11, fig. 9), and the terminal supero-marginalia are triangular.

The chief modifications which take place in the mid-zones are due to advances along the lines already suggested. As in the *Parkinsoni* series, additional components usually become added to the terminal supero-marginal, which in that case becomes, owing to the increase in its length, "plough-share" shaped (Plate 11, fig. 8). There is also a development of rugosities on the interior margin of the supero-marginalia. This development reaches its maximum in the early high zones.

It is uncertain whether the variations present in the upper *cor-anguinum* beds and upwards are merely expressions of a single phase of variability of the lineage, or whether there are several branching stocks. The supply of associated ossicles or complete specimens is insufficient to determine this.

For purposes of description it is convenient to divide the forms into two species and a variety, but it must be understood that there is no certain basis for this.

In *M. uncatus*, Forbes, may be placed all forms which have oblong supero-marginalia (Plate 11, fig. 5).

In *M. quadratus*, Spencer, may be placed all forms which have square supero-marginalia (Plate 11, fig. 6).

Both types of supero-marginalia exist, as a rule, contemporaneously in the same locality, and both may acquire rugosities. It is worth noticing that the rugose supero-marginalia of *M. uncatus* offer some considerable general resemblance to those of *Mitraster rugatus* (*Cp.* figs. 3 and 5, Plate 11).

These rugose *M. uncatus* ossicles may, however, be nearly always distinguished from those of *Mitraster rugatus* by their larger size (length $>$ 4 mm.). *Mitraster rugatus* cannot be traced into the zone of *A. quadratus* where the first-named ossicles are found.

There is a small variety of *M. quadratus* which is of great interest. Its supero-marginalia range from 3–5 mm. in length as opposed to a usual length of 6–7 mm. in the case of *M. quadratus* "proper." It first attracted my attention when investigating a very large collection (several hundreds of ossicles) from a pit near the top of the sub-zone of *A. quadratus* in Hampshire. There all the ossicles of the *uncatus* series, which were found, were of this small variety. It appears to be very

common both in the sub-zone of *O. pilula* and the sub-zone of *A. quadratus* of Sussex, in the neighbourhood of Newhaven. In other pits of corresponding horizons in the same counties it is apparently absent.

Although the variety, which I propose to call *parvus*, only differs in size from the species "proper," its curious occurrence suggests that it is a distinct offshoot, very probably a mutation of DE VRIES. Comparisons are suggested with the var. *depressus* of *Crateraster quinqueloba* (p. 121).

THE MITRASTER SERIES.

There are three species in this series, namely, *M. Hunteri*, Forbes, *M. compactus*, Forbes, and *M. rugatus*, Forbes. Forms belonging to these species have been fully described (SLADEN and SPENCER, 45, pp. 59–68). The genus must have branched off from Metopaster in early times. The forms show ancestral relationships with the "low-zonal" forms of *Metopaster Parkinsoni* in (*a*) the limited number of median supero-marginalia (never more than two on each side of disc), (*b*) their flat terminal supero-marginalia, and (*c*) the large size of the first proximal infero-marginalia which articulate with each of the large terminal supero-marginalia (see p. 111).

The series on the whole develops along parallel lines to the *uncatus* series. The marginalia remain low, and the supero-marginalia usually possess the characteristic *uncatus* profile (Plate 11, fig. 1).

It is probable that there are two species series in the genus—

(1) The *M. Hunteri* series.

(2) The *M. compactus* and *M. rugatus* series.

(1) *M. Hunteri* is first known from the zone of *Holaster planus*. The ossicles are broad, there is an *uncatus* profile, but as yet rugosities are not strongly developed. Both narrow and broad ossicles are found in the zone of *Micraster cor-anguinum*, and from here to the top of the sub-zone of *Actinocamax quadratus* strongly marked rugosities are characteristically developed (Plate 10, fig. 23). In the lower beds of the zone of *Belemnitella mucronata*, where the species is found in fair abundance (Plate 10, figs. 21, 22), the ossicles return to the *H. planus* form described above. Up to this time punctations have always been present. The ossicles from the "upper *mucronata*," however, show a tendency to become smooth. These latest known ossicles are narrow (Plate 11, fig. 2).

(2) Those of the second series always remain narrow. It is possible that they are descended from a form of *Metopaster Parkinsoni* such as that met with in the zone of *Micraster cor-testudinarium* of Seaford (p. 111). *Mitraster compactus* is found in the zone of *Holaster planus*, and possesses neither spine pits nor rugosities. *M. rugatus* (Plate 11, fig. 3) is closely similar in form to *M. compactus*, but shows its greater elaboration by the possession of rugosities. It is characteristic of the zone of *M. cor-anguinum*. The series has not been traced into the "high" zones.

METOPASTER UNDULATUS SERIES.

This series is distinguished from the *Metopaster Parkinsoni* series by the varying diameter of the spine pits on the central area, by the confluence of the central area and the margin, and by the obtusely rounded terminal supero-marginalia.

The series appears to arise from a "quadratus" form, *Metopaster decipiens*. A feature of note in the series is the reduction in the number of median supero-marginalia in the newer forms.

1. *Metopaster decipiens*, n. sp.

Specific Characters.—Forms small and depressed, central area of both supero- and infero-marginalia much reduced and confluent with the area of the rabbet edge. Terminal supero-marginalia either triangular or obtusely rounded.

Material.—Fragmentary specimens of this species are represented in the collection of Dr. BLACKMORE and M. JANET. Isolated ossicles are present in the collection of Mr. BRYDONE. The specimen figured (Plate 10, fig. 18) is taken as the holotype of the species.

Description.—The figure given shows the general character of a view of the abactinal surface. It will be noticed that the central area of the supero-marginalia is much reduced. Often it is entirely absent from the infero-marginalia. The confluence of the edge of the central area and the rabbet edge is characteristic, and serves not only to distinguish the form from *Metopaster exsculptus*, but also to show the affinity with *M. undulatus*.

The terminal supero-marginalia are triangular in the type specimen, which is from the zone of *A. quadratus*. In the specimen in the possession of M. JANET, which is from a somewhat higher horizon (zone of *B. mucronata* of Villers St. Lucien, near Beauvais) they are, however, squat and obtusely rounded. This latter specimen shows six interradial supero-marginalia.

2. *Metopaster undulatus*, n. sp.

Specific Characters.—Surface of supero-marginalia uneven and wavy. Spine pits on supero-marginalia usually large, but varying considerably in diameter on different portions of the same plate. Terminal supero-marginalia squat and obtusely rounded. Spine pits on infero-marginalia small, distributed fairly regularly on the exterior portion of the plate, but more crowded towards the exterior margin. Deeply entrenched oblong pedicellaria commonly present on both series.

Material.—The species is abundant in the chalk of Trimingham and in that of the Island of Rügen. The ossicle figured (Plate 15, fig. 20) is taken as the holotype of the species.

Description.—Careful sorting of the collections from Rügen and those from Trimingham resulted in the discovery that the terminal supero-marginalia and the

median supero-marginalia were present in equal numbers. I have, therefore, reconstructed the abactinal margin of the form (Plate 10, fig. 19) with but four plates on each side of the disc. If this view be correct the reconstruction serves to give an idea of the general appearance of the form as usually developed at this horizon.

The ornament of the supero-marginalia is very characteristic. The spine pits usually vary very considerably in size and spacing (Plate 15, fig. 20), although on a small proportion of the plates there is a tolerable uniformity in both these characters. The largest spine pits are about the same size as those found commonly on *M. tumidus* from the Skrivekridt. The surface of the plate is usually undulate. The surface of the infero-marginalia is flat. The spine pits are somewhat smaller in size than those on the superior series and are more regular in form (Plate 15, fig. 23). Their disposition is stated above. This disposition reminds one very strongly of that in *Mitraster Hunteri.*

All the ossicles of the species found in the middle beds of the zone of *B. mucronata* are rugose. Similar ossicles are found in the lower beds of the upper *mucronata.* A terminal supero-marginal of this rugose variety is figured (Plate 10, fig. 20). A well-preserved specimen of this variety from Trimingham is in the possession of Mr. BRYDONE. It shows four median supero-marginalia on each side of the disc. The form probably represents a step in the reduction from the six supero-marginalia of *M. decipiens* to the two supero-marginalia of the upper *mucronata* form of this species.

ANOMALOUS FORMS OF THE "METOPASTER" GROUP.

The various shallow water deposits which fringed the main Chalk seas show a zonal distribution of fauna differing somewhat from that already described.

The Marsupites Zone of Vendôme (*France*).—FILLIOZAT (17) has recently collected considerable material from certain neritic deposits found in Vendôme which contain plates of Marsupites. He has kindly sent me his collection of ossicles from these beds. It is noteworthy that the high-zonal form *M. tumidus* is represented as a definite variety which offers some points of resemblance to the Maestrichtian form. Both the median and the terminal supero-marginalia almost exactly resemble the Belgian ossicles already described (p. 114). The main point of difference is that the central area of the French ossicles is quite devoid of spine pits.

The Actinocamax mammillatus and Belemnitella mucronata Beds of N.E. Scania.—These beds contain a form of *Metopaster Parkinsoni* which offers many points of resemblance to the low-zonal forms already described.

Metopaster Parkinsoni, var. *calcar.*

Description.—This variety is especially interesting as it shows strong affinities with *Metopaster thoracifer*, which we have seen is characteristic of the Unter-Pläner (Cenomanian) of Saxony and the Turonian of Branscombe, Devon.

We saw that the terminal supero-marginalia of *M. thoracifer* were exceedingly variable. One, two, or three horns might be present or the surface in certain cases might possess a number of irregular rugosities. This variety also shows considerable range in variability, but the majority of the terminal plates possess only two horns (Plate 15, figs. 12–15). These horns are very prominent and give an unmistakable character to the ossicles. They may be as much as 8 mm. high. Often the ornament on the plate is almost confined to the horn (Plate 15, fig. 16).

The remaining ossicles even more closely resemble those of *M. thoracifer* from the Unter Pläner. The ornament may be coarse or fine, and the supero-marginalia when low, as is frequently the case, may possess the "uncatus" profile. Some of the ossicles are moderately high, thus showing some advance since low-zonal times.

The occurrence of this primitive form in this isolated sea offers much opportunity for speculation (see also p. 159).

Non-punctate Forms from N.E. Scania.

We have seen that in the main Chalk sea there arose three groups of non-punctate forms from the *M. Parkinsoni* series. A fourth series of forms occurs in the enclosed sea of N.E. Scania.

Metopaster crista-galli, n. sp.

Specific Characters.—Paired ultimate supero-marginalia long, low and triangular, with a distinct ridge on which are projections which simulate the appearance of a cock's comb.

Material.—Ossicles with these characters have only been obtained from one locality, namely, Karlshamn in the extreme north of the area. The ossicles figured (Plate 15, fig. 18) are taken as the syntypes of the species. They are preserved in the collection of the Geologiska Institut, Lund.

Description.—The specific characters given adequately describe the type ossicles. There are, however, a few terminal supero-marginalia, both from Karlshamn and the adjacent locality of Barnakalla, which are similar in shape, but are devoid of the cockscomb-like ridge.

I have not been able to recognise any median marginalia in the small collection from the locality which I could associate with these terminal plates.

CRATERASTER—TEICHASTER SERIES.

Genus—CRATERASTER, novum. (κρατήρ = a crater).

This genus is founded to include the species formerly called *Pentagonaster quinqueloba*, Goldfuss, and *P. obtusus*, Forbes. The ornament of these species is very different from that of the recent genus Pentagonaster. It much more approaches that of the recent genus Anthenea.

Generic Characters.—Lateral faces of the marginalia with crater-like pits. Abactinal faces of marginalia usually with rugosities.

It is difficult to assign other characters definitely to the genus as the forms vary to a considerable extent from zone to zone. *C. quinqueloba* has usually a compact appearance. If the arms are produced they taper gradually and the ornament is not reduced. *C. obtusus* has produced obtuse arms and the ornament is usually reduced. *C. quinqueloba* is taken as the type species of the new genus.

The evolution of the series composed of *Crateraster quinqueloba* and its direct descendant *Teichaster favosus* is one of the most interesting and instructive of all Starfish series. It will be seen that there is a stage of elaboration, both of height and ornament, followed by regression. The "species series" then again undergoes elaboration which is of a type distinctly different from that in the earlier stage.

The Evolution of Crateraster quinqueloba, Goldfuss.

The characters which show change as the species is traced upwards are :—

(1) The height and slope of the marginalia.

(2) The character of the ornament on their lateral surfaces.

(3) The character of the ornament on the abactinal surface of the supero-marginalia, and that on the actinal surface of the infero-marginalia.

The species has not been found lower than the zone of *H. sub-globosus.* A well-preserved specimen from this zone is in the United Collieries Museum, Dover. The marginalia are low and their lateral margins are well rounded. Both the supero- and infero-marginalia have equal-sized adjoint hexagonal spine pits on their abactinal and actinal faces respectively. The crater-like pits on the lateral faces of the marginalia carry spines.

Closely similar forms appear in the zone of *Rh. Cuvieri.* Ossicles from this zone are figured Plate 12, figs. 1–4. It will be seen, however, that here rugosities are being developed between the abactinal spine pits. In the immediately succeeding zones rugosities completely crowd out the spine pits both on this face and on the lateral faces. The rugosities on the lateral faces are at first only feebly developed (Plate 12, fig. 5).

These changes are accompanied by changes in height and slope, which culminate in the zone of Marsupites. Here the ossicles are high and steep sided (Plate 12, figs. 6–10). The rugosities on the lateral faces are strongly developed. Often they are arranged so as to simulate the circular spine pits of the earlier forms. In the most elaborated forms small rugosities (Plate 12, fig. 9) are developed between the spine pits on the infero-marginalia. Regression now takes place and the changes described above occur in reverse order. Ossicles from the zone of *B. mucronata* which show this are figured Plate 12, figs. 12, 13.

A well-marked depressed variety, var. *depressus*, occurs in the zone of *A. quadratus.*

It has the steep sloped marginalia (Plate 12, fig. 11) and the ornament of the elaborated form. Forms with produced arms also occur in the sub-zone of *A. quadratus*.

C. obtusus appears to be a somewhat rare low-zonal and low mid-zonal offshoot.

Genus—TEICHASTER, novum. (τεῖχος = a wall).

Generic Characters.—Body high, steep-sided. Marginalia usually with straight parallel sides, rarely distinctly wedge or pear-shaped. Ornament upon the abactinal and actinal faces consists of hexagonal, closely-touching, shallow spine pits. Spine pits on the lateral faces slightly circular. Pedicellaria valvate, oblong.

The forms belonging to this genus are in direct succession to those of Crateraster. We have seen that *C. quinqueloba* passed through a phase of elaboration and then regressed, so that in the lower beds of the zone of *B. mucronata* it had lost almost the whole of its rugosities, and had re-acquired the spine pits which were characteristic of its earlier stages. The form, which was rapidly becoming rare, now took on a period of renewed and intense activity, during which its marginalia again became stout and high. The new forms (which can all be placed in one species, *T. favosus*, n. sp.) are some of the most abundant in the upper *mucronata* and Danian beds, and are only surpassed in dominance by members of the *Metopaster Parkinsoni* series. Teichaster, unlike Crateraster, has a predominantly punctate ornament in all its stages. It is this absence of the development of rugosities which distinguished the two genera.

Teichaster favosus, n. sp.

Types.—The specimen figured (Plate 12, fig. 14) is taken as the holotype of the species. It is in the collection of the British Museum (Nat. Hist.), and was discovered by Mr. FABER in the *mucronata* chalk of Studland, Dorset. The ossicles figured (Plate 16, figs. 14–16; Coll. Brit. Mus.) are regarded as paratypes. They are from the *mucronata* chalk of the Island of Rügen.

Description.—The type specimen was discovered in a fragmentary condition, but has now been carefully reconstructed. In general appearance it is almost identical with *C. quinqueloba*.

The median supero-marginalia are a little more than 3 mm. long and are not quite 4 mm. in height. In the higher portions of the Studland beds, ossicles are found 7 mm. in height, whilst at Trimingham and Rügen the supero-marginalia are as much as 10·5 mm. high. This progression in height is figured on Plate 12, figs. 15–17. The characteristic ornament is shown (Plate 12, fig. 18; Plate 15, figs. 15, 16).

Var. *retiformis.*—In the "newer Bryozoa-chalk" of the Danian of Denmark, the normal facies of the species is replaced by a new variety. The ornament is more finely reticulate, and the abactinal face of the supero-marginalia is distinctly raised. Often the ossicle is distinctly wedge- or even pear-shaped (Plate 12, fig. 19). This change in form brings about a superficial resemblance to the supero-marginalia

of *Metopaster mammillatus* and *Pycinaster crassus*, both of which occur in the same beds (*Cp.* Plate 12, fig. 19; Plate 10, fig. 16; Plate 11, fig. 15).

Supero-marginalia with a similar character are found in the Danian beds of Annetorp, Sweden. Here the infero-marginalia are extremely thick (Plate 12, fig. 17) and unmistakably distinct from all other Asteroid ossicles in the Chalk. The ornament has largely disappeared from the lateral faces.

The infero-marginalia of the "newer Bryozoa-chalk" of Denmark are more similar to the *mucronata* forms than are those from Annetorp.

In the "older Bryozoa-chalk" of Denmark there are transition forms between the true species and the variety.

THE PYCINASTER SERIES.

Genus—PYCINASTER, Spencer, 1907.

SLADEN and SPENCER (45, pp. 21 and 95).

The smooth (occasionally slightly ornamented) marginalia of the forms belonging to this genus are readily recognised. Their height, irregular internal outline, as seen in profile, and the frequent presence of the unique pedicellaria, distinguish them from plates of all other species.

The large mass of material which I have had opportunity to examine since the completion of the monograph named above has enabled me to trace out in detail the evolution in the genus. Some errors were made previously, but these are now corrected.

There are four species:—

Pycinaster humilis, n. sp.—Low and of small size, occurring in the "Low" zones.

Pycinaster angustatus, Forbes.—Of medium size, occurring in the zones of *M. cor-anguinum* to Marsupites inclusive.

Pycinaster magnificus, n. sp.—High and of large size, occurring in the zones of *A. quadratus* and in the Lower and Middle beds of the zone of *B. mucronata*.

Pycinaster crassus, Spencer.—High and of large size, with thick marginalia, occurring in the Upper beds of *B. mucronata* and the Danian.

It will be seen that the main distinction between the species is that of size and height. The ossicles become larger and higher as the species advances in age. They also develop a prominent abactinal tumidity. It is only the greater convenience in practice of a short specific name, as compared with a long varietal name, that has made me found species for the various zonal facies of the form.

The collector may, without difficulty, learn to assign isolated ossicles of this genus to their original positions. The supero-marginalia may be always distinguished from the infero-marginalia by their shape (see Plate 11, figs. 11–17) and by the prominent attachment for the internal muscles. The median supero-marginalia have a flat or

depressed lateral face and are distinctly wedge-shaped. The more distal supero-marginalia are tumid on their lateral face and not, as a rule, distinctly wedge-shaped. The median infero-marginalia are oblong in lateral view, owing to their parallel sides and their greater height as compared with their length. These proportional dimensions alter as the distal region of the arm is approached, so that the plates there appear square.

The pedicellaria are, when present, usually on the half of the plate nearest to the articulatory surfaces of the marginal series with each other. This affords a further distinction between the plates of the two series.

1. *Pycinaster humilis*, n. sp.

Specific Characters.—Marginalia small and low. Supero-marginalia of arm almost square, with well marked hexagonal spine pits. Infero-marginalia rounded externally when viewed in profile.

Material.—The ossicles figured (Plate 11, fig. 11) are regarded as paratypes of the species. There is a fragmentary specimen also in the collection of Dr. ROWE, which is taken as the holotype. This is from the Chalk Marl (zone of *Sch. varians*) of Dover.

Description.—The paratype shows a fairly complete view of the infero-marginalia of one interbrachial arc and of the base of one arm. Scattered ossicles of both marginal series belonging to two other interbrachial arcs and corresponding arms may also be seen.

The median supero-marginalia are represented by five ossicles. They are wedge-shaped and almost flat both laterally and abactinally. The supero-marginalia which border the arms are square and have a prominent tumidity which reaches its maximum height abactinally. This tumidity is not symmetrically developed about the median line but is so constructed as to produce a curious skew effect. It is these plates which are so characteristic of the species and therefore useful for zoning in the field.

A portion of a specimen of this species is preserved in the Norwich Museum. It was obtained from Swaffham (Norfolk) and is probably from the zone of *H. planus*. It is interesting as it possesses prominent mammillations on the arms just as does the high-zonal *P. crassus*.

2. *Pycinaster angustatus*, Forbes.

This species has already been fully described, SLADEN and SPENCER (45, pp. 21–24, Plate 9, figs. 1A, 1B).

Typical marginalia of the species are figured here (Plate 11, figs. 12 and 13). It is to be noted that the ossicles figured in SLADEN and SPENCER (Plate 26, figs. 1A, 1B) as *Pentaceros punctatus*, and later, p. 95, described as belonging to *Pycinaster senonensis*, are really a variety of this species common in the upper beds of the zone of *M. cor-anguinum*.

3. *Pycinaster magnificus*, n. sp.

The marginalia of this form were described in SLADEN and SPENCER (45, pp. 95–96), as belonging to a species *Pycinaster senonensis*, Valette. Large smooth round ossicles found in the same beds were assumed to be associated with these marginalia and one of these round ossicles in the possession of Dom VALETTE was taken as the type of the species. Mr. BRYDONE has recently taken considerable trouble to collect with a view to discover whether the association of the round ossicles with undoubted marginalia of Pycinaster was correct. He has discovered a specimen which shows that the round ossicles are associated with marginalia of a species of Stauranderaster (*S. senonensis*) and that they are therefore the abactinal ossicles of the disc of this species (see p. 134). VALETTE's original determination of the ossicles as belonging to Stauranderaster (Pentaceros) is therefore correct. It is necessary therefore to find a new specific name for the large marginalia (Plate 11, figs. 14, 15) which are found in great abundance in the sub-zone of *A. quadratus* and in the lower beds of the zone of *B. mucronata.*

Material.—Only a very few associated ossicles of the species are known. They are not sufficient in number to enable one to reconstruct the form. The superomarginal figured (Plate 11, fig. 15) is taken as the holotype of the species.

Description.—Marginalia of this species are often very large indeed, showing that the form was the giant amongst the Chalk starfish. The largest marginal which has passed through my hands was as much as 20 mm. high. The supero-marginalia are usually very distinctly wedge-shaped. Pedicellaria are not met with so commonly as in the earlier forms.

4. *Pycinaster crassus*, Spencer.

This species was described in SLADEN and SPENCER (45, pp. 96, 97 and corresponding plates). The marginalia are distinguished from those of *P. magnificus* by their greater thickness and by the frequent return to the low-zonal "skewness." The square marginalia of the extremity of the arms often carry prominent mammillations (Plate 15, fig. 4).

Some very thick marginalia apparently belonging to the species have been collected by M. FILLIOZAT from beds which are assigned to the zone of Marsupites, Vendôme. It is to be noted that these beds contain another species, *Metopaster tumidus*, which is also usually found in the upper *mucronata* beds (see also p. 119).

THE CALLIDERMA GROUP.

This group includes a large number of forms which have a comparatively undifferentiated ornament consisting as a rule of hexagonal closely fitting spine pits. The chief variations arise through the spine pits becoming circular in form.

The ornament is essentially a primitive one and the absence of differentiation

makes it difficult to ascertain exactly whether, strictly speaking, the group is a natural one. It is quite possible that we have represented here relatives of ancestral forms which have given rise to many of the chief modifications already described. The group might therefore consist of growths from the stem of many ancestral stocks which, on account of their want of differentiation, are difficult to separate. Nevertheless it is possible to trace some definite races and their modifications through the whole of the zones of the Chalk.

The following table indicates the main relationships of the species in the group :—

A. Forms with comparatively short arms and an interbrachial arc—

Series 1.—*Calliderma* (*Tylaster*) *jurensis*, Münster—Jurassic forms. *Calliderma Smithiæ*, Forbes ; *Chomataster præcursor*, n. sp., and *Chomataster acules*, n. sp.—Cretaceous forms.

Series 2.—*Calliderma latum*, Forbes, a short-lived low-zonal modification of *C. Smithiæ*.

B. Forms with long arms and a well-rounded interbrachial arc—

Series 3.—*Ophryaster magnus*, n. sp. ; *Oph. lunatus*, Woodward, and *Oph. oligoplax*, Sladen. Forms which are especially important in the high-zonal periods but whose ancestry is doubtful.

Series 4.—*Comptonia elegans*, Gray, and *C. Comptoni*, Forbes. Lower Cretaceous forms of doubtful relationship.

THE CALLIDERMA—CHOMATASTER SERIES.

Series 1.

We may summarise the probable history of the species in sub-group A as follows : In Triassic or early Jurassic rocks there existed a small low form with closely fitting hexagonal spine pits. In the Upper Jurassic rocks this form became large and high and the spine pits tended to become restricted to certain portions of the plate. The ossicles of this latter form belong to the species *Tylaster jurensis*, Münster, as restricted by FRAAS (19, p. 244). In the Lower Cretaceous rocks and the low zones of the Chalk the species tended to return to its primitive form. This form, known as *Calliderma Smithiæ*, persists through the mid-zones of the North European Chalk, and a closely related species (*C. Emma*, Gray) is even now living in the Japanese seas.

In the high zones of the North European Chalk the form again became high and the ornament eventually disappeared. The species in which this takes place have been placed in a new genus Chomataster.

Genus—CALLIDERMA, Gray, 1847.

SLADEN and SPENCER (45, p. 4).

The forms belonging to the genus are stellato-pentagonal. Primitively they were probably depressed and the ornament on their marginalia of a shallow hexagonal type.

1. *Sub-genus*—TYLASTER, nov. sub-gen. (τύλος = a swelling).

Sub-generic Characters.—Body high. Ornament frequently confined to a portion of the plates.

This sub-genus is founded to include certain Jurassic and Lower Cretaceous forms which are akin to *Calliderma Smithiæ.* They may all be placed in the species *Tylaster jurensis* (Münster).

The following figured ossicles may be assigned to the species :—

(*a*) From the Jurassic, the ossicles figured by GOLDFUSS, Plate 63, figs. 6 *a–e*, as *Asterias jurensis*, and those figured by QUENSTEDT, Taf. 91, figs. 23–54, as *Asterias impressa*, figs. 85–100, as *Asterias spongiosa*, and figs. 131–134, 137, 145–148, as *Asterias jurensis.*

(*b*) From the Cretaceous, the form figured as *Goniaster arduennensis*, Peron, PERON (36).

The species is also represented in the Tourtia of Essen (zone of *P. asper*) and in the Upper Greensand of South England (Coll. Brit. Mus.; Mus. Pract. Geol.). These ossicles are figured here, Plate 12, figs. 20, 21.

2. *Calliderma Smithiæ*, Forbes.

SLADEN and SPENCER (45, pp. 6, 115, and 123, and corresponding plates).

The form is characteristically depressed and the ornament usually of a uniformly distributed, shallow hexagonal type. Often the ossicles of the distal portion of the arm are, however, somewhat high and these may possess spine pits distinctly circular in outline.

Low Zones—

Forms belonging to the species are especially abundant in the "low" zones. The marginalia exhibit considerable variation. These variations may be classified as follows :—

A. *Variations in Shape.*—These may best be seen in profile view.

(1) Low forms.

(i) Forms with a distinct hump on the lateral portion of the abactinal surface of the supero-marginalia (Plate 12, fig. 22).

(ii) Forms with a gradual slope of the same surface (Plate 12, fig. 23).

(iii) Forms with a groove between the supero- and infero-marginalia.

(2) High forms. These differ from *Ty. jurensis* in the uniform distribution of the spine pits over the whole of the plate.

B. *Variations in Ornament.*—There is considerable variation in the size of the spine pits upon the marginalia of different individuals. Some forms have fine spine pits, others have coarse spine pits (45, p. 115, text-fig. 8 (A) and (B)). Again large spinelets may be developed upon the outer edge of the plates. A careful examination of whole specimens shows that there is almost every possible combination of variety in shape and ornament.

As the species becomes less abundant there is less variability. The general profile view becomes constant. The abactinal surface of the supero-marginalia has always an even slope and the groove at the junction of the supero- and infero-marginalia disappears. High forms become rare. The ornament is almost always of the fine hexagonal type, but circular spine pits may occur at the junction of the abactinal and lateral faces.

Mid-zones—

The species is comparatively rare in the mid-zones except in the beds bordering upon or included in the sub-zone of *O. pilula.* Here many large ossicles have been found. These ossicles (Plate 12, figs. 24, 29) are somewhat broader than those found in the low zones, and in general appearance cannot be distinguished from those of *C. Emma* found at the present day in the Japanese seas.

High Zones—

In the high zones the forms become high. As the mid-zonal representatives of the series exist at the present day it appears advisable to form a new genus, Chomataster, to include these high-zonal representatives of the series.

Genus—CHOMATASTER, nov. gen. (χῶμα = a mound).

Generic Characters.—Body high. General form probably as in Calliderma. Supero-marginalia either with fine hexagonal spine pits or smooth. A large spine pit often present near the abactinal face. Infero-marginalia always with a fine hexagonal ornament.

There are two species—

Chomataster præcursor, n. sp. Specific characters: Spine pits on the supero-marginalia arranged in a fine hexagonal pattern.

The supero-marginal figured (Plate 12, fig. 27) is taken as the holotype.

Ch. acules, n. sp. Specific characters: Only one large spine pit present on the supero-marginalia.

The supero-marginal figured (Plate 16, fig. 8) is taken as the holotype.

Only isolated ossicles are known of either of these species. *Ch. acules* is taken as the type species of the genus.

3. *Ch. præcursor.*

Description.—This species includes the forms which arise immediately from *C. Smithiæ.* The evolution generally proceeds by a further extension of the narrowing of the articular faces of the supero- and infero-marginalia. At the same time the ossicles increase in height. Occasionally a large spine pit is developed at the junction of the lateral and abactinal faces of the supero-marginalia. The series figured (Plate 12, figs. 25–28) shows this. These changes appear to take place in England about the horizon of the middle and upper beds at Studland (*vide infra*, p. 147). At other times there does not appear to be a narrowing of the base of the supero-marginalia, but the ossicle remains thick and grows high (Plate 12, fig. 27). The infero-marginalia, apparently corresponding to these supero-marginalia, occasionally have a "cut back" face as in Tylaster. There is a considerable superficial resemblance between these two forms (*Cp.* Plate 12, figs. 20, 21, 26).

This high thick form is abundant at Köpinge, Sweden, where a form with a narrow base is found only occasionally (Plate 16, figs. 28, 29).

4. *Ch. acules.*

Description.—In the upper beds of the zone of *B. mucronata* many supero-marginalia are found which are very high and from which the fine hexagonal spine pits have entirely disappeared. There is almost always, however, on these ossicles a large circular spine pit near the abactinal face (Plate 16, fig. 8). The ossicles commonly are 5·5 mm. long and 10·5 mm. high.

The infero-marginalia fit exactly opposite to the supero-marginalia. They always retain the "Calliderma" ornament.

Series 2. *Calliderma latum*, Forbes.

This species has been described in SLADEN and SPENCER (45).

It is probably not a true species, but merely a lineage variety expressing a phase of the general variability in the lineage at that period.

THE OPHRYASTER SERIES.

Series 3. *Genus*—OPHRYASTER, novum. (ὀφρύς = a brow).

Generic Characters.—General form depressed. Arms long, interbrachial arcs well rounded. Spine pits often circular and well separated. Inner margin of supero-marginalia often brow-like.

Certain Cretaceous species were placed by SLADEN in the genus Nymphaster, which was originally founded by him to include a number of recent species brought to light by deep-sea exploration. These Cretaceous species included *N. Coombii*, Forbes; *N. oligoplax*, Sladen; and *N. marginatus*, Sladen. SLADEN, however, remarks (45, p. 21), with respect to *N. oligoplax*, that "the whole facies of this

fossil lends strong support to the presumption that this species may ultimately need to be placed in a distinct genus, but I do not feel warranted in taking that step on the basis of such scanty material."

The genus Nymphaster, as defined by SLADEN, includes forms in which the plates on the radial areas of the abactinal surface of the disc are well separated to allow of the passage of papulæ. Specimens of "*N.*" *oligoplax* discovered by Dr. ROWE and Mr. BRYDONE show that the abactinal surface of the form is in the primitive completely covered condition. It is necessary therefore to remove, at any rate, the species "*N.*" *oligoplax* into a new genus. It is probable also that *N. marginatus* and the form known as *Pentagonaster lunatus,* Woodward, have the same generic characters. The genus differs from Calliderma chiefly in the character of the arms and that of the interradial arcs. The ornament varies from that of the Calliderma type to a punctate type. There are five species. *O. oligoplax* is taken as the type species of the genus.

1. *Ophryaster magnus*, n. sp.

Specific Characters.—Body large. Supero-marginalia almost square. Spine pits may be hexagonal and closely touching or circular, and somewhat widely separated.

Material.—Ossicles of the species are particularly abundant in the chalk of the Island of Rügen. The ossicle figured (Plate 16, fig. 25) is taken as the holotype.

It is to be noted that there is considerable general resemblance between this form and *O. oligoplax.* It is possible that it is directly descended from that form which is abundant in the slightly lower horizon of Trimingham.

2. *Ophryaster oligoplax*, Sladen, sp.

This species is described in SLADEN and SPENCER (45, pp. 19–21). Ossicles of the species are distinguished from those of *O. magnus* by the possession of a narrow interior area upon which no spine pits are to be found (Plate 13, fig. 26). The spine pits are well separated.

3. *Ophryaster lunatus,* S. Woodward.

Described in SLADEN and SPENCER (45, p. 25).

The marginalia resemble those of *O. oligoplax* in the punctate character of their spine pits, but there is no smooth area.

I have seen very few ossicles which can be said to belong to this species. It may be only a variety of *O. oligoplax.* The holotype was found at Norwich, where chalk occurs near the Trimingham horizon.

It is also possible that *Ophryaster marginatus*, Sladen, and *O. Coombii,* Forbes, are merely variants of species already described.

THE COMPTONIA SERIES.

Series 4. *Comptonia Comptoni*, Forbes, and *Comptonia elegans*, Gray.

Described in SLADEN and SPENCER (45, pp. 69–72, Plate 17, figs. 2, 3, 4).

The exact relationship of these forms to the remaining species of the group is very uncertain. The marginalia are slightly more rounded in profile view than is usually the case in species of Calliderma, and the arms are further produced. The matrix of the fossils is a coarse sandstone, and, in consequence, the ornament on the plates is in a wretched state of preservation.

The authorities of the Geologische und Palæontologische Museum, at Berlin, have kindly lent me types of *Stellaster Schulzei*, RÖMER, F. A., figured (39, t. 6, fig. 21), and *S. tuberculifera*, DRESCHER (16), t. 8, fig. 5. These are only preserved as impressions in sandstone. The first-named species appears to be identical with *Comptonia Comptoni* and the second with *Calliderma Smithiæ*.

GENERIC AFFINITIES NOT CERTAIN.

Genus—TRACHYASTER, novum (τραχὺς = rugged).

Generic Characters.—Marginalia without a distinct rabbet edge. Ornament composed mainly of rugosities. Spine pits rarely present.

This genus is founded to include two species: *Nymphaster radiatus*, Spencer (described, SLADEN and SPENCER (45), p. 73, Plate 25), and *Nymphaster rugosus*, Spencer (described, same monograph, p. 94, Plate 29). These species appear to be closely related to each other, and to represent stages of rugose elaboration in some series allied to Calliderma. Ossicles of the species are found in some abundance in the Chalk Marl (zone of *Sch. varians*).

Tr. radiatus has rugosities arranged lineally. Frequently fusion of the rugosities takes place so as to form a beaded ornament (Plate 13, fig. 27).

Tr. rugosus has rugosities which are disposed somewhat more irregularly than in the previous species.

THE STAURANDERASTER SERIES.

Family—STAURANDERASTERIDÆ, novum.

It appears desirable to form a new family for the genus Stauranderaster, which is described below. The generic characters do not permit its association with any family which has already been described. The family characters are the same as those of the genus, which, as at present defined, contains all the species which are sufficiently nearly related to be placed in the family.

It is possible that later, with advancing knowledge, it may be necessary to subdivide the genus.

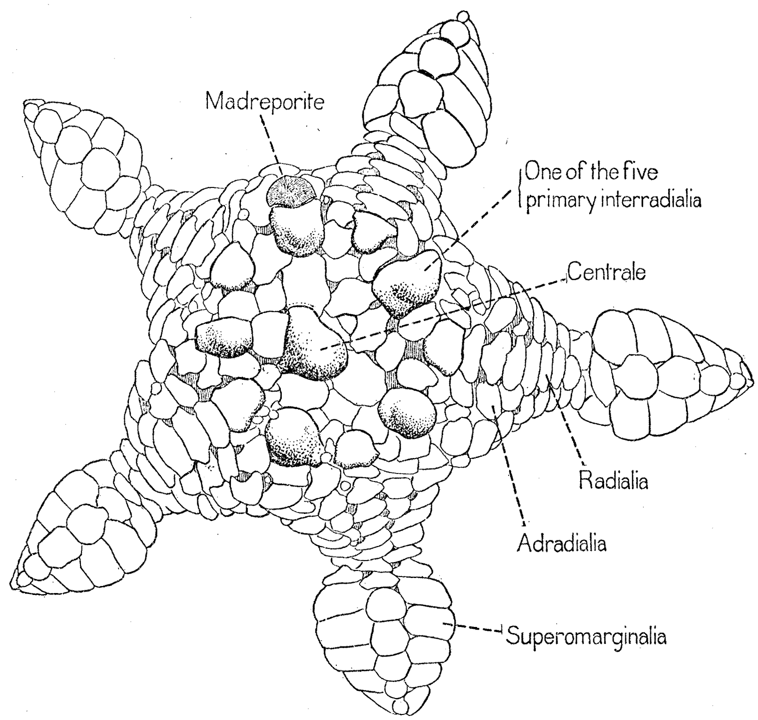
Genus—STAURANDERASTER, Spencer, 1907.

SLADEN and SPENCER (45, p. 125).

The genus was founded to include certain Chalk forms which had breast-plate shaped marginals and a circlet of prominent tumid ossicles on the abactinal (dorsal) face of the disc. The possession of this circlet of plates gives a strong superficial resemblance to Pentaceros (Oreaster). The peculiar shape of the marginals and the ornament of the plates (*vide infra*) are but two of the many characters which suggest that the genus Stauranderaster is a representative of a specialised family of mesozoic Starfish which differ widely from modern forms.

Generic Characters.—Body high, with produced arms. Plates with a rabbet edge. Ornament on plates confined, when present, to the central raised area. Proximal marginalia breast-plate shaped. The genus apparently occurs in both the Jurassic and Cretaceous strata.

The general structure of the species of the genus is well exemplified by *S. bulbiferus* (text-fig. B). It is necessary to describe this in some detail, as its ossicles, which are



TEXT-FIG. B.

frequently found in the field, differ considerably in their form according to their position. In the base of the arm the radialia, supero-marginalia, and infero-marginalia are very similar in appearance. They are thin, imbricating, and distinctly breast-plate shaped. The rabbet edge and central area are clearly defined. The ossicles of the swollen distal portion of the arm, on the other hand, show considerable differences. The radialia are club-shaped, with a swollen head (Plate 13, fig. 10). The supero-

marginalia are high, polygonal, and closely fitting (Plate 13, figs. 1, 2, 4, and 6). Both these series have frequently a very indistinct rabbet edge. The inferomarginalia are low and have a distinct rabbet edge. On account of their ornament and shape, they are liable to be mistaken for ossicles of *Metopaster Parkinsoni*. A close examination shows, however, that the interior edge of the plate in the species under description is grooved throughout for the fitting of the neighbouring plates.

The abactinal plates of the disc are irregular in shape. The centrale and the primary radialia and interradialia are usually very distinctly swollen.

The remaining species of Stauranderaster do not differ in fundamental structure from the above. Only one other species, *S. gibbosus*, has, however, its arms swollen distally.

The following description appears to show that the various forms of Stauranderaster fall into the following lineage groups :—

S. bulbiferus, Forbes.	*S. Boysii*, Forbes.	*S. coronatus*, Forbes.
	S. gibbosus, n. sp.	*S. pistilliferus*, Forbes.
	S. senonensis, Valette.	

Some of the above species undoubtedly have near allies in the Jurassic. The ossicles figured by QUENSTEDT (37, Tab. 91, figs. 110–112), from the Weisser Jura, under the name of *Asterias spongiosa*, bear a strong resemblance to those of *S. bulbiferus*, whilst the ossicles figured by FRAAS (19, Plate 30, figs. 17–33), under the name of *Pentaceros primævus*, Zittel, and those figured in GOLDFUSS (22, Plate 63, fig. 6, *f–h*), under the name of *Asterias jurensis*, bear an equally strong resemblance to those of *S. Boysii* (see also SLADEN and SPENCER, 45, p. 108).

1. *Stauranderaster bulbiferus*, Forbes.

A description of the general form of the species has already been given. The species is of fairly frequent occurrence, and has important zonal modifications which are described below.

Zonal Modifications.—There appears to be little advance in the species from the zone of *Rh. Cuvieri* to the lowest portion of the zone of *M. cor-anguinum*. The early forms were small and with clear-cut ornament, which is usually of a fine character resembling that of *S. Boysii*. The swollen plates of the disc also resemble those of *S. Boysii* in their hemispherical shape and in the absence of a produced base. Typical ossicles from these low-zonal horizons are figured (Plate 13, figs. 1, 2, 3, and 8).

During mid-zonal times the forms increased very rapidly in size. At the same time rugosities appeared on the distal polygonal marginalia, thus destroying the clear-cut character of the spine pits (Plate 13, fig. 5). More rarely the proximal radialia assume the same character. The large primary radialia and interradialia are no longer hemispherical in form, as they have acquired a produced base, which is often widely spreading (Plate 13, fig. 9). Occasionally the primary plates are scarcely swollen.

The form appears to have attained its maximum size in the sub-zone of *Offaster pilula*. After that period there is diminution in magnitude and in frequency of occurrence.

The high-zonal forms can frequently be distinguished by the absence of spine pits upon the distal marginalia and by the development of rugosities upon these plates (Plate 13, fig. 7).

As in the case of other species there is considerable variation in the ornament of individuals living at the same time. In both the zones of *A. quadratus* and *B. mucronata* specimens are to be found in which the spine pits are clearly cut and scarcely disguised by rugose elevations. It is to be noted, however, that the maximum in elaboration does not occur except in its proper sequence. No rugose ossicles without spine pits have been observed in zones lower than that of *B. mucronata*.

It is only as a very exceptional occurrence that ossicles have been noted devoid of both spine pits and rugosities. These occur in the zone of *M. cor-anguinum* (Colls. BRYDONE and JANET).

The ossicles of the species from the Unter-Pläner (Cenomanian) of Saxony are larger than those of the English low-zonal forms, and have a characteristic coarse punctation.

2. *Stauranderaster Boysii*, Forbes.

This species has been fully described, SLADEN and SPENCER (45, pp. 80–81).

The ornament is of a finer character and more closely set than is usual in *S. bulbiferus*. The arms are long and tapering. The distal marginalia are, in consequence, smaller and differ considerably in shape from those of *S. bulbiferus*.

In the British Museum specimen, 46600, the ornamented central area is seen to be gradually contracting. A specimen from the zone of *M. cor-anguinum* (Coll. Dr. ROWE) shows the evolution a stage further. Here all the spine pits have disappeared except on the large abactinal ossicles of the disc.

These changes lead the way to the smooth form of the species which appears in abundance in the sub-zone of *A. quadratus* of the South of England, and is a valuable zonal guide to this horizon and that of the lower *mucronata*. This form has been described by VALETTE under the name of *Pentaceros senonensis*.

3. *Stauranderaster senonensis*, Valette (*cp.* also p. 125).

The large abactinal ossicles of this species readily catch the eye of the field worker and are well represented in the various collections examined. They are usually smooth (Plate 13, fig. 14), but occasionally minute punctations may be present.

A series of associated ossicles collected by Mr. BRYDONE enable one to state that the remaining plates are similar in general form to those of *S. Boysii*.

4. *Stauranderaster gibbosus*, n. sp.

Specific Characters.—General form as in *S. Boysii*, except that the distal portion of the arm is very much swollen. Spine pits frequently lipped.

Material.—A fairly preserved specimen of the species and a fragment of an arm of another individual were discovered by Mr. FABER in the *quadratus* chalk of Rottingdean. Unfortunately many of the ossicles of the specimen are displaced. Sufficient remain, however, to establish the connection between the species and *S. Boysii.*

The first-named specimen is taken as the holotype of the species. The fragment of the arm is taken as a paratype of the species. Isolated ossicles are common in several collections.

Description.—Except that the extremity of the arm is swollen, the general form of the species is similar to that of *S. Boysii.*

The swollen arm extremity causes the supero-marginalia in this region to become high, thick, and quadrant shaped (Plate 13, fig. 11).

Lipped pits are found on some but not all of the plates. Occasionally pits of this character may be observed on the distal arm ossicles of *S. Boysii*, thus confirming the near relationships of these forms.

Minute articulatory prominences are frequently to be seen on the marginalia. These prominences fit into sockets on neighbouring plates. They may also be found in *S. Boysii*, *S. senonensis*, and *S. bulbiferus* (Plate 13, fig. 2).

Varieties.—In the upper *mucronata* and Danian large abactinal ossicles appear which have usually a similar ornament to that described above. They are pyramidal rather than hemispherical in shape (Plate 13, fig. 12). They may, however, be smooth (Plate 16, fig. 30). To this variety is given the name var. *pyramidalis.*

5. *Stauranderaster coronatus*, Forbes.

A full description of this species has been given in SLADEN and SPENCER (45, p. 82). It is a smooth form fairly common in the low zones. Its punctate ancestor has not as yet been identified.

S. squamatus, Forbes, appears to be a rugose variety of *S. coronatus.* The primary abactinal ossicles are nodular in the type specimen, but it is just possible that in other members of the species they may have been smooth and hemispherical.

6. *Stauranderaster pistilliferus*, Forbes.

Owing to the kindness of the authorities of the Museum of Practical Geology, Jermyn Street, I have had the opportunity of cleaning and studying the specimen mentioned in SLADEN and SPENCER (45, p. 89).

Although the specimen consists of one arm only, it is the most perfect example of the species which has come under my observation.

The arm in cross-section shows a median row of radialia and two rows of marginalia along each side. One or two very small ossicles suggest the presence of the inter-marginalia which appear to be general in the genus.

The radialia and the two series of marginalia are very similar in outer view. They are, as described by FORBES, "narrow, shuttle-shaped and frequently tumid in the centre." There is a narrow rabbet edge, which is much more evident on the younger distal ossicles than on the older proximal ossicles. The tumid central area appears usually to have been covered with closely crowded granular spines, contained in very shallow spine pits. Often these spine pits are very difficult to distinguish. In certain cases they may have been absent.

The largest supero-marginalia are 5 mm. broad and 2·7 mm. long.

The infero-marginalia are similar in size.

The large plates which must have originally formed a circlet round the disc are characteristically high. Although the exact number cannot be determined it is probable, as FORBES states, that they were five in number. Their position suggests that they were the primary radialia. Several rows of ventro-lateralia enter the arm. These ossicles are small, smooth, tumid, and quadrate. Their diameter was about 1·5 mm. The adambulacralia appear to have carried two rows of spines. There were three spines in each row. The ossicles figured (Plate 13, figs. 16–19) are from an associated set discovered by M. JANET. They illustrate well the above descriptive details.

The earliest recorded example of the species is from the collection of zone of *Micraster cor-testudinarium*, Seaford (Coll. Dr. ROWE). Ossicles from the neighbouring chalk at the base of the zone of *Micraster cor-anguinum* have also been found at Seaford (Coll. Mr. BRYDONE), and at Purley, Surrey. The large primary radialia are primitive in character, inasmuch as they are but half the height of the similar ossicles in the type specimen, which must have come from a higher horizon. Ossicles similar to those of the type are found in the higher portions of the zone of *Micraster cor-anguinum* to the lower portions of the zone of *Actinocamax quadratus* inclusive.

Stauranderaster ? decoratus, Geinitz.

GEINITZ has described (21, Taf. 22, figs. 26–33; Taf. 23, figs. 1–6, p. 89) a number of ossicles from the Unter Pläner of Saxony under the name of *Oreaster decoratus*. The species appears to be related to certain Jurassic genera, the so-called "*Pentaceros*" *jurassicus* of Zittel and "*Pentaceros*" *pustuliferus*, Fraas.

The general shape of the ossicles suggests a near affinity with the genus Stauranderaster. The ossicles are distinguished by their irregular shape and, frequently, by the presence of wart-like protuberances (Plate 13, fig. 21).

It is difficult to place the species in a series with any Cretaceous species which may definitely be assigned to Stauranderaster.

THE HADRANDERASTER SERIES.

Genus—HADRANDERASTER, Spencer, 1907.

This genus was founded to include forms which have characteristically thick marginalia. In outer view the marginalia are irregularly elliptical in outline.

One species was described (45, pp. 86, 125) under the name of *Hadranderaster abbreviatus*, Spencer. The ossicles described by GEINITZ (21, S. 90, Taf. 21, figs. 15–20), under the name of *Oreaster simplex*, are of the character described above, and as there is but one species of the genus this latter species name has priority.

Ossicles of the species are figured here, Plate 11, figs. 25–26.

The ossicles described by GEINITZ as *Oreaster perforatus* and figured (figs. 21–22) on the same Plate as *O. simplex* belong merely to a smooth variant of that latter form. Smooth ossicles, without, however, the large spine pit figured by GEINITZ, are also found somewhat commonly in the sub-zone of *A. quadratus* of Hampshire.

Family—SPHÆRASTERIDÆ, Schöndorf, 1906.

This family was founded by SCHÖNDORF (44, p. 303) to include certain Jurassic forms which have a high dome-shaped body without protruding arms.

The forms which were described in SLADEN and SPENCER (45, pp. 85, 99, 121 and 125), under the name of *Stauranderaster argus*, Spencer, and *S. ocellatus*, Forbes, are apparently direct descendants of the Jurassic Sphærasteridæ.* I have during the last few years been able to examine a few well-preserved forms which show that these species never had produced arms, as did the species of Stauranderaster, and that the general body form was most probably originally high and dome-shaped, although in the fossil specimens it has lost this shape in consequence of collapse after death.

The genus Tholaster, *novum*, is founded to include these Cretaceous species. SCHÖNDORF was inclined to regard the Sphærasteridæ as nearly related to the recent Pentacerotidæ. Personally, I am inclined to regard them as more nearly related to the recent Asterinidæ, which have a similar body form and not dissimilar ossicles.

THE THOLASTER SERIES.

Genus—THOLASTER, novum (θολός = a dome).

Generic Characters.—Body dome-shaped, composed of irregular ossicles which are usually ocellate. Arms included in the disc area.

Two species have been described, *Th. argus*, Spencer, SLADEN and SPENCER (45,

* SCHÖNDORF, in a letter to me, advanced independently a similar opinion.

p. 97, Plates 25 and 29), *Th. ocellatus*, Forbes, SLADEN and SPENCER (45, p. 85, Plate 25).

The ossicles of *Th. ocellatus* are cut away at the top. Small rugosities, arranged usually in a madreporiform pattern, are present on this cut-away surface (Plate 13, fig. 24). The ossicles of *Th. argus* are either not cut away, or if they are cut away they have no rugosities (Plate 13, figs. 22, 23).

Both species are persistent throughout the chalk. *Th. ocellatus* is particularly characteristic of the zone of Marsupites and the succeeding sub-zone of *Offaster pilula.* It is probable that they are not two divergent offshoots from a parent stock, but the specific names are retained on account of their convenient use as descriptive terms.

Order—PAXILLOSA.

Family—ASTROPECTINIDÆ, Gray, 1840.

Forms belonging to this family have in a large number of instances a prominent ridge on the marginalia. This ridge deepens somewhat near the junction of the two series (see Plate 11, fig. 19). The genus Arthraster, which almost certainly belongs to another family, possesses a somewhat similar ridge, but the profile view of its ossicles is distinctly different.

The possession of the ridge and characteristic profile is important, as it serves for the ready identification of "Astropectinid" ossicles, an important matter since their presence always suggests the proximity of shore or shallow-water conditions.

The Jurassic and Cretaceous forms have previously been placed in the recent genus Astropecten. A close study suggests, however, that they should be placed in new genera. The abactinal plates of the disc are rarely, if ever, strongly paxilliform, and the close set of the same plates indicates that there were no pores present for the passage of papulæ as in the modern representatives.

THE LOPHIDIASTER SERIES.

Genus—LOPHIDIASTER, nov. gen. (λοφίδιον = a ridge).

Generic Characters.—Marginal, strongly ridged. Spines on marginalia either minute or absent.

There are two species, *L. ornatus*, n. sp., and *L. pygmæus*, von Hagenow, M.S. Apparently *L. pygmæus* is directly descended from *L. ornatus.*

1. *Lophidiaster ornatus*, n. sp.

Specific Characters.—Body of medium size; R : *r* : : 45 mm. : 15 mm. Ornament on infero-marginalia usually consists of prominent rugosities. Outer wing of ridge of the infero-marginalia often strongly pronounced.

Material.—The form described by SPENCER in SLADEN and SPENCER (45, p. 90,

Plate 25, figs. 2, 2*a*), as *Astropecten* sp., is taken as the holotype. The ossicles figured (Plate 11, figs. 19, 22, of this paper) are the paratypes.

Description.—The supero-marginalia are about 4 mm. broad and 1·6 mm. long. Their surface is fairly even and is ornamented by shallow spine pits. The characteristic ornament of the infero-marginalia is figured (Plate 11, fig. 22).

Distribution.—The species appears to be fairly abundant in the shallow water deposits which precede the true Chalk. It then disappears, except from certain beds in Devon (see p. 142), until we reach the zone of *H. planus*, which, as is well known, was a period of uplift. The subsequent depression causes it again to be lost sight of in England, but it is known to occur in the contemporaneous shallow-water beds of the Continent, as, *e.g.*, in the Uintacrinus beds of Recklinghausen, Westphalia.

The ossicles of the series, when they once again appear in England, in the sub-zone of *O. pilula*, are smaller, and present characteristics which enable us to place them in a second species.

2. *Lophidiaster pygmæus*, n. sp. *ex* von Hagenow M.S.

Specific Characters.—Ossicles small. Ornament faint or absent.

Material.—Certain ossicles from the chalk of the Island of Rügen are preserved in various Continental museums (Berlin, Brussels) under the name of *Asterias pygmæa*, von Hagenow, but I have been unable to trace this name in literature. In consequence, I have decided to take the ossicles figured in this paper (Plate 13, fig. 20) as type ossicles of the species.

Description.—There are two fragments of a single specimen of this species in the possession of Mr. BRYDONE. These show that the abactinal plates of the disc were flat, not paxilliform. Long spines were carried by these plates. The ornament on the supero-marginalia is, as a rule, much fainter than is the case in the earlier species (Plate 16, figs. 18, 19). The ossicles themselves are much smaller, as they rarely exceed 2·5 mm. in breadth. The infero-marginalia are somewhat broader.

Variety.—The Maestrichtian beds of St. Pierre yield infero-marginalia which possess a very sharp ridge (Plate 11, fig. 21). Very similar ossicles have been obtained from the Lutétien (*Calc. grossier*) of the Paris basin (Coll. M. JANET).

FAMILY UNCERTAIN.

Genus—ARTHRASTER, Forbes, 1848.

SLADEN and SPENCER (45, p. 91).

The marginalia of the genus possess a broad ridge running along the whole length of the plate. They are thicker and more symmetric in appearance than those belonging to the Astropectinidæ.

The genus obviously cannot be placed in a "paxillose" family, as its abactinal plates are of the same general character as are the marginalia.

THE ARTHRASTER SERIES.

There are two species :—

Arthraster Dixoni, Forbes (described, SLADEN and SPENCER, pp. 91–93, and corresponding Plate).

Arthraster cristatus, Spencer (described, SLADEN and SPENCER, p. 93, and corresponding Plate).

A. Dixoni is a low-zonal form, whilst *A. cristatus* occurs in the mid and high zones. *A. cristatus* is figured in this paper (Plate 11, figs. 23, 24 ; Plate 15, fig. 7).

Genus—PHOCIDASTER, nov. gen. (φωκίς = a pear).

Phocidaster grandis, n. sp.—I have given this name to certain ossicles which are found fairly abundantly in the Greensand facies of the zone of *P. asper*, as developed in the beds of Warminster and the "tourtia" of Essen. The shape of the plates is well seen in the photographs (Plate 13, figs. 28, 29). The ornament is smooth. Until more is known it appears inadvisable to give exact generic and specific distinctions.

Section III.—STRATIGRAPHICAL CONCLUSIONS.

It is convenient to describe the general zonal succession of the Asteroid fauna as follows :—

(1) The general succession as exhibited in the main depths.

(2) The fauna of the deposits laid down near the shore.

The General Succession as Exhibited in the Main Depths.

This may best be understood if an endeavour be made to picture the genesis and life-history of each starfish and the conditions under which successive beds were deposited. In order to do this effectively, we must trace as many species as possible back to their Jurassic ancestors.

The Jurassic strata of England and North France were almost entirely deposited near the shore line. The deposits, unfortunately, owing to their composition, present no weathered surfaces, so that isolated ossicles of starfish are much more difficult for the collector to perceive than are those on the surfaces of white chalk. That starfish existed in considerable numbers under these conditions, however, is evidenced by a collection of upwards of one thousand ossicles obtained by Mr. MOCKLER from his washings of the Bradford Clay.

These ossicles, as also the specimens described in the monograph of Dr. WRIGHT (51), show that the dominant starfish were species belonging to the Astropectinidæ. This is noteworthy, inasmuch as the modern representatives of the family live in water of no great depth. There appears to have been, in consequence, little change of habit since Jurassic days.

A more widely representative fauna occurs in the Wurtemberg Jura, where, besides members of the Astropectinidæ, the high form of the Calliderma series, known as *Tylaster jurensis* (p. 126), and representatives of the Stauranderasteridæ and the Sphærasteridæ are found.

The sandy and argillaceous beds of the Neocomian, Aptian, and Albian (Lower Cretaceous) have yielded very few Asteroidea. They are of considerable thickness and represent a period in which there must have been opportunity for evolutionary changes. Nevertheless, we shall see that the earliest Cenomanian beds contain starfish which retain a strong affinity with Jurassic forms.

The Fauna of the Low Zones—

The oldest beds, those of the zone of *Pecten asper*, are developed as Greensand neritic deposits in the South of England, and at Essen in Germany. The fauna of the English Greensand of Warminster, Wilts, shows, by the occurrence of *Tylaster jurensis*, strong Jurassic affinities. It also contains *Phocidaster grandis*, a species of unknown ancestry, found only up to the present in these beds and those of the corresponding horizon at Essen.

The Cenomanian thalassic deposits of the Unter-Pläner of Saxony possess a more typically Cretaceous fauna. *Metopaster thoracifer* is present in some abundance. *Pycinaster humilis* and *Calliderma Smithiæ* make their first known appearance.

Nevertheless, the Jurassic affinity of the fauna is shown by the presence of *Stauranderaster? decoratus* (p. 136), and by the form of the ossicles of *Stauranderaster bulbiferus* (p. 133).

There is nothing quite comparable to this Unter-Pläner fauna in the Cenomanian deposits of England. Ossicles of *Metopaster thoracifer* (plain variety) are present in the Chloritic Marl of Dorset, and in the Upper Greensand of the same area a few ossicles of a primitive form of Metopaster have been found. On the other hand, I I have never obtained ossicles of this genus from any other Cenomanian deposits in England. Even washed material from the Chalk Marl of Cambridge does not yield forms of the genus. It may be that the early occurrence in Dorset is merely a sporadic appearance. A fauna which in many respects is closely analogous to that of the Unter-Pläner is found in the Turonian zone of *Rh. Cuvieri*, of Branscombe, Devon. The fauna in this neighbourhood shows many interesting peculiarities in its local distribution, and is deserving of description in detail.

A probable explanation of these peculiarities is to be found in the presence of a Greensand ridge which JUKES-BROWNE and ROWE have independently shown to have existed in the neighbourhood of the Hooken, and to have not only interrupted the horizontal continuity of the whole of the *Rhynchonella Cuvieri* zone and of a part, at least, of the *Terebratulina gracilis* zone, but also to have established two distinct facies of the fauna (ROWE, 41 (iii), p. 24). This ridge presented a steep slope on the west side, for there in the Bury Cliffs, 2 miles distant, there are at least 60 feet

of chalk belonging to the zone of *Rhynchonella Cuvieri.* On the east the slope is much more gentle; here the chalk of the zone thickens very slowly, and does not attain a thickness of 60 feet nearer than Pinhay, 8 miles away.

The Asteroid fauna on the west side is remarkably abundant, and shows distinct relationships with the Unter-Pläner fauna. Here alone in England the horned variety, *Metopaster thoracifer*, is present in profusion, and there are a few ossicles of *Stauranderaster? decoratus.* Ossicles of Metopaster are not found in the somewhat scanty fauna of the zone east of the ridge, which must have presented an effective barrier, nor even in the same zone in the Isle of Wight. A plain form of *Metopaster thoracifer* appears further east in the *Rhynchonella Cuvieri* zone of Dover.

Generally in England it is recognised that the sea gradually deepened during the deposition of the chalk of the zones of *Rhynchonella Cuvieri* and *Terebratulina lata.* Some elevation took place in *Holaster planus* times (WOODS, 50). This elevation does not appear to have been accompanied by any change in the direction in which the forms are evolving. Shore species, however, migrated into areas from which they had been previously excluded by the prolonged subsidence. Ossicles of the "astropectinid" Lophidiaster reappear. They are represented in collections from all localities in which the zone is found, even at such distances apart as France and Lincolnshire. It is interesting to note that this shore species is present in all the zones—*Terebratulina lata* to *Micraster cor-testudinarium*—upon the eastern gradual slope of the Greensand bank of Devon.

Renewed subsidence took place after the *Holaster planus* uplift and continued for a prolonged period. It was during this prolonged subsidence that the greater part of the chalk of the mid-zones was deposited.

The Fauna of the Mid-Zones—

A distinct break in the fauna appears to occur between the low and mid-zones, This is due—

(1) To the fact that there appears to be a considerable thickness of barren chalk above the beds which occupy the lower quarter of the zone of *Micraster cor-anguinum.* Consequently when the Asteroids are again met with in any abundance some interval of time has elapsed.

(2) To some acceleration in elaboration. In the "mid" zones many Cretaceous starfish reach their acme of elaboration, as, *e.g.*, *Crateraster quinqueloba*, *Mitraster rugatus*, and *Tholaster ocellatus*, and there appears to be an acceleration in elaboration as forms approach their highest point of development.

The general succession of the fauna is very similar in S.E. England, N.E. England, and N. France. Elaboration appears to have been generally uniform throughout this area. Nevertheless one can perceive that there was not complete uniformity of distribution of all the species.

Crateraster quinqueloba appears to have been much more abundant in S.E. England than in N. France. In this latter area species of Stauranderaster (particularly *S. Boysii*) and Tholaster are more abundant than in England. *S. Boysii* is so rare in the zone of *M. cor-anguinum* in Kent and Hampshire, and so abundant in comparison in Normandy, that it appears to occur merely as an unsuccessful colonist in England, with a migration-centre further south.

C. quinqueloba from N.E. England is not so elaborated as that from the South. There are rarely any rugosities present on the lateral faces of the marginalia. This more primitive condition suggests migration from a southern centre.

Species of Metopaster appear on the whole to be more uniformly distributed. It is only in Yorkshire that we find much variation from the Hampshire types. *Calliderma Smithiæ* appears to be more abundant in Kent and Normandy than in Hampshire.

This provincial distribution of Asteroids is paralleled by the distribution of sea urchins. ROWE has shown that examples of Micraster, one of the commonest fossils in S. England, are comparatively rare in Yorkshire, at any rate in coast sections. *Infulaster rostratus*, on the other hand, is very common in the zone of *M. cor-anguinum* in Yorkshire, and very rare in the southern chalk. ROWE has also shown that the same shape-variations of Micraster are distinctive of contemporaneous deposits in widely separated areas. The results of the study of the Asteroidea are in accordance with these observations.

The evolutionary changes in the forms are so very gradual that it is difficult to find forms which are distinctive of the various horizons. *Metopaster exsculptus* is very common in the zones of *M. cor-anguinum* and Uintacrinus in the South of England, and very rare outside these zones.

The zone of Marsupites is characterised both in Kent and Hampshire by the abundance of the most highly elaborated form of *Crateraster quinqueloba*. Mr. BRYDONE has sent me collections of Asteroidea from 77 exposures in the Marsupites band of Hampshire. No less than 65 of these contained *Crateraster quinqueloba*, often to the exclusion of any other form.

The sub-zone of *Offaster pilula* contains the depressed form of this species (p. 121), and the large ossicles of *Pycinaster magnificus*. Large forms of *Calliderma Smithiæ* and *Tholaster ocellatus* are also fairly common.

The Fauna of the High Zones—

The horizons included under this designation are the sub-zone of *Actinocamax quadratus*, the zone of *Belemnitella mucronata*, and the Danian.

It is universally conceded that the zone of Marsupites indicates the period of maximum subsidence of the Chalk Sea. Uplift then took place. The distinction between the "mid"- and "high"-zonal faunas is possibly brought about partly by the fact that the uplift caused some redistribution of the faunal provinces. The uplift

was not uniform throughout the Chalk Sea, but occurred so that the land in the West emerged from the sea at an earlier date than that in the East. This accounts for the greater thickness of the "high" beds in Norfolk, Denmark, Sweden, and North Germany. A further result of the direction of uplift was probably to make the western end of the sea much more gulf-like in nature. In consequence a severer competition between the forms living in this area arose. The available area was diminished and disturbance of provincial faunas took place. We may take as an example of this the distribution of members of the *Stauranderaster Boysii* series. We have seen that the punctate form, *Stauranderaster Boysii*, had N. France as its zonal province. The evolution of the form took place so as to form a smooth species *Stauranderaster senonensis*. This species is not uncommon in the zone of *Offaster pilula* of the department of Yonne, it occurs in a collection of about a dozen ossicles from the corresponding zone at Beauvais, and is also apparently common in the *quadratus* chalk of Yorkshire.

For some reason the species found it difficult to penetrate into the Chalk seas of the South of England during the "mid"-zonal period. It suddenly appears in great abundance in the lowest chalk of the "high" zones, and for some time is one of the commonest and most characteristic fossils.

The fauna of the sub-zone of *A. quadratus* and that at the base of the zone of *Belemnitella mucronata* are remarkably similar. The above-mentioned form *Stauranderaster senonensis*, rugose forms of *Metopaster uncatus*, *M. quadratus*, and *Stauranderaster bulbiferus* are common, as are also very large forms of *Pycinaster magnificus* and the small depressed variety of *Crateraster quinqueloba*. Regression forms of *Crateraster quinqueloba* "proper" and *Metopaster Parkinsoni* are also found (see p. 156).

The near approach of the shore line to Hampshire is shown by the presence in fair abundance of the astropectinid species *Lophidiaster pygmæus*. This genus had disappeared from our ken since the depression following *Holaster planus* times. The form on its reappearance has undergone but little change.

The full thickness of the chalk comprised in the zone of *B. mucronata* must be very great. Dr. ROWE (41 (v), p. 285) has shown that there are 475 feet belonging to the zone at the western end of the Isle of Wight. Unfortunately much of this is reef chalk from which no collection can be made, but fossils can be collected up to a height of 250 feet above the base of the zone.

More than 450 feet are exposed in the Island of Rügen (LAPPARENT, 30, p. 1457). The beds in the Isle of Wight can be traced to their junction with those of the zone of *A. quadratus*, whilst those in the Island of Rügen are known to be the uppermost beds of the zone, but the Asteroid fauna of the beds of the Isle of Wight at no point touches that of the Rügen beds. We shall see that there is chalk in existence which must be intermediate in age between the uppermost beds in the former locality and the bottom beds of the latter. There is in consequence probably more than

800 feet of *mucronata* chalk.* Up to the present no very satisfactory sub-division of this has been advanced.

STOLLEY (46) has founded the following sub-zones based upon studies of the N. German chalk :—

Upper *mucronata*, zone of *Scaphites constrictus*, *Trigonosema pulchellum*.
Middle *mucronata*, zone of *Scaphites spiniger*, *Heteroceras polyplocum*.
Lower *mucronata*, zone of *Epiaster gibbus*.

The great rarity of Ammonites in the English chalk precludes their use as zonal guides. *Epiaster gibbus* is not found in the lowest beds of the *mucronata* of Hampshire (BRYDONE, 9, p. 123), but is confined in this region to the zone of *M. cor-anguinum*.

An attempt is made in this paper to subdivide the zone into three divisions. The evidence is not, however, complete as to the equal value of all the subdivisions, nor as to their correlation with the sub-zones of STOLLEY:

(1) A "Lower" sub-division exposed in—
England, in Hampshire, the Isle of Wight, Dorset, Norfolk.
France, at Villers St. Lucien, near Beauvais, N. France ; at Meudon, near Paris.

(2) A "Middle" sub-division exposed in—
England, in the Isle of Wight, Dorset, Norfolk.
France, at Meudon.

(3) An "Upper" sub-division exposed in—
England, in Norfolk.
Germany, in the Island of Rügen and N. Germany.
Denmark, both in Seeland and Jutland.
Sweden, in S.W. Scania.
France, in Charentes, Aquitaine.

There are, of course, other localities in which *mucronata* beds are found. The above classification, however, is based upon an actual examination of the Asteroid fauna of the beds concerned.

The Hampshire beds are only about 50 feet thick. They can be traced downwards into beds belonging to the sub-zone of *A. quadratus*. The fauna in the beds is very similar to that of the *quadratus* beds and may be regarded as a passage fauna.

By far the greater mass of the *mucronata* chalk of the Isle of Wight belongs to the "Lower" subdivision. The base of the zone is exposed at Scratchells Bay in the

* A deep boring in Denmark (3, p. 104) has gone through 2708 feet without exposing any other than Danian, *mucronata* or *quadratus* fossils. RAVN estimates from palæontological evidence that about 2000 feet belongs to the *mucronata* chalk. Even if it be assumed that his evidence is not entirely conclusive, there is in Denmark at least 1300 feet of chalk more than that existing in England. About 100 feet of this is Danian, but the remainder must belong to the *mucronata* zone.

west of the island. The Asteroidea here are of the same type as those found at the same horizon in Hampshire. In the east of the island the junction with the *quadratus* chalk is found at Whitecliff Bay. About 150 feet of *mucronata* chalk is exposed here. The occurrence of *Metopaster tumidus*, the characteristic *mucronata* member of the *Parkinsoni* series in these beds, shows the wide range of that form. Except in the first appearance of *M. tumidus* and the fact that *Crateraster quinqueloba* and *Metopaster uncatus* begin to become rare, there is little to mark this fauna as distinct from that of *quadratus* beds.

The 275 feet of chalk accessible in the Isle of Wight at Alum Bay shows a more extensive diversity of the fauna. The members of the *Crateraster quinqueloba* series, after a period of regression which bid fair to cause their extinction (pp. 121–122), assume a further period of predominance and show renewed elaboration. The new series, the "Teichaster" Series, now appears. At first, as is to be expected, the forms are low.

The fauna of the greater mass of the *mucronata* chalk found at Studland in Dorset appears to be contemporaneous with that already described from the Isle of Wight. An unknown thickness near the base of the Studland beds is cut off by a fault (ROWE, 41, ii, p. 32). This is unfortunate, as it renders it impossible to test any conclusions drawn from the respective faunas, as to the contemporaneity of the Isle of Wight and Studland beds, by exact measurements of thickness made in the field.

The fauna of the upper fifty feet of Studland chalk is classified here in the middle sub-division of the *mucronata*. The members of the Teichaster series have become higher. Further the ossicles found belonging to the Calliderma–Chomataster series are no longer the low forms of *Calliderma Smithiæ* but the high forms of *Chomataster præcursor*. A second form which is apparently characteristic of the higher *mucronata* beds and which begins to be noticeable here is *Metopaster undulatus*.

A distinct gap in our knowledge of the succession of the *mucronata* occurs here. Higher beds than those of Studland are not found in the south of England. We must journey to Norfolk to pick up the succession. From this point it is better to recommence our description in the reverse succession and deal with the rocks which are known to underlie immediately the Danian. These are met with in the Skrivekridt of Denmark. At Stevns Klint the *mucronata* beds may be seen immediately to underlie the Danian "Limsten." Characteristic ossicles are those belonging to the form of *Metopaster tumidus* figured Plate 15, fig. 1, and high forms of *Teichaster favosus*. Similar ossicles are found at Möen (Seeland) and Aalborg (Jutland).

The various collections which have been examined from the Island of Rügen unfortunately cannot be identified as belonging to any particular horizon out of the 450 feet exposed. Nevertheless the occurrence of this same form of *Metopaster tumidus* suggests that some beds are contemporaneous with those of the Skrivekridt

of Denmark. This conclusion agrees with that of DEECKE, RAVN, and other workers.

The same Skrivekridt fauna is found at the Alte Fabrik, Hemmoor, Hanover.

The ossicles from Rügen also show that a more primitive lower form of *Metopaster tumidus* was common, as was also *M. tumidus*, var. *radiatus*. *Chomataster acules* and *Metopaster undulatus* (both rugose and non-rugose) forms are also characteristically abundant. *Metopaster uncatus* is never found, nor is *Calliderma Smithiæ*. *Crateraster quinqueloba* is very rare, and so are forms of the Stauranderasteridæ. *Pycinaster crassus* has replaced *P. magnificus*.

Except that the "Skrivekridt" form of *Metopaster tumidus* is absent, the fauna of Trimingham, Norfolk, is almost exactly similar to that of the Rügen beds. The only remaining differences are probably those due to local conditions. *Ophryaster oligoplax* is very common at Trimingham but rarely found in collections from Rügen; *Metopaster tumidus*, var. *radiatus*, is smoother at Trimingham than at Rügen and there is some difference in the frequency of occurrence of *Lophidiaster pygmæus*. The exact age of the Trimingham beds has been a matter of some controversy and it is gratifying that these results support the conclusions of the careful work of BRYDONE (4–7).

The fauna of Weybourne, Norfolk, shows resemblances both to that of Trimingham and that in Dorset. It is, however, somewhat more primitive than the Trimingham fauna, inasmuch as all the ossicles of Chomataster belong to the species *præcursor*, whilst the *Metopaster undulatus* is of the earlier rugose form (p. 119).

Both these forms were mentioned as occurring at Studland, Dorset. That the Weybourne beds are somewhat later than the Studland beds is shown, however, by the non-occurrence at Weybourne of *Stauranderaster senonensis* and *Pycinaster magnificus*, both common characteristic fossils of the *mucronata* of the South of England.

It is probably to a more exact knowledge of the chalk in Norfolk, and in particular in the immediate area of Norwich, that we must look for the beds which will connect the horizons of Studland and Weybourne.

Beds of both the lower and middle subdivisions probably occur there. A collection forwarded by Dr. ROWE from pits in the area suggests, by the form of the ossicles of the Calliderma-Chomataster series, that the horizon in which they occurred was possibly not far removed from that of the Upper Studland beds.

The lower subdivision is exposed in France at Villers St. Lucien, near Beauvais. The Asteroids indicate a horizon not far removed from that exposed in Hampshire. This chalk is succeeded by the *mucronata* chalk of Margny-les-Compiègne and Meudon.

The few ossicles from Meudon include a form of *Mitraster Hunteri* (Plate 10, fig. 21) closely similar to that obtained from the lower *mucronata* chalk of the Isle of Wight

and also one ossicle of *Chomataster præcursor* similar to those from the upper beds of Studland. This suggests that the Meudon chalk belongs to both the lower and middle subdivisions as here defined.

Typical ossicles of *Metopaster tumidus* of Skrivekridt form have been obtained from the department of Charentes in the province of Aquitaine. This is the most southerly known occurrence of the species. The most northerly locality in which rocks of an upper *mucronata* horizon occur is S.W. Scania. The chalk here is not *in situ* but occurs in the form of large blocks, sometimes as much as 800 feet long and 15 metres thick, which are embedded in boulder clay and completely thrust over the Danian. Ossicles from these erratics have been collected at Jordberga and Hästhogshüsen.

The Danian.—These beds, as the name indicates, are characteristically developed in Denmark. Neither Ammonites nor Belemnites have been discovered in them. The characteristic fossils are *Nautilus danicus* and certain Gasteropods which are characteristic of the Tertiary. This disappearance of the Ammonites, which have previously characterised the Secondary deposits, and the appearance of the precursors of the Tertiary Gasteropods have induced some authors to place these beds in the Eocene. It will be seen by a reference to the zonal table (pp. 164, 165), that the Asteroids of the Danian are very closely related to those of the Upper Senonian and, in fact, belong to groups of forms which are as characteristically secondary as the Ammonites, and, like them, do not proceed upwards into Tertiary beds. Recent researches by Dr. BRÜNNICH NIELSEN (35), based upon a study of the Brachiopoda, have disclosed that the Danian chalk can be divided into three horizons: (1) The "older" Bryozoa-chalk, (2) the "newer" Bryozoa-chalk, and (3) the Crania-chalk.

Dr. NIELSEN kindly sent me a large collection of Asteroidea made in the same localities as those from which he had obtained Brachiopoda. Investigation of these fully bore out the distinction he had established between the "older" and the "newer" Bryozoa-chalk. No large terminal supero-marginalia of *Metopaster mammillatus* are found in the "newer" Bryozoa-chalk, for the species series has so far advanced that all members show catagenesis in this character (see p. 115). A variety, *retiformis*, of *Teichaster favosus* is also characteristic of these newer beds.

The Asteroid fauna of the Crania-chalk as developed at Herfölge shows little distinction from that of the "newer" Bryozoa-chalk. At Vodrofgaard and Copenhagen Harbour there is, however, a Greensand facies, in which no large ossicles are found. It is possible that this is due to a great reduction in size of the Danian sea, and in consequence some reduction in the food supply.

A large collection of ossicles from the Danian of Annetorp, Sweden, was examined. As has been shown for other groups, there is a very close correspondence between the Danish and Swedish faunas. Forms characteristic of both the "older" and the "newer" Bryozoa-chalk were obtained from Annetorp.

Metopaster mammillatus is found as far afield as the Vincenttown limestone of New Jersey, U.S.A. This occurrence helps to confirm the reputed Danian age of these beds.

The Fauna of the Cretaceous Rocks Deposited near the Shore.

The following faunas, which were deposited near the shores, differ in many respects from those already described :—

Marsupites Zone of Vendôme.—M. FILLIOZAT (17) has discovered certain neritic deposits in Vendôme which contain Marsupite plates. The Asteroidea of these deposits include *Metopaster tumidus* of a form closely allied to that found in the Maestrichtian (upper *mucronata*) of Belgium, and a thick form of Pycinaster somewhat resembling *Pycinaster crassus*, the characteristic upper *mucronata* form of the deep-sea area. I am at a loss to explain the occurrence of these forms in view of the otherwise marked parallel between the English and French chalk faunas (see also p. 119).

Greensand Beds of Teufelsmauer, near Weddersleben, Germany.—These beds also contain *Metopaster tumidus*. Their horizon is stated to be Lower Senonian. The occurrence of *M. tumidus* suggests an Upper Senonian age.

Trümmerkreide of N.E. Scania.—Many isolated exposures of chalk occur in N.E. Scania. This chalk generally differs from the fine-grained chalk of the more southern basin. It contains a large admixture of quartz grains, which suggest the close proximity of the shore. At the quarries at Balsberg there are great blocks of gneiss in the chalk, with the remains of Serpula, Brachiopods, and Bryozoa upon them. DE MORGAN (34) explains this by the supposition that the chalk was deposited near an island of gneiss, masses of which fell from the cliffs into the sea.

There are said to be two zones represented, a lower zone of *Actinocamax mammillatus*, in which *A. mammillatus* is common and *B. mucronata* rarely found, and an upper, in which there is no Actinocamax but in which *Belemnitella mucronata* abounds. STOLLEY (46) has shown that the area was occupied by a sea which was isolated from the main chalk area. The Actinocamax series took on a separate line of evolution, which resulted in the production of *A. mammillatus* rather than *A. quadratus*. The sea was not completely enclosed, as *A. mammillatus* is found, although rarely, accompanying *A. quadratus* in the rocks of N. Germany.

Later, *B. mucronata* invaded the area and became dominant.

The Asteroid fauna is very remarkable. All the forms of the *Metopaster Parkinsoni* series found in the greater number of localities (Balsberg, Stafversvad, Ignaberga, Oppmanna, Hemmingslycke) belong to a var. *calcar*, which resembles very closely the forms found characteristically in the Cenomanian and Turonian deposits of the main chalk sea. At the same time a form of *Metopaster uncatus* occurs, which is found in the sub-zone of *A. quadratus* of Hampshire.

The fauna of Karlshamn, in the extreme north of the area, differs somewhat from that already described. *Metopaster tumidus* of the typical *mucronata* type appears. A new species, *Metopaster crista-galli*, not otherwise met with, is also found. It may be that this species migrated in from even more northerly areas. The chalk of

Karlshamn is zoned with that of *A. mammillatus.* The occurrence of *M. tumidus* suggests that in certain localities *A. mammillatus* was contemporaneous with the *B. mucronata* of the main Chalk sea, a conclusion which agrees with the observations of STOLLEY (46).

The Maestrichtian of Belgium and the Montian of France.—The uppermost beds of the Upper Senonian of Belgium and the Danian beds of France show shallow-water conditions of deposit (HAUG, 23, p. 1304; DE LAPPARENT, 30, p. 1471). The Asteroid ossicles are often rolled and worn, and occasionally difficult to identify. The fauna of these shallow-water deposits differs considerably from that of the corresponding deeper water deposits of E. England, N. Germany, Denmark, and Sweden. Several large collections have been examined from the Maestrichtian of Belgium. These beds contain *Belemnitella mucronata* and *Scaphites constrictus*, and are hence usually classified with the upper *mucronata.* They, however, also contain *Nautilus danicus*, a typical Danian form. This has led RAVN (38, p. 443) to suggest that the Maestrichtian beds were deposited in an interval of time which is represented by a lacuna in the Danish rocks. This lacuna probably occurs at the junction of the Senonian and Danian deposits. Some support was afforded to the suggestion of RAVN's by the fauna of the Asteroidea. *Metopaster tumidus*, the typical Upper Senonian Asteroid, is present in some abundance. It is, however, of a form somewhat distinct from that in the more northern area (see p. 114). At the same time, a few ossicles of *Metopaster mammillatus*, the typical Danian form, are found. The explanation of this phenomenon may, perhaps, be sought for in the supposition that the Maestrichtian area was isolated from the main Chalk sea, possibly by currents. The species of Metopaster consequently assumed a special varietal shape. From time to time migrants accidentally make their way into the area and give a clue to the contemporaneity of the deposits.

Teichaster favosus and *Chomataster acules* are so rarely found in Belgium that this theory of isolation receives considerable support. It will be remembered (see pp. 146, 147) that these two forms are amongst the most typical of those found in the Upper Senonian and Danian of the main Chalk sea.

A variety of *Lophidiaster pygmæus* occurs which appears to be represented in the Calcaire Grossier (Eocene) of N. France. This transition from Cretaceous to Tertiary forms in the area is paralleled by the fauna of the Gasteropods (HAUG, 23, p. 1304). A small collection of ossicles from the pisolitic chalk of Laversine, near Beauvais (Coll. M. JANET), contained worn ossicles of *Stauranderaster bulbiferus* and *Metopaster mammillatus.* This is in accordance with the reputed Danian (Lower Montian) age of these beds (DE LAPPARENT, 30, p. 1471).

The Greensands of Köpinge.—A part of these Greensands are usually classified (STOLLEY, 46), with the middle *mucronata* (zone of *Sc. spiniger*), and a part with the upper *mucronata* (zone of *Sc. constrictus*). Ossicles from these beds are represented in several collections. The great majority belong to *Chomataster præcursor*, a typical

Asteroid of the middle *mucronata*. No ossicles characteristic of a higher horizon have been observed.

Cretaceous Asteroidea from Egypt.

A careful description of a collection of Asteroidea found in the Cretaceous (mid-zonal) rocks of Abou Roach was one of the latest pieces of work undertaken by the late Prof. DE LORIOL (31). The forms were collected by M. FOURTAU, and by his courtesy it has been possible for me to compare the original specimens with material from N.W. Europe.

DE LORIOL described the following species :—

Comptonia Schlumbergeri, de Loriol.
Comptonia Fourtaui, de Loriol.
Forbesiaster Wrighti, de Loriol.
Metopaster Teilhardi, de Loriol.
Pachyaster Ægyptiacus, de Loriol.
Sladenia Fourtaui, de Loriol.
Chariaster elegans, de Loriol.

None of these species can be placed in the "species series" described in the previous sections.

The species described under the generic name Comptonia show the primitive ornament which probably characterised not only Comptonia, but also many other Asteroid root-stocks.

Metopaster Teilhardi is not a species of a true Metopaster, Sladen. The marginalia do not possess the characteristic ornament of that genus. The only points of resemblance are the general shape of the body (without produced arms) and the fusion of the more distal supero-marginalia to form a large terminal plate. In the Egyptian "Metopaster" the more distal infero-marginalia also undergo a corresponding fusion. This never occurs in forms of the true genus.

The remaining genera have, up to the present, only been found in the area. It is interesting to note, however, that *Sladenia Fourtaui* presents characters which suggest that it is a primitive representative of the recent genus Echinaster, Müller and Troschel.

It is clear that these Egyptian Cretaceous rocks contain an Asteroid fauna which belongs to a distinct province from that of N.W. Europe.

Section IV.—VARIATION AND EVOLUTION.

An endeavour is made in the following sections to arrive through measurement at data which will :—

(1) Express variation within a zonal period.

(2) Indicate the rate of evolution and afford evidence as to its continuity or discontinuity.

(3) Discover the causes of the formation of new species.

Material and Method.—It has not been possible to collect together such a number

of well-preserved specimens of any one species as would afford statistical evidence of variability. In consequence, reliance has to be placed upon measurements of isolated ossicles. Fortunately, the majority of the supero-marginalia of any individual members of the *Metopaster Parkinsoni* lineage are closely similar. Hence any one of these ossicles will show whether the individual to which it originally belonged was small or large, high or depressed, and so on. Further, these ossicles are some of the most abundant and readily recognisable of all those found in the chalk.

The two measurements which were chosen were :—

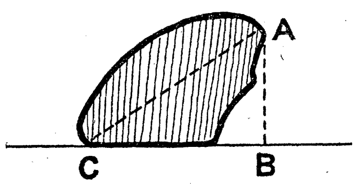
(1) That of the height of the ossicles as showing the depth of the individual.

(2) That of the length of the ossicles as showing the size of the individual.

It will be seen that each measurement bears direct relationship to the size of the visceral cavity (p. 158).

In addition, variations in the size of the spine pits and the general form of the surface of the plates have also been considered. These features are the main of those which vary in the species-series considered.

A glance at Plate 10, figs. 12–16, shows that the height of the ossicles, as seen in profile view, increases as we progress upwards through the chalk. The method by which this increase in height can be measured can best be understood by reference to the accompanying diagram (text-fig. C). The supero-marginal was placed with its lower articulating surface plumb upon a straight line drawn upon an even surface of plasticine. Measurements of AB and BC, made by means of callipers, furnished with a micrometer screw, gave AB/BC = tan BCA. By means of tables the angle can be found in the usual way. This angle is termed the ossicular angle.



TEXT-FIG. C.

Variation in the Individual.

First of all measurements must be considered which will throw light on the variability of the supero-marginalia of the same specimen.

Four sets of associated ossicles of *Metopaster tumidus* from Trimingham (Mr. BRYDONE'S Collection) gave the following measurements for tan BCA :—First set : 0·59, 0·60, 0·60, 0·59, 0·58, 0·59, 0·60, 0·65, 0·60, 0·63, 0·60, 0·60, 0·64, 0·64, 0·60, 0·64, 0·64, 0·61, 0·66, 0·61, 0·61, 0·62, 0·69. Second set: 0·74, 0·77, 0·75, 0·77, 0·66, 0·71, 0·74, 0·77, 0·81, 0·77, 0·77. Third set : 0·66, 0·65, 0·66, 0·63, 0·59, 0·65, 0·64, 0·64, 0·64, 0·65, 0·66, 0·62, 0·57. Fourth set : 0·73, 0·75, 0·76, 0·72, 0·81, 0·67, 0·72, 0·79, 0·70, 0·73, 0·86, 0·86, 0·65, 0·68.

A further set from the zone of *Micraster cor-anguinum* (Mr. BRYDONE'S Collection) gave the following :—0·46, 0·50, 0·51, 0·54, 0·47, 0·49, 0·50, 0·49, 0·46, 0·49, 0·54.

It will be seen therefore that if we measure this character in a single ossicle the chances are that it affords a fair index of the same character in the whole of the similarly situated ossicles of the specimen of which it once formed a part, and it follows that if we measure in this manner 50 isolated ossicles we have an index of the character of approximately the same number of individuals.

It is also obvious that if there were the same number of marginalia in all members of the species series, and at the same time little variation in the length of the ossicles in the same specimen, the size of any individual could be deduced from measurements of a single ossicle.

(1) *Evidence as to the Constancy of the Number of Supero-marginalia*—

(*a*) *Low zones.*—A specimen from the low zones has been figured in the monograph of the Palæontographical Society (see p. 110). This shows that there were four supero-marginalia, two median and two terminal, counting from the tip of one ray to the tip of the adjacent ray. A fragmentary specimen in the possession of Mr. DIBLEY, from the zone of *T. gracilis*, shows that there were in other forms at least six supero-marginalia in the above position. The number of supero-marginalia was probably increasing during this period.

(*b*) *Mid-zones.*—A large number of specimens are known from these zones. Almost always there are eight supero-marginalia along each side. Individuals with one or two intercalated ossicles are found, but they are rare variations.

(*c*) *High zones.*—Unfortunately no specimens have been found in the zone of *B. mucronata* and the Danian which would enable us to say with certainty the number of supero-marginalia possessed by the forms. The reconstructed specimen of *M. tumidus*, var. *radiatus* (Plate 14, fig. 3), from the Collection of Mr. BRYDONE, suggests that there may have been two more ossicles intercalated in each side during the lower *mucronata* period. It is improbable that there was any greater divergence than this.

The evidence appears to show therefore that, except in zones at the base of the chalk, the number of supero-marginalia in individuals of the species series varies only to a slight degree.

(2) *Evidence as to Similarity in Length of Ossicles of the same Specimen*—

The variability of ossicles with respect to this character in the same individual was assessed by measurement of the associated ossicles already mentioned and by investigations on the specimens in the Collections of the British Museum (Natural History). Specimen 40239 (Brit. Mus.) shows the amount of variation usually met with. The lengths of the individual median supero-marginalia which were preserved were as follows :—4·6, 4·9, 4·8, 4·2, 4·6, 5·1, 4·1, 4·5, 4·5, 4·5, 4·8, 4·7, 4·5, 4·6, 4·9, 4·5, 4·8, 5·0, 4·2, 4·6, 4·8, 4·1, 5·0. Variations exceeding these were very rare.

Variation in the Race.

We may now pass on to a consideration of similar measurements made of the whole of the ossicles of the *M. Parkinsoni* lineage from the various zones. For convenience the results are tabulated so that the ossicular angles fall into the following seven groups:—17–23°, 24–30°, 31–37°, 38–44°, 45–51°, 52–58°, each group representing an interval of seven degrees. It will be seen that the wide limits of each group allow for the range of variability discovered in the individuals.

Zone.	17–23°. $\tan^{-1} 0{\cdot}30$–$\tan^{-1} 0{\cdot}43$.	24–30°. $\tan^{-1} 0{\cdot}44$–$\tan^{-1} 0{\cdot}59$.	31–37°. $\tan^{-1} 0{\cdot}60$–$\tan^{-1} 0{\cdot}77$.	38–44°. $\tan^{-1} 0{\cdot}78$–$\tan^{-1} 0{\cdot}99$.	45–51°. $\tan^{-1} 1{\cdot}0$–$\tan^{-1} 1{\cdot}27$	52–58°. $\tan^{-1} 1{\cdot}28$–$\tan^{-1} 1{\cdot}67$.	No. of ossicles measured.*
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	
Danian (Sweden)	2	6	22	34	34	2	205
"U" *B. mucronata* (Rügen)	3	22	37	26	10	2	204
"L" *B. mucronata* –sub-zone of *A. quadratus*	24	54	22				41
Sub-zone of *O. pilula* – Marsupites	5	21	71	3			63
M. cor-anguinum .	4	48	43	5			58
Low zones . . .	18	67	15				43

* Except where otherwise stated, the ossicles measured were from the English Chalk (mostly Hants and Wilts).

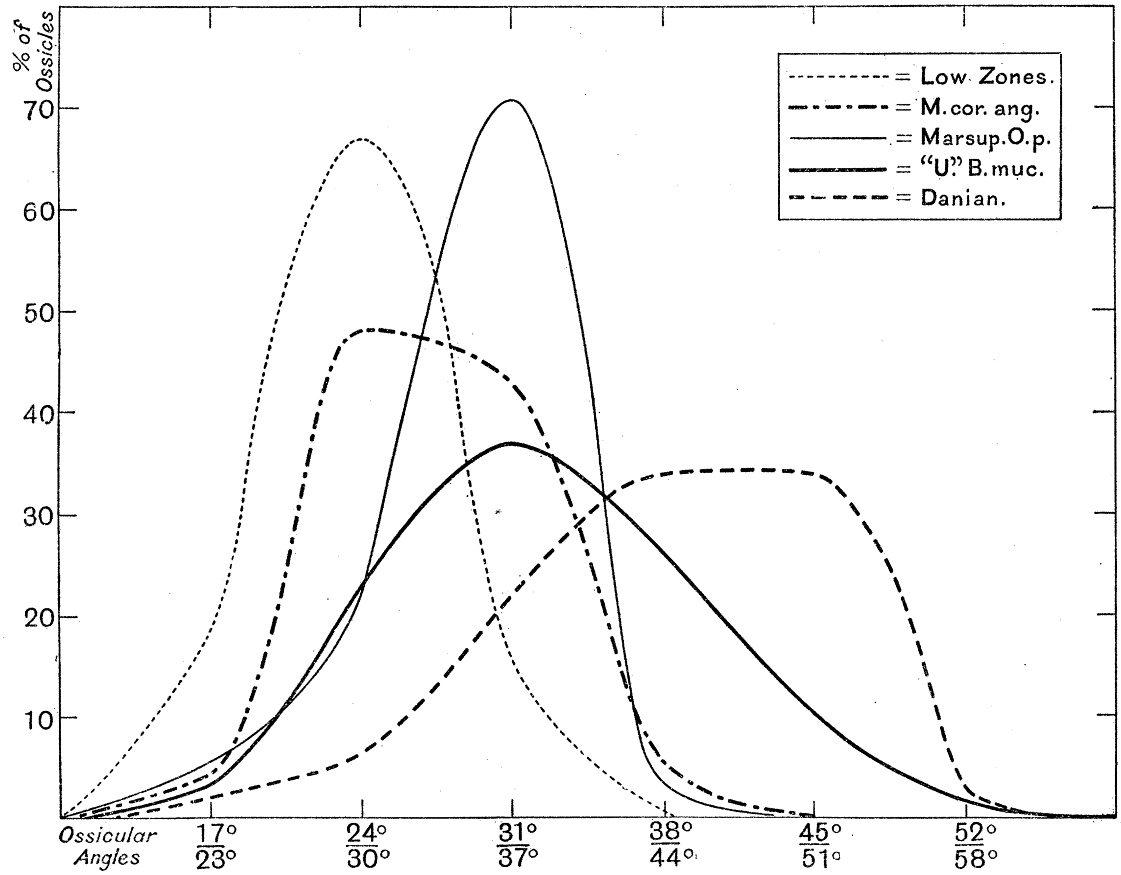
It may be objected that the above measurements only deal with a limited amount of material. Observations were therefore made with a view to testing the validity of such criticism. Sixty-three ossicles were measured from the Danian of Denmark. The percentages corresponding to those in the table were 2 per cent., 6 per cent., 19 per cent., 28 per cent., 43 per cent., 2 per cent.: a remarkably close agreement with the measurements from the same horizon in Sweden.

Again, the mean ossicular angle for 24 ossicles from the zone of *Rh. Cuvieri* of Devonshire was found to be 26°, whilst 13 ossicles measured from the closely succeeding zone of *T. lata* had a mean ossicular angle of 28°.

Similar results were obtained from corresponding measurements of small numbers of ossicles from neighbouring horizons in the mid-zones. It may safely be argued therefore that the character of the ossicular angle in this lineage is a fair index of horizon even with a limited mass of material.

It was found that the ossicular angle of forms of *M. exsculptus* were similar to those of *M. Parkinsoni*, and the measurements of these are included.

The measurements given in the above table can be shown graphically by means of curves (text-fig. D).



TEXT-FIG. D.*

It is seen :—

(1) That in each zone the osssicular angle of members of the lineage varies continuously about a mode.

(2) That there are two periods of elaboration ; the first up to the top of the sub-zone of *Offaster pilula*, the second during the upper part of the zone of *Belemnitella mucronata* and in the Danian. Between these two periods there is a period of regression.

(3) That increase in height is accompanied by a spreading out of the range of the variation and that the period of maximum elaboration coincides with that of maximum variability.

Further details concerning each of these conclusions are given below.

Variation is, in general, Continuous.—It is clear that there is no apparent discontinuity in the variations in height. Parallel results may be obtained from measurements of length. Observations upon the size of the diameter of the circular

* The curve for the regression period has been omitted in the figure as it detracted from clearness. Mr. W. F. SHEPPARD suggested that integral curves would afford clearer details. I have not, however, used them, as the "humpbacked" curves are more familiar to the modern biologist.

spine pits, the amount of the plate which possesses spine pits, the size and form of protuberances upon the plates, also fail to show any pronounced break in graduation in character.

In fact, it is clear, from the description of the species given in Section II, that the great majority of the variations exhibited in Chalk starfish are of the continuous type.

Discontinuous variations ("mutations" of DE VRIES, more properly called saltations) may occur. Previously it has been explained that both *Crateraster quinqueloba*, var. *depressus* (p. 121), and *Metopaster quadratus*, var. *parvus* (p. 117), may be true saltations. These saltations, however, are lost sight of after a racial life of comparatively short duration.

Correlation of Variations.—The fact that variation is continuous is the main cause of difficulty to the field geologist who wishes to determine zonal horizons, for, unless a fair amount of material be obtained, it is frequently far from easy to decide whether the specimens are truly typical of the horizon.

Fortunately, some species possess a number of diverse characters which, although each fluctuates about a mean, do not show marked correlation in their variability. Thus ossicles of *Metopaster tumidus* and *M. mammillatus* are especially valuable as zonal guides, for they are not only abundant but also possess four imperfectly correlated characters, namely, height, size, and frequency of spine pits, and prominent tumidities. If the ossicles are low, a character which in itself would suggest a low horizon, they almost always show other characters typical of their own true horizon.

A. W. ROWE (40), in his investigation of the Micrasters, made a detailed study of the variations of 18 characters. All these characters do not elaborate at the same rate in each individual. The consequent diversities of form allow the chalk in which they are found to be zoned almost foot by foot.

Elaboration is often Periodic.—It is also noticeable that the evolution of the ossicular angle is not a straightforward advance, but an advance in two periods which are separated by a period of marked regression. Similar rhythms in the path of the evolution have also been noticed with respect to the size of the ossicles, the diameter of the spine pits and protuberances upon the plate surfaces (p. 109). Periodicity has also been noticed in the development of the Calliderma–Chomataster and Crateraster–Teichaster lineages (pp. 126 and 121).

This periodicity has been noticed by several workers. BUCKMAN (10) in describing the lineage history of the Inferior Oolite Ammonites states (p. cc) that "In test ornament, elaboration is anagenetic, and simplification is catagenetic. The transverse ornament may show the following successive stages of morphogeny: in anagenesis, striation, subcostation, costation, unituberculation, bituberculation, multi-tuberculation; and, in catagenesis, the same stages in reverse order till all ornament is again lost, and smoothness is returned to. Or, after a period of decline, renewed elaboration may take place; thus a species which shows in its ontogeny catagenesis from

tuberculate to subcostate may elaborate fresh anagenetic stages from subcostate to tuberculate: *Sonninia renovata* is a notable example."

LANG (28) has clearly shown three elaboration periods in the evolution of Parasmilia. Between these there are two periods of regression. BERNARD (2) lays great stress upon the same phenomenon.

The diagrams drawn by LANG (p. 288) show that in Parasmilia there is a short period of rapid katagenesis followed immediately by a long period of rapid anagenesis. In the starfish there is considerable diversity in the lineages with respect to this. In the *M. Parkinsoni* series, for instance, rapid regression in the ossicular angle is at once succeeded by a long period of elaboration, while rapid regression in the diameter of the spine pits is succeeded by a long period (*T. lata* to mid-*mucronata*) in which there is no change in the character, after which rapid elaboration again sets in.

The Amount of the Range of the Variation is Periodic.—Together with this periodic wave in elaboration, there is a periodicity in the amount of the range of the variation. The right ends of the curve (text-fig. D) become "nipped" on the left in the zonal periods on which there is a decline in elaboration and become correspondingly spread out during increase in elaboration. These rhythmic phases of the range of the variation have not hitherto been noticed. The nipping in of the curve is at first sight somewhat analogous to the "periodic" selection of WELDON (49). In the regression curve, however, only the "giants" disappear, whilst in "periodic" selection both the "giants" and "dwarfs" are eliminated.

The close connection between the rhythmic phase of the quality of the character and the range in variability is important, as it indicates that a strong innate influence is at work in the production of variations and suggests that frequently too much stress has been laid upon the influence of environment or physiological adaptation to external conditions. There does not appear to have been any change during the Chalk epoch in external conditions sufficiently marked to bring about regression. On the other hand, there is a close connection between the general vitality of the race as shown by the numbers of ossicles found and the elaboration phases. Thus *Metopaster tumidus* and *M. mammillatus* are the most elaborated forms of the *Parkinsoni* lineage and are distinctly the dominant forms of the period in which they lived. Out of about 1,200 ossicles from the Danian of Denmark, 850 belonged to *M. mammillatus*, and out of 250 from the same locality but of *mucronata* age 150 were identified as belonging to *M. tumidus*. The ossicles from Annetorp and Rügen gave corresponding results.

On the other hand the proportion of ossicles of *M. Parkinsoni* in the zone of Marsupites is less than 15 per cent., whereas ossicles of *Crateraster quinqueloba*, which here reaches its stage of maximum elaboration, numbered more than 60 per cent.

It may be that forms of a lineage which is at its dominant phase may have a greater resistant power to their environment than at other times. Care must be taken, however, to obtain further knowledge before too wide an interpretation be placed upon this suggestion.

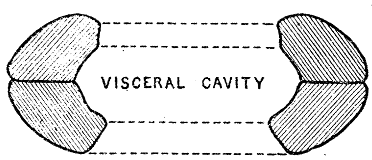
Causes of Change in the Lineage.

Selection.—The most obvious way to look for an explanation of the advance in height in the *Metopaster Parkinsoni* lineage is to endeavour to find some physiological advantage which would give "high" starfish an advantage in the struggle for existence. That "high" starfish have some such physiological advantage appears to follow from a comparison of the length of life of the various lineages. Thus, the *Metopaster uncatus* series branched off at a very early period from the *Parkinsoni* series (pp. 115 and 116). Although in other respects the course of evolution is parallel, the *uncatus* series, unlike the *Parkinsoni* series, never built up high forms. It is this want of plasticity which may have caused their comparatively early extinction.

The *Mitraster* series, which branched off at the same time as the *uncatus* series, also never built up high forms. Members of the series are never abundant, and it is perhaps significant that they appear to occur most commonly during the period (*A. quadratus*–low *mucronata*) which is characterised by regressed low forms of *M. Parkinsoni*. The series persists, however, until late *mucronata* times.

Now it is not difficult to hazard an explanation as to the advantage of the increase in height of the ossicles.

An investigation of the infero-marginalia of the species belonging to the *Metopaster Parkinsoni* series showed that they have an increase in height corresponding to that of the supero-marginalia (see, *e.g.*, Plate 10, figs. 12–16). The body of the starfish therefore increases in height as we progress upwards through the zones. The marginalia border the visceral cavity (text-fig. E), and the increase in depth allows a greater proportionate space for the digestive organs and gonads. It is possible that an increase in size of the digestive organs gives individuals an advantage. It is obvious that the larger the gonads the more fertile any individual will be. Its young will be in greater numbers and tend to crowd out the progeny of less favoured stock. Progress in height will thus be ensured.



TEXT-FIG. E.

If we assume that the increase of space for the digestive organs gave a physiological advantage, and if selection took place, it is clear that the selective death rate would tend to weed out the "low" starfish at an early age and allow "high" starfish to live for a longer time. The size of the ossicle gives an indication of the age at which the starfish perished. Small ossicles will in general indicate young starfish, whilst large ossicles suggest a more mature old age.

If we therefore construct tables which show the relation between the size of the ossicle and the ossicular angle, we can see whether an increase in height was of advantage to the individual in the struggle for existence. Examples of such tables are given below :—

	Length of ossicle.	Ossicular angles.						Mean ossicular angle.
		20°	27°	34°	41°	48°	55°	
	mm.							°
Rügen	3·0–3·9	5	12	6	6			30·0
	4·0–4·9	1	24	37	9			32·3
	5·0–5·9		8	25	21	5		36·7
	6·0–6·9	1	1	6	9	5	3	41·0
	7·0–7·9			1	5	5	1	44·5
	8·0–8·9				3	3		44·5
	9·0–9·9					2		48·0
M. cor-anguinum . .	1·0–1·9		5	2	1			30·5
	2·0–2·9		7	11	1			31·8
	3·0–3·9	2	11	7	1			29·3
	4·0–4·9		4	4				30·5
	5·0–5·9		1	1				30·5

It is seen that, although the measurements of ossicles from the *mucronata* chalk of the Island of Rügen suggest that the low-angled forms died at an earlier age than the high forms, there is no evidence of such selective action in the period represented by the zone of *M. cor-anguinum*.

Other tables which were constructed gave analogous results. It follows, therefore, that the measurements do not support the view that selection, following upon the "advantage" of increased space for the digestive organs, moulded "low" into "high" forms.

Further, it is clear that selection following upon the increased space for either the digestive organs or the gonads will not explain the interposition of a period in the lineage history when regression in height takes place.

Lineage History is pre-determined.—The balance of evidence afforded by the investigations, the results of which are given in the descriptions of the "species series," suggest that the path of evolution is strictly defined. Parallel stages are passed through by all the races, and it is possible to prophesy some considerable part of the lineage development of a form even before the whole of its members are known. These results are comparable with those obtained by HYATT and BUCKMAN from the study of Ammonites and with the well known observations of other observers upon many groups. They undoubtedly lead to the conclusion that the course of at least some variations is not fortuitous but predetermined for the race.

The fact that closely allied races differ in their capacity for elaboration supports this hypothesis. There appear to be essential differences developed in the germ cells of the *Metopaster uncatus* and *Mitraster Hunteri* lineages when they branch off from the *Metopaster Parkinsoni* stem which prevented their building up high forms, differences which also suggest "step" mutations at birth.

Action of the Environment.—The rate of elaboration is, however, influenced in some way by the environment. The primitive characters of the members of the *Parkinsoni* series which lived in high-zonal times in the inland sea of N.E. Scania have already been mentioned (p. 119).

Again, the ossicles of the same series from the shallow-water deposits of the Maestrichtian of Belgium also exhibit a lower ossicular angle than those of contemporaneous forms living in the main Chalk sea. Twenty-nine ossicles from this locality had a mean tangent of the ossicular angle of only 0·59, whilst the corresponding figures for the ossicles from the upper *mucronata* of Rügen was 0·72. Investigation was made therefore to discover if possible some cause of the influence.

(1) *Depth of Water.*—The differences between these "shallow" and "deep" water faunas cannot have arisen from the direct action of the depth of water in which the starfish lived. The changes in depth in the main Chalk sea, such as, *e.g.*, the uplift in *Holaster planus* times, appear to have no determinable influence upon the rate of elaboration of the various characters in the lineages.

(2) *Food Supply.*—There is also no evidence that the differences in elaboration are due to relative starvation. The *Metopaster tumidus* from the Maestrichtian area are just as large as those from the Rügen area.

(3) *Consanguineous Fertilisation.*—The larvæ of starfish are usually free-swimming organisms which live, drifting at the mercy of the currents, at the surface of the sea. Hence it is not surprising that the examination of ossicles from the same horizon, although of different localities, gives corresponding results so long as we deal with material from the main Chalk sea. The method of life of the larvæ allowed constant admixture of forms from all parts of the area. In a small inland sea, such as that in N.E. Scania, there must have been to a much greater extent a cross-fertilisation of forms nearly akin. It is possible also that the action of currents had a similar effect by causing the isolation of the shallow-water fauna of Maestricht. Unfortunately this supposition cannot be tested, but it is advanced as a possible explanation of the phenomena observed.

Conclusions.

It will be seen from the preceding statements that it is possible to obtain suggestive conclusions from detailed observations upon material which at first sight looked far from promising. Isolated ossicles and fragmentary specimens allow us to follow the Chalk starfish through very much of their lineage history.

It is seen that hereditary changes are in definite directions, which are as a whole parallel in character for the majority of the lineages. The ebb and flow in the vitality of the lineages is, however, not regular, but exhibits pulsations which are independent of outside influences, so far as can be tested by observations upon changes in the depth of water and the general conditions of existence. It is these phenomena which suggest the relative negligibility of environmental influence as compared with that of inborn racial character.

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INDEX.

ZONAL RECORDS.

The following signs are used in the table of zonal records :—

CC = Very common.
C = Common.
RC = Rarely common.
R = Rare.
RR = Very rare.
+ is used when ossicles of the species are present, but not in sufficient numbers to determine the frequency of occurrence.

An asterisk (*) is placed above certain records of *Lophidiaster ornatus* to indicate that these records refer to one locality (see p. 142).

The records relating to the *Metopaster Parkinsoni* series are not arranged alphabetically but according to the development of the species in the lineage.

In the Low zones various counties are grouped. S.E. England = Kent, Surrey, Sussex, and Hampshire. S.W. England = Devon and Dorset. N.E. England = Yorkshire, Lincolnshire, and Norfolk.

In the zone of Marsupites the ossicles from Kent and Sussex and Yorkshire were almost entirely from the collection of Dr. ROWE, and in consequence the limits of the zone for these counties is taken as defined by him (41, Kent and Sussex, p. 296). The ossicles from Hampshire were obtained by Mr. BRYDONE and the records refer to the "bands" as defined (8, pp. 8, 9.)

In order to economise space the following records are not placed in the table :—

Cenomanian ... Lincolnshire : *Calliderma Smithiæ.*
Cap de la Hève, N. France : *Stauranderaster* (?) *decoratus*, *Tholaster ocellatus.*

Turonian ... ... Normandy : *Calliderma Smithiæ*, *Crateraster quinqueloba*, *Metopaster Parkinsoni*, *Pycinaster humilis*, *Stauranderaster bulbiferus*, *S. gibbosus.*

Senonian ... ... Ober Pläner of—
Archlan, *M. Parkinsoni*, *C. Smithiæ.*
Piss, *C. Smithiæ.*
Zone of *Micraster cor-anguinum* (in the sense of ROWE, see p. 105), of—
Yorkshire, *Stauranderaster coronatus*, *Crateraster quinqueloba.*
Norfolk, *Calliderma Smithiæ*, *Crateraster quinqueloba*, *Metopaster Parkinsoni*, *M. uncatus.*
Zone of Uintacrinus of Recklinghausen, Westphalia, *Lophidiaster ornatus*, *Crateraster quinqueloba* ?

[*Continued on p.* 170.

TABLE OF

					Zone of *P. asper*.		Zone of *Sch. varians*.	Zone of *H. subglobosus*.		Zone of *Rh. Cuvieri*.			Zone of *T. gracilis*.			Zone of *H. planus*.				Zone of *M. cor-test.*, and lower quarter, *M. cor-ang*.		
	Jurassic.	Neocomian.	Aptian.	Albian.	Upper Greensand, England.	"Tourtia," Essen, Germany.	Chalk and chloritic marl, England.	Unter Pläner, Germany.	S.E. England.	S.W. England.	S.E. England.	N.E. England.	S.W. England.	S.E. England.	N.E. England.	S.W. England.	S.E. England.	N.E. England.	Normandy, France.	S.W. England.	S.E. England.	
Arthraster series—																						
A. cristatus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
A. Dixoni, Forbes	...	...	...	...	...	...	C	...	R	RC	R	...	R	RR	...	R	...	...	...	...	...	2
Calliderma series—	+																					
C. latum, Forbes	...	...	...	...	...	...	...	...	C	...	...	...	...	...	...	...	...	...	...	...	...	3
C. Smithiæ, Forbes	...	...	...	...	+	+	CC	+	CC	CC	CC	+	CC	CC	+	CC	CC	C	C	C	C	4
Sub-gen. Tylaster—																						
Ty. jurensis, Münster	+	...	+	...	+	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
Comptonia series—																						
C. Comptoni, Forbes	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6
C. elegans, Gray	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7
Chomataster series—																						
Ch. acules, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8
Ch. præcursor, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9
Crateraster series—																						
Cr. obtusus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	10
Cr. quinqueloba, Goldfuss	...	...	...	...	...	...	...	...	+	C	+	+	C	+	...	+	RC	+	+	RC	RC	11
,, var. *depressus*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	12
Hadranderaster series—																						
H. simplex, Geinitz	...	...	...	...	...	...	...	+	...	...	...	...	R	R	...	...	...	...	...	...	...	13
Lophidiaster series—	+	+	+																			
L. ornatus, Spencer	...	...	...	+	...	...	...	...	...	...	...	...	*	...	...	C	C	+	+	*	RR	14
L. pygmæus, von Hagenow, M.S.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15
Metopaster Parkinsoni series—					+																	
M. thoracifer, Geinitz	...	...	...	...	...	...	+	C	...	CC	+	...	RR	...	...	...	...	...	...	...	...	16
M. Parkinsoni, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	C	+	+	C	C	R	C	C	C	17
,, var. *calcar*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18
M. exsculptus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19
M. tumidus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20
,, radiate var.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21
M. mammillatus, Gabb	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	22
,, radiate var.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23
Metopaster uncatus series—																						
M. uncatus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	RC	+	...	RC	+	...	...	RC	C	24
M. quadratus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	25
Metopaster undulatus series—																						
M. decipiens, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	26
M. undulatus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	27
,, rugose var.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	28
Mitraster series—																						
M. Hunteri, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	29
M. rugatus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30
M. compactus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	...	...	+	...	31
Ophryaster series—																						
O. magnus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32
O. oligoplax, Sladen	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	33
Phocidaster grandis, Spencer	...	...	...	...	+	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	34
Pycinaster series—																						
P. angustatus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35
P. crassus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	36
P. humilis, Spencer	...	...	...	...	+	+	+	+	C	C	+	...	C	+	...	RC	+	+	C	+	+	37
P. magnificus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	38
Stauranderaster series—	+																					
S. Boysii, Forbes	...	...	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	+	39
S. bulbiferus, Forbes	...	...	...	...	...	...	...	C	...	C	...	...	RC	...	+	R	+	...	+	...	+	40
S. coronatus, Forbes	...	...	...	...	...	...	+	+	+	CC	+	...	RC	+	+	...	...	+	...	+	...	41
S. gibbosus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	42
,, var. *pyramidalis*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	43
S. pistilliferus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	44
S. senonensis, Valette	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	45
Teichaster series—																						
T. favosus, Spencer	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	46
,, var. *retiformis*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47
Tholaster series—																						
Th. argus, Spencer	...	...	...	...	...	...	...	...	...	RC	+	...	...	+	...	R	+	+	...	+	+	48
Th. ocellatus, Forbes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	+	49
Trachyaster series—																						
Tr. radiatus, Spencer	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	50
Tr. rugosus, Spencer	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	51

←———— Low Zones ————→

ZONAL RECORDS.

	Zone of *M. cor-anguinum* (upper three-quarters).			Zone of Marsupites.				Sub-zone of *O. pilula*.					Sub-zone of *A. quadratus*.		Passage beds.		"L" Mucronata.					"M" Mucronata.					"U" Mucronata.				Danian. Denmark.			Danian.
	Kent and Sussex.	Hampshire and I. of Wight.	Normandy.	Kent and Sussex.	Hampshire (Uinta band).	Hampshire (Marsupite band).	Yorkshire.	Hampshire.	Yonne, France.	Beauvais, N. France.	Yorkshire.	Sussex.	Hampshire.	Sussex.	Hampshire.	Trümmerkreide, Sweden.	Isle of Wight.	Dorset.	Norfolk.	Beauvais, N. France.	Meudon, France.	Isle of Wight.	Dorset.	Norwich.	Weybourne, Norfolk.	Meudon, France.	Trimingham, Norfolk.	Isle of Rügen.	Skrivekridt, Denmark.	Maastrichtien, Belgium.	Older Bryozoa-chalk.	Newer Bryozoa-chalk.	Crania-chalk.	Annetorp, Sweden.
1	R	R	R	...	RR	RR	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RR	...	...	RR	...	...	...
2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	R	R	RC	RC	R	RR	+	RC	...	+	+	RC	RC	RC	R	...	RC	RC	+	...	...	...	RC	C	...	...	...	...	...	...	...	...	...	...
5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	RC	R	...	R	R	R	R
9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RC	R	R	+	+	C	RC	...	...	...	...	...	...
10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	C	C	R	CC	CC	CC	+	C	...	+	+	C	C	RC	C	...	+	R	+	+	...	...	R	...	...	...	RR	RR	...	...	...	...	...	...
12	...	...	...	...	...	...	...	RC	...	...	...	C	RC	C	RR	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	RR	...	R	...	...	...	RC	R	RR	RR	...	...	RR	...	...	...	...	...	...	...	...	...	...	...	RR	...	...	...	...
14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...	...	...	...	...	RR	C	RR	...	...	...	...	...	...	...	...	RR	C	...	...	R	CC	R	C	R	R	RC	...
16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	C	C	C	RC	RC	RC	+	C	+	+	+	C	C	C	C	...	C	C	...	...	...	...	C	...	...	...	...	...	...	...	...	...	...	...
18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	C	C	+	...	...	...	+	...	...	...	+	...	RR	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RC	...	...	...	...	...	RC	...	...	...	RC	RC	C	C	...	...	...	...
21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CC	CC	R	...	...	...	...	...
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RR	C	...	...	RC
23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CC	CC	CC	CC
24	C	C	C	C	C	C	...	C	...	...	+	CC	CC	C	C	R	R	R	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	...	...	+	R	R	R	...	C	...	...	...	C	C	C	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	...	...	...	...	...	...	...	...	...	...	...	RR	R	...	RR	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CC	CC	R	...	...	RR	...	...
28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	+	...	C	C	...	...	...	...	...	...
29	R	R	RC	...	...	...	...	...	...	...	...	...	RC	...	RC	...	RC	R	...	+	...	...	...	...	...	...	...	RC	RR	...	RR	RR	...	...
30	C	C	C	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	CC	...	...	...	...	...	...
33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RC	...	...	...	...	RC	RC	...	...	C	...	...	...	...	...	...	...
34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35	R	R	R	RC	R	RC	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	+	...	RC	RC	R	R	RC	RC	...	RC
37	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38	...	...	...	...	...	...	...	C	C	+	+	RC	CC	RC	CC	?	C	CC	...	+	...	...	RC	+	...	...	...	...	...	...	...	...	...	...
39	+	+	C	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40	C	C	RC	R	R	RC	...	RC	+	+	...	C	RC	C	RC	...	...	...	...	+	...	...	...	...	...	...	RR	...	...	RR	...	...	...	...
41	...	+	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
42	R	...	...	...	...	RR	...	RR	...	...	...	RC	RC	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	RR	RR	...	...	R	R	...	R
44	R	R	R	R	...	...	...	R	...	...	+	RR	R	RR	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
45	...	...	...	...	...	...	+	RR	+	+	+	RR	CC	R	CC	...	RC	C	...	+	...	...	C	...	...	...	RR	RR	...	R	RR	RR	RR	...
46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	C	C	...	...	...	...	C	...	...	...	CC	CC	CC	R	CC	...	...	...
47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	R	C
48	R	R	C	R	R	RR	+	RR	...	...	...	R	R	R	R	...	+	...	...	+	...	...	...	...	...	...	...	RR	RC	...	RC	R	RC	...
49	R	R	C	RC	RC	RC	...	C	...	+	...	C	R	C	...	...	...	...	...	...	...	...	R	...	...	...	RR	RR	...	...	R	R	...	...
50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

←——Mid Zones——→ | ←——High Zones——→

Senonian ... ... Zone of Marsupites—

Near Beauvais, N. France, *Calliderma Smithiæ*, *Crateraster quinqueloba*, *Metopaster Parkinsoni*, *M. quadratus* *Pycinaster angustatus*, *Tholaster argus*.

Vendôme, France, *Metopaster tumidus*, *Pycinaster crassus*.

Craie à Belemnitelles, N. France, *Calliderma Smithiæ*, *Crateraster quinqueloba*, *Metopaster Parkinsoni*, *M. uncatus*, *Stauranderaster bulbiferus*, *S. senonensis*.

Senonian Greensand, Teufelsmauer, near Weddersleben, Germany, *Metopaster tumidus*.

Craie à *A. quadratus*, Beauvais, N. France, as for Craie à Belemnitelles.

Zone of *A. quadratus* of Lüneburg, N. Germany, *Calliderma Smithiæ*, *Metopaster Parkinsoni*.

Zone of *B. mucronata*—

Hemmoor (Alte Fabrik), N. Germany, *Metopaster tumidus*, *Teichaster favosus*.

Köpinge, Sweden, *Chomataster præcursor* ; Lophidiaster sp., *Metopaster Parkinsoni*, Pycinaster sp.

Charentes, Aquitaine, *Metopaster tumidus*, *Stauranderaster senonensis*.

Danian ... ... Vincenttown limestone of New Jersey, U.S.A., *Metopaster mammillatus*.

Calcaire pisolithique of Laversine, near Beauvais, N. France, *Metopaster mammillatus*, *Stauranderaster bulbiferus*.

DESCRIPTION OF PLATES.

PLATE 10.

Fig.		Zone.	Locality.	Collection.
	Metopaster Parkinsoni series (pp. 110–114).			
	(*a*) Terminal Supero-marginalia.			
1	Of Low-zonal *M. thoracifer*, Geinitz	Cenomanian.	Plauen.	Munich.
2	" " "	*Rh. Cu.*	Branscombe.	Rowe.
3	" " "	"	"	"
4	Of Low-zonal *M. Parkinsoni*, Forbes (var. *abbreviatus*	*M. ca.* $\frac{1}{4}$.	Seaford.	Brydone.
5	Of Mid-zonal *M. Parkinsoni*	*M. ca.* $\frac{3}{4}$.	Hants.	"
6	" "	*O. p.*	Wilts.	Blackmore.
7	" *M. exsculptus*, Spencer	*M. ca.* $\frac{3}{4}$.	"	"
8	Of High-zonal *M. tumidus*, Spencer	*B. muc.* "U."	Rügen.	Brit. Mus.
9	" *mammillatus*, Gabb	Danian.	Annetorp.	Lund. Mus.
	(*b*) Abactinal views of Supero-marginalia.			
10	Of Low-zonal *M. thoracifer*	Cenomanian.	Gamighügel.	Munich.
11	" *M. Parkinsoni* (var. *abbreviatus*) . .	*M. ca.* $\frac{1}{4}$.	Seaford.	Brydone.
	(*c*) Profile views of Marginalia (see p. 152).			
12	Of Low-zonal *M. thoracifer*	*Rh. Cu.*	Branscombe.	Rowe.
13	Of Mid-zonal *M. Parkinsoni*	*M. ca.* $\frac{3}{4}$.	Hants.	Brydone.
14	" "	*O. p.*	Wilts.	Blackmore.
15	Of High-Zonal *M. tumidus*	*B. muc.* "U."	Rügen.	G-p.M., Berlin
16	" *M. mammillatus*	Danian.	Annetorp.	Lund. Mus.
	(*d*) Actinal view of Infero-marginalia.			
17	Of Mid-zonal *M. exsculptus*	*M. ca.* $\frac{3}{4}$.	Hants.	Brydone.
	Metopaster undulatus series (pp. 118, 119).			
18	Abactinal view of a broken specimen of *M. decipiens*, Spencer	*A. q.*	Wilts.	Blackmore.
19	Abactinal view of reconstructed margin of *M. undulatus*, Spencer	*B. muc.* "U."	Rügen.	Brit. Mus.
20	Abactinal view of Terminal Supero-marginal of rugose var. of *M. undulatus*	*B. muc.* "M."	Weybourne.	Brydone.
	Mitraster Hunteri, Forbes (p. 117).			
21	Abactinal view of specimen (6/7 of nat. size) . .	*B. muc.*	Meudon.	Janet.
22	A pair of terminal Supero-marginalia of same specimen			
23	A pair of terminal Supero-marginalia	*M. ca.* $\frac{3}{4}$.	Hants.	Brydone.

All the figures, except where otherwise stated, are magnified three diameters.

The contractions used for the zones are readily intelligible if reference be made to the zonal table, p. 104. *M. ca.* $\frac{1}{4}$ = lower quarter; *M. ca.* $\frac{3}{4}$ = upper three-quarters of zone of *M. cor-anguinum.*

A full list of the collections is given, pp. 99, 100. The contraction used (Plate 10, fig. 15) indicates the Geologisch-palæontologisches Museum, Berlin.

Plate 11.

Fig.		Zone.	Locality.	Collection.
	Mitraster Hunteri, Forbes (p. 117).			
1	Profile view of Marginalia	*B. muc.*	I. of Wight.	Rowe.
2	Abactinal view of a Supero-marginal	*B. muc.* "U."	Rügen.	Brit. Mus.
	Mitraster rugatus, Forbes (p. 117).			
3	Abactinal view of a Supero-marginal	*M. ca.* $\frac{3}{4}$	Hants.	Brydone.
	Metopaster uncatus series (p. 116).			
	(*a*) Abactinal view of Supero-marginalia.			
4	Of early Mid-zonal form of *M. uncatus*	*M. ca.* $\frac{3}{4}$	,,	,,
5	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
6	,, ,, *M. quadratus*	*B. muc.* "L."	,,	,,
	(*b*) Abactinal views of terminal Supero-marginalia.			
7	Of Mid-zonal form of *M. quadratus* (partially broken down)	*O. pilula*	,,	,,
8	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
	(*c*) Profile views of Marginalia.			
9	Of Mid-zonal form of *M. uncatus*	*M. ca.* $\frac{3}{4}$	,,	,,
10	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
	Pycinaster series (pp. 124, 125).			
11	Lateral view of marginalia of *Py. humilis*	*Rh. Cu.*	Branscombe.	Rowe.
12	,, ,, ,, *Py. angustatus*	Marsup.	Margate.	Brydone.
13	Profile ,, ,, same species	,,	,,	,,
14	Lateral ,, ,, *Py. magnificus*	*A. q.*	Hants.	,,
15	Profile ,, ,, same species	,,	,,	,,
16	Lateral ,, ,, *Py. crassus*	*B. muc.* "U."	Trimingham.	,,
17	Profile ,, ,, same species	,,	,,	,,
	Lophidiaster series (p. 139).			
	(*a*) Profile views of Marginalia.			
18	Of a modern species of Astropecten.			
19	Of *Lophidiaster ornatus*	*P. asper.*	Hooken.	,,
20	Of *L. pygmæus*	*B. muc.* "U."	Rügen.	Brit. Mus.
21	,, ,,	,,	St. Pierre.	Brussels.
22	(*b*) Actinal view of marginal of *L. ornatus*	*P. asper.*	Hooken.	Brydone.
	Arthraster cristatus, Spencer (p. 140).			
23	Abactinal view of plate of arm ?	*M. ca.* $\frac{3}{4}$	Hants.	,,
24	Profile view of same.			
	Hadranderaster simplex, Geinitz (p. 137).			
25	Outer view of a marginal	Marsup.	,,	,,
26	Profile view of same.			

Plate 12.

Fig.		Zone.	Locality.	Collection.
	Crateraster-Teichaster series (pp. 120–123).			
	(*a*) Views of Low-zonal forms (*Crateraster quinqueloba*).			
1	Profile view of Marginalia	*Rh. Cu.*	Branscombe.	Rowe.
2	Lateral view of same.			
3	Abactinal view of the Supero-marginal.			
4	Actinal view of the Infero-marginal.			
5	Lateral view of an Infero-marginal	*T. l.*	Devon.	„
	(*b*) Views of Mid-zonal forms (*C. quinqueloba*).			
6	Profile view of Marginalia	Marsup.	Hants.	Brydone.
7	Lateral view of same.			
8	Abactinal view of the Supero-marginal.			
9	Actinal view of the Infero-marginal.			
10	Lateral view of another Supero-marginal . . .	„	„	„
11	Profile view of Marginalia of var. *depressus* . .	*O. pilula.*	„	„
	(*c*) Views of High-zonal forms of			
	(1) *C. quinqueloba.*			
12	Profile view of Marginalia	*B. muc.* "M."	Studland.	„
13	Abactinal view of a Supero-Marginal	*B. muc.* "L."	I. of Wight.	Rowe.
	(2) *Teichaster favosus.*			
14	Abactinal view of a restored specimen (6/7 nat. size)	„	„	Brit. Mus.
15	Profile view of Marginalia	*B. muc.* "M."	Studland.	Brydone.
16	„ „ „	*B. muc.* "U."	Rügen.	Brit. Mus.
17	„ „ „ (var. *retiformis*) . .	Danian.	Annetorp.	Lund. Mus.
18	Lateral view of a Supero-marginal	*B. muc.* "U."	Trimingham.	Brydone.
19	Lateral view of a Supero-marginal (var. *retiformis*)	Danian.	Annetorp.	Lund. Mus.
	Calliderma-Chomataster series (pp. 126–129).			
	(*a*) Profile views of Marginalia.			
20–21	Of Low-zonal *Tylaster jurensis*	*P. asper.* ?	Warminster ?	Mus. Prac. Geol.
22	„ *Calliderma Smithiæ*	*Rh. Cu.*	Branscombe.	Rowe.
23	„ „ „	*H. p.*	I. of Wight.	Brydone.
24	Of High-zonal „ „	*A. q.*	Hants.	„
25	„ „ „	*B. muc.* "L."	Norfolk.	Rowe.
26	„ *Chomataster præcursor*	*B. muc.* "M."	Studland.	„
27	„ „ „	„	Köpinge.	Lund. Mus.
28	„ „ *acules*	*B. muc.* "U."	Rügen.	Brit. Mus.
	(*b*) Abactinal views of Supero-marginalia.			
29	Of High-zonal form of *C. Smithiæ*	*A. q.*	Hants.	Brydone.
30	Of *Ch. præcursor*	*B. muc.* "M."	Studland.	„
31	(*c*) Lateral view of reconstructed arm of *Ch. acules* (slightly less than natural size)	*B. muc.* "U."	Rügen.	Brit. Mus.

Plate 13.

Fig.		Zone.	Locality.	Collection.
	Stauranderaster bulbiferus, Forbes (p. 133).			
	(*a*) Series to show ornament on Supero-marginalia near extremity of arm.			
1	Of Low-zonal form	*M. ca.* $\frac{1}{4}$	Whitchurch.	Brit. Mus.
2	Profile view of same.			
3	Portion of surface of same × 18.			
4	Of Mid-zonal form.	*M. ca.* $\frac{3}{4}$.	Hants.	Brydone.
5	Portion of surface of same × 18.			
6	Of High-zonal form	*B. muc.*	I. of Wight.	Rowe.
7	Portion of surface of same × 18.			
	(*b*) Abactinal views of the primary Radialia.			
8	Of Low-zonal form	*Rh. Cu.*	Branscombe.	"
9	Of High-zonal form	*A. q.*	Hants.	Brydone.
	(*c*) Profile view of distal radial of arm.			
10	Of High-zonal form	"	"	"
	Stauranderaster Boysii series (pp. 134, 135).			
11	Fragment of extremity of arm of Mid-zonal *S. gibbosus*, Spencer.	*O. pilula.*	Sussex.	Faber.
12	Abactinal view of primary Radialia of High-zonal *S. gibbosus*, var. *pyramidalis.*	Danian.	Stevns.	Copenhagen Mus.
13	Profile view of same ossicle.			
	(*c*) Primary Radial of *S. senonensis*, Valette.			
14	Abactinal view	*A. q.*	Hants.	Brydone.
15	Marginal of *S. senonensis*	"	"	"
	Stauranderaster pistilliferus, Forbes (p. 135).			
16	A primary Radial	*M. ca.* $\frac{3}{4}$	Dieppe.	Janet.
17	Abactinal view of radial	"	"	"
18	Profile view of radial	"	"	"
19	" " a marginal.	"	"	"
	Stauranderaster ? decoratus, Geinitz (p. 136).			
20	Outer view of marginal	Cenomanian.	Gamighügel.	Munich.
21	" "	"	Cap de la Héve.	Janet.
	Tholaster series (pp. 137, 138).			
22	Outer view of marginal of *Th. argus*, Spencer . .	*M. ca.* $\frac{3}{4}$	Dieppe.	"
23	" " " " . .	*M. ct.*	Seaford.	Rowe.
24	" " *Th. ocellatus*, Forbes . .	*O. pilula.*	Hants.	"
25	" " *Tholaster* sp.	Cenomanian.	Gamighügel.	Munich.
	Ophryaster oligoplax, Sladen (p. 130).			
26	Abactinal view of a Supero-marginal	*B. muc.* "U."	Trimingham.	Brydone.
	Trachyaster radiatus, Spencer (p. 131).			
27	Abactinal view of a marginal × 18	*Sch. varians.*	Cambridge.	Brit. Mus.
	Phocidaster grandis, Spencer (p. 140).			
28	View of marginal	*P. asper. ?*	?	Mus. Pract. Geol.
29	Lateral view of another marginal	"	?	"

PLATE 14.

Fig. 1.—An abactinal view of a reconstruction of the margin of *Metopaster tumidus*, Spencer. The ossicles which compose this reconstruction were chosen from a large collection of ossicles washed out of the "upper *mucronata*" chalk of the Island of Rügen. The reconstruction is in the collection of the British Museum (Natural History), p. 113.

Fig. 2.—A side view of a partial reconstruction of the margin of one side of the disc of the same species. (Material as above.) Coll. Brit. Mus., p. 113.

Fig. 3.—An abactinal view of a reconstruction of the margin of the radiate variety of *Metopaster tumidus*. The ossicles from which the reconstruction was made were obtained from the "upper *mucronata*" chalk of Trimingham, Norfolk, by Mr. BRYDONE. Portions of two rays were found, as also sufficient associated material to complete one half of an interradius. Mr. BARLOW, of the British Museum, made casts from this material, and reconstructed a complete margin. The original set of ossicles is in the collection of Mr. BRYDONE.

The photos are by Mr. HERRING, of the British Museum, p. 113.

PLATE 15.

Except when otherwise stated the ossicles figured on this plate are from the zone of *B. muc.* "U" of the Island of Rügen and are preserved in the British Museum of Natural History.

Metopaster tumidus, Spencer (pp. 113, 114).

Fig. 1.—Lateral view of a Terminal Supero-marginal. × 3.
Fig. 2.— „ „ Supero-marginal. × 3.
Fig. 3.— „ „ second Supero-marginal. × 3.
Fig. 4.—Abactinal view of a third Supero-marginal. × 3.
Fig. 5.—Lateral view of a fourth Supero-marginal (probably var. *radiatus*). × 3.
Fig. 6.—Profile view of a Supero-marginal. × 3.
Fig. 7.—Actinal view of an Infero-marginal. × 3.

Metopaster mammillatus, Gabb (pp. 114, 115).

Ossicles figured 8, 9 and 10 are from the Danian (Saltholmskalk) of Denmark. Coll. Copenhagen Mus.

Fig. 8.—Lateral view of a fragment. Nat. size.
Fig. 9.—Profile view of two end ossicles of fragment. Nat. size.
Fig. 10.—Lateral view of one of the Supero-marginalia. × 3.
Fig. 11.—A Terminal Supero-marginal from the Danian Limsten of Stevns. Nat. size. Coll. BRÜNNICH NIELSEN.

Metopaster Parkinsoni, var. *calcar* (pp. 119, 120).

All the ossicles figured are from the Trümmerkreide of N.E. Scania.

Fig. 12.—A pair of Terminal Supero-marginalia. Nat. size. Coll. Lund. Mus.
Figs. 13 & 14.—A pair of Terminal Supero-marginalia. Nat. size. Coll. Brit. Mus.
Fig. 15.—Lateral view of ossicle figured fig. 14. Nat. size.
Fig. 16.—Inner view of same. × 2.
Fig. 17.—Lateral view of a Supero-marginal. × 3. Coll. Lund. Mus.

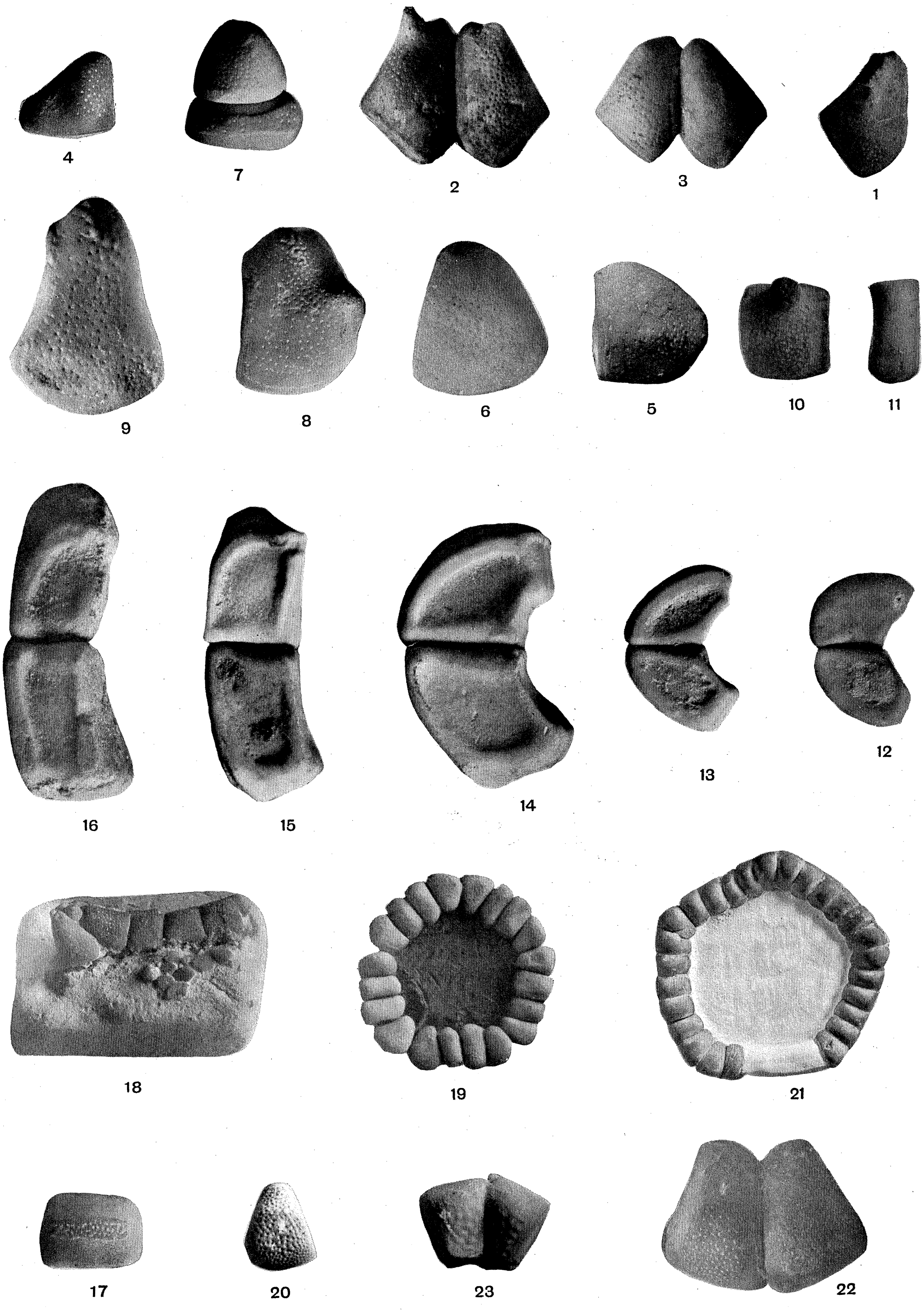
Metopaster crista-galli, Spencer (p. 120).

From the Trümmerkreide of N.E. Scania. Coll. Lund. Mus.

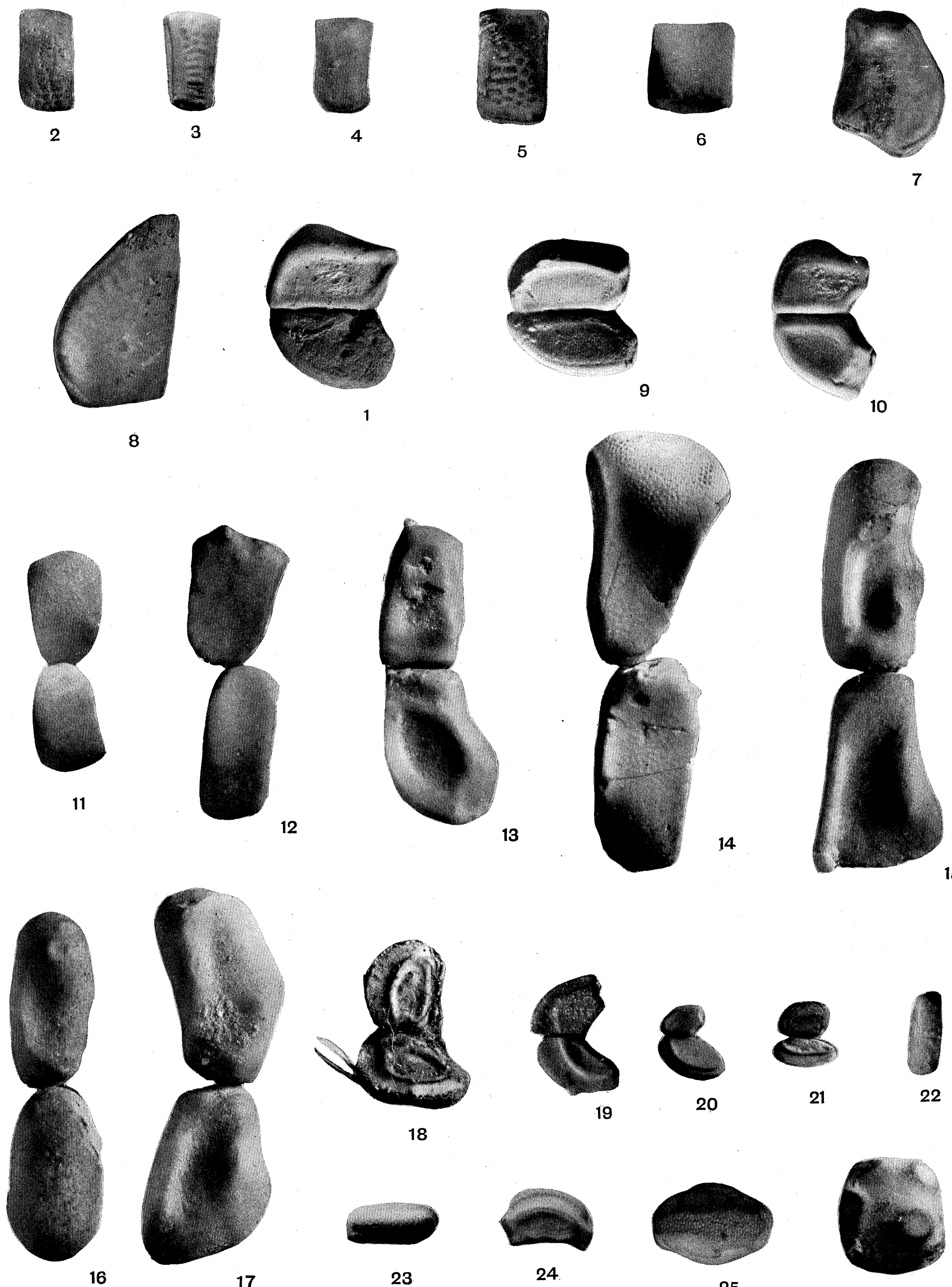
Fig. 18.—A pair of Terminal Supero-marginalia. Nat. size.
Fig. 19.—Lateral view of one of above. Nat. size.

Metopaster undulatus, Spencer (pp. 118, 119).

Fig. 20.—Abactinal view of a Terminal Supero-marginal. × 3.
Fig. 21.— „ „ Supero-marginal. × 3.
Fig. 22.—Lateral view of same. × 3.
Fig. 23.—Actinal view of an Infero-marginal. × 3.
Fig. 24.—An Infero-marginal showing pedicellaria. × 3.
Fig. 24*a*.—Portion of surface of same highly magnified (× 12) to show shape of pedicellaria.



F. J. Little photo. *University Press, Cambridge*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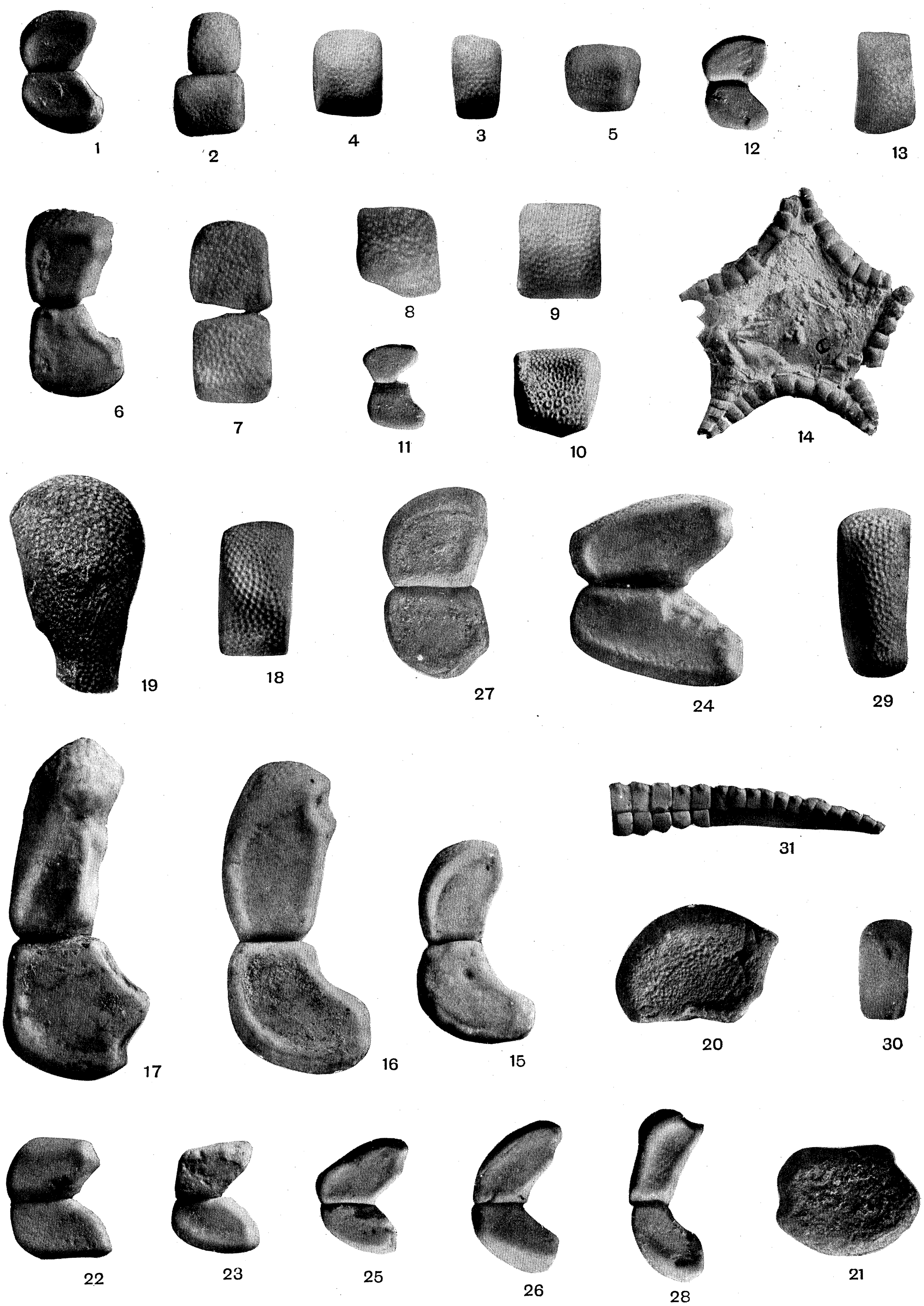
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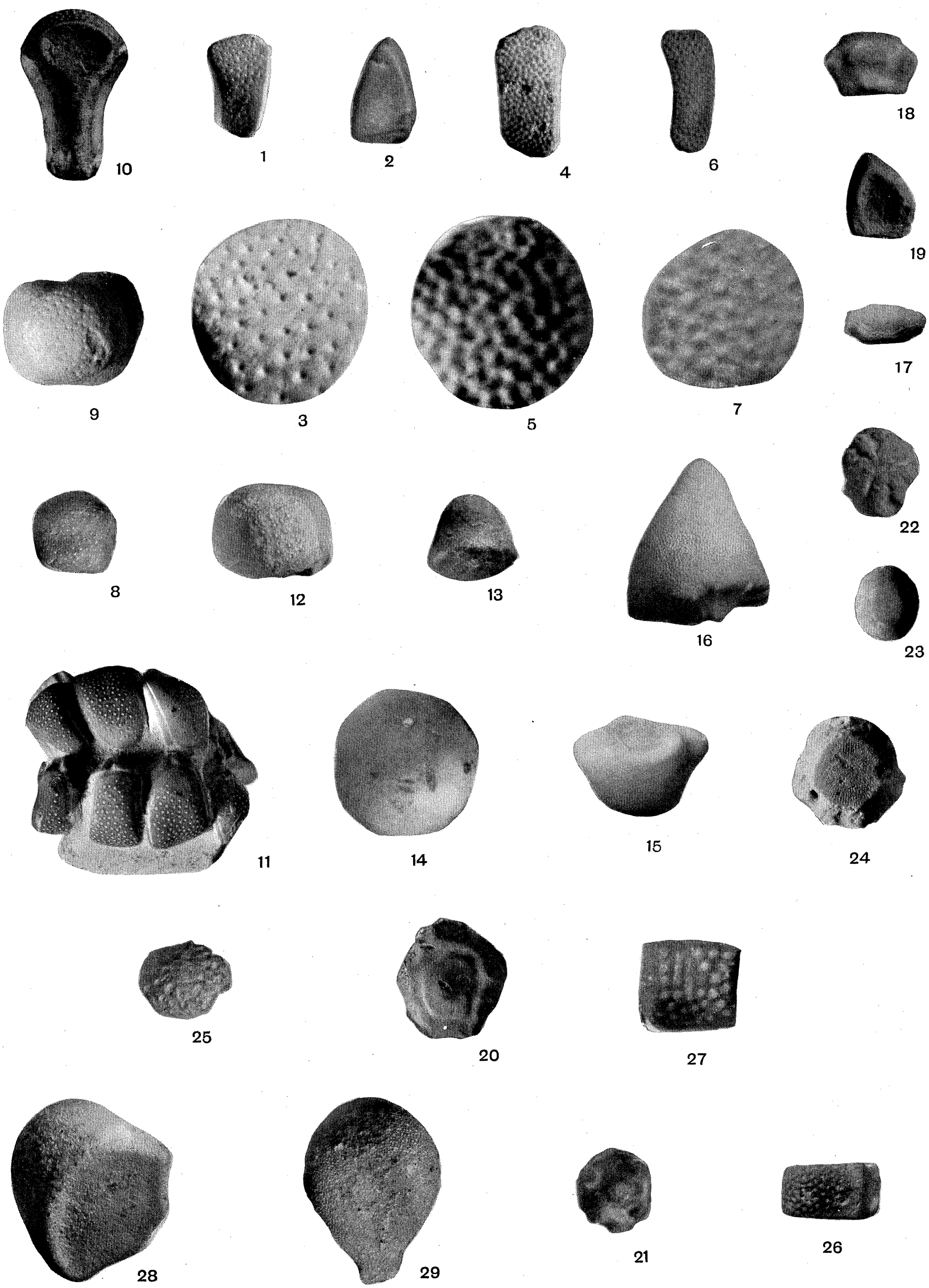
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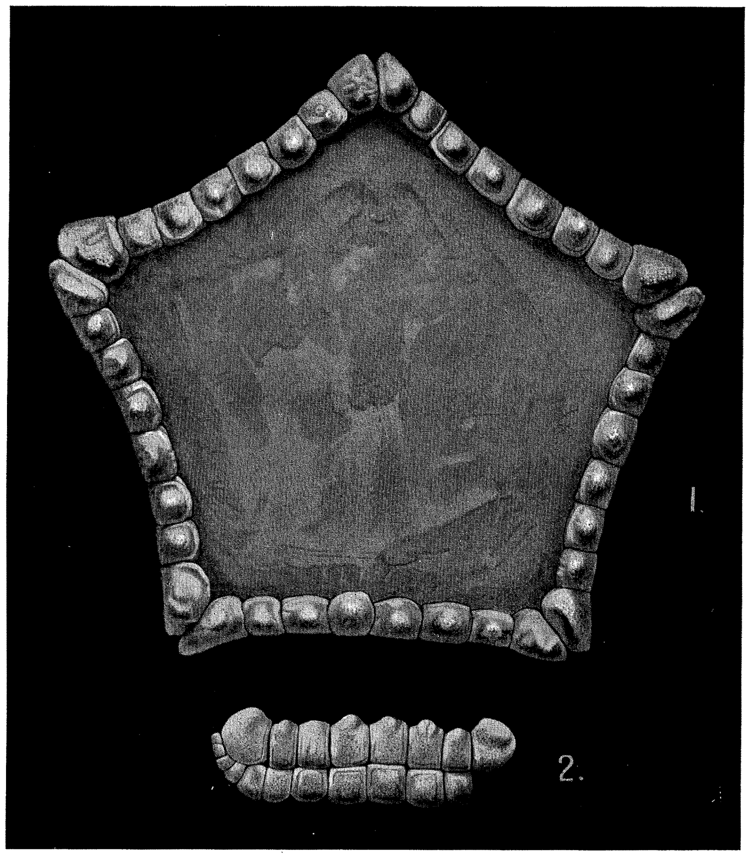

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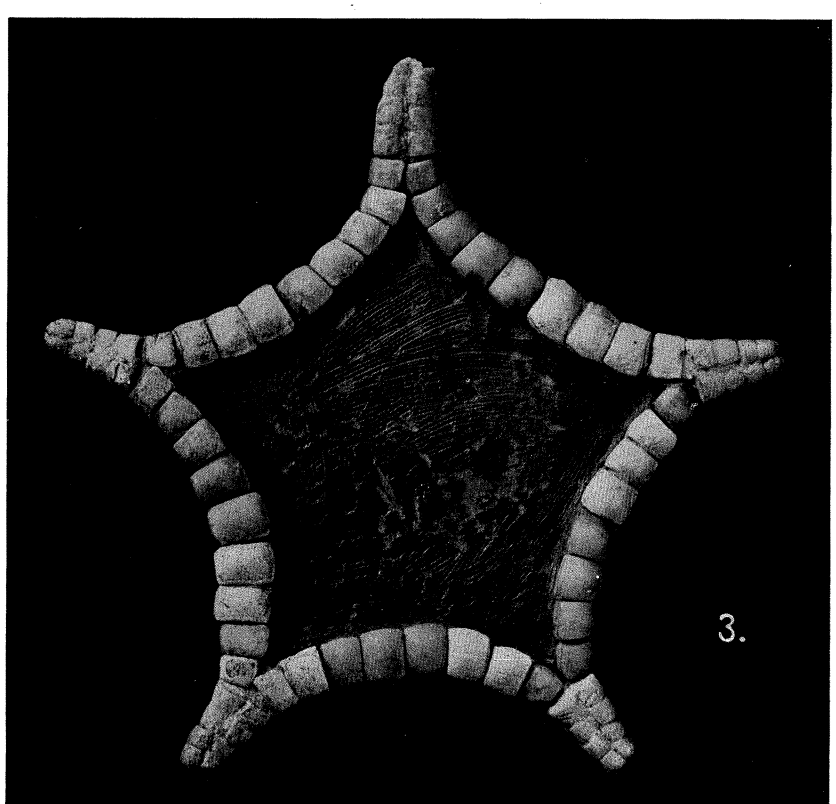

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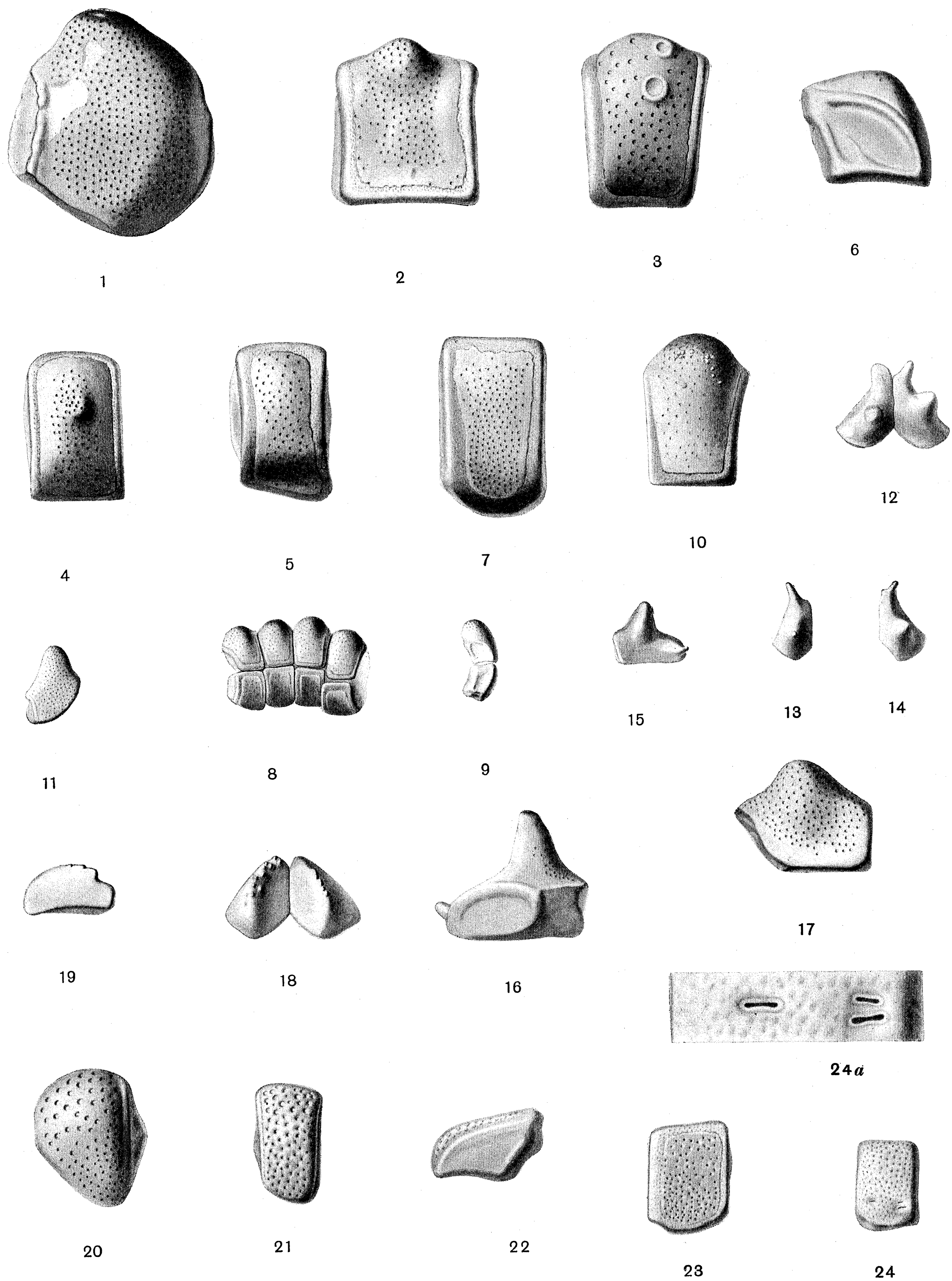

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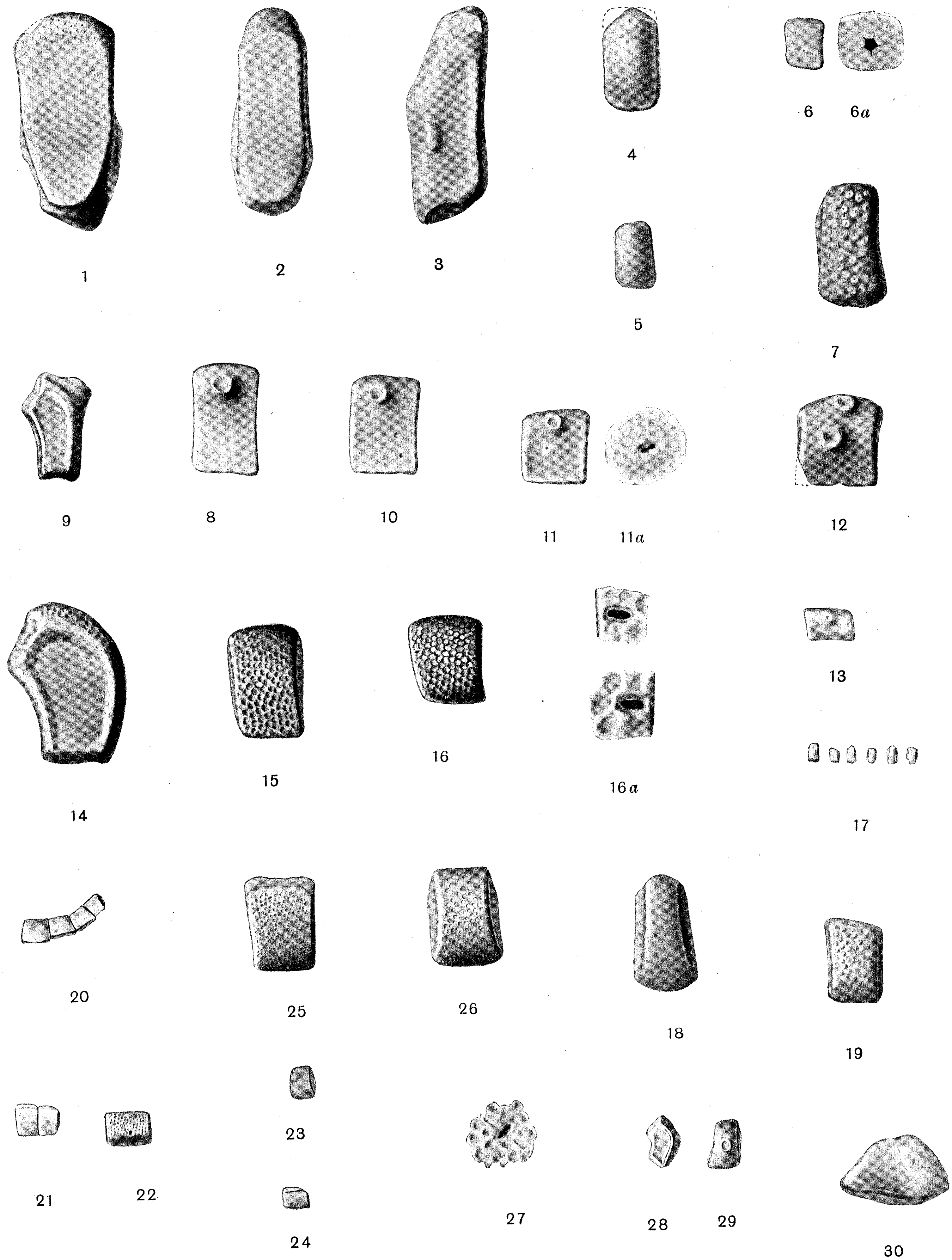
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Plate 16.

All the ossicles figured on this plate, with the exception of those figured 28 and 29, are from the zone of *B. muc.* "U" of the Island of Rügen. They are preserved in the British Museum (Natural History).

Pycinaster crassus, Spencer (p. 125).

Fig. 1.—Lateral view of a Supero-marginal. × 3.
Fig. 2.— ,, another Supero-marginal. × 3.
Fig. 3.—Profile view of an Infero-marginal. × 3.
Figs. 4 & 5.—Lateral views of small Supero-marginalia. × 3.
Fig. 6.—A small Marginal which possesses a pedicellaria. × 3.
Fig. 6*a*.—The pedicellaria highly magnified.

Arthraster cristatus, Spencer (p. 140).

Fig. 7.—Outer view of a Marginal. × 6.

Chomataster acules, Spencer (p. 126).

Fig. 8.—Lateral view of a Supero-marginal. × 3.
Fig. 9.—Profile view of same. × 3.
Fig. 10.—Lateral view of another Supero-marginal. × 3.
Fig. 11.— ,, a third Supero-marginal showing pedicellaria.
Fig. 11*a*.—Portion of surface of same highly magnified to show shape of pedicellaria.
Fig. 12.—A Supero-marginal with two large spine pits. × 3.
Fig. 13.— ,, from near extremity of arm. × 3.

Teichaster favosus, Spencer (p. 122).

Fig. 14.—Profile view of a Supero-marginal. × 3.
Fig. 15.—Lateral view of another Supero-marginal. × 3.
Fig. 16.— ,, a third Supero-marginal to show pedicellaria. × 3.
Fig. 16*a*.—Portions of surface of same magnified to show shape of pedicellaria.

Lophidiaster pygmæus, von Hagenow, M.S. (p. 139).

Fig. 17.—Six Marginals. Nat. size.
Fig. 18.—A smooth Supero-marginal. × 6.
Fig. 19.—A rugose Supero-marginal. × 6.

Ophryaster magnus, Spencer (p. 130).

Fig. 20.—Four Supero-marginalia in abactinal view. Nat. size.
Fig. 21.—Two Infero-marginalia in actinal view. Nat. size.
Fig. 22.—Supero-marginal from near extremity of arm, showing a large spine pit. × 3.
Fig. 23.—Abactinal view of a Supero-marginal. Nat. size.
Fig. 24.—An Infero-marginal showing a valvate pedicellaria. Nat. size.
Fig. 25.—Abactinal view of a Supero-marginal. × 3.
Fig. 26.— ,, another Supero-marginal. × 3.
Fig. 27.—Portion of surface of a Supero-marginal highly magnified (× 12) to show shape of pedicellaria.

Chomataster præcursor, Spencer (p. 126).
From the *B. mucronata* Greensand of Köpinge, Sweden.

Fig. 28.—Profile view of a Supero-marginal. Nat. size. Coll. Lund. Mus.
Fig. 29.—Lateral view of same.

Stauranderaster gibbosus, var. *pyramidalis*, Spencer (p. 134).

Fig. 30.—Lateral view of an abactinal ossicle. × 3.

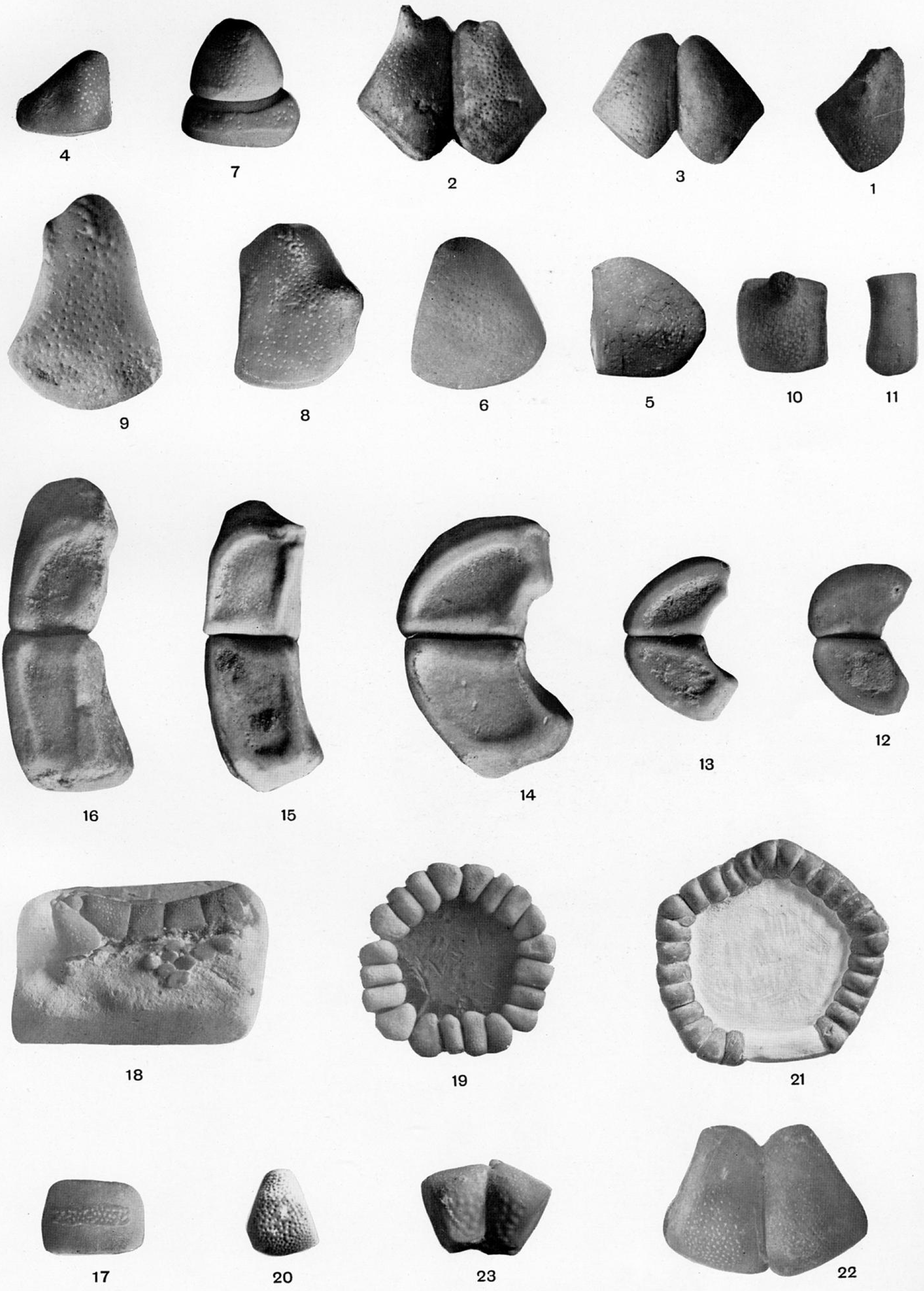


PLATE 10.

Fig.		Zone.	Locality.	Collection.
	Metopaster Parkinsoni series (pp. 110–114).			
	(*a*) Terminal Supero-marginalia.			
1	Of Low-zonal *M. thoracifer*, Geinitz	Cenomanian.	Plauen.	Munich.
2	„ „ „	*Rh. Cu.*	Branscombe.	Rowe.
3		„	„	„
4	Of Low-zonal *M. Parkinsoni*, Forbes (var. *abbreviatus*)	*M. ca.* ¼.	Seaford.	Brydone.
5	Of Mid-zonal *M. Parkinsoni*	*M. ca.* ¾.	Hants.	„
6	„ „	*O. p.*	Wilts.	Blackmore.
7	„ *M. exsculptus*, Spencer	*M. ca.* ¾.	„	„
8	Of High-zonal *M. tumidus*, Spencer	*B. muc.* "U."	Rügen.	Brit. Mus.
9	„ *mammillatus*, Gabb	Danian.	Annetorp.	Lund. Mus.
	(*b*) Abactinal views of Supero-marginalia.			
10	Of Low-zonal *M. thoracifer*	Cenomanian.	Gamighügel.	Munich.
11	„ *M. Parkinsoni* (var. *abbreviatus*) . .	*M. ca.* ¼.	Seaford.	Brydone.
	(*c*) Profile views of Marginalia (see p. 152).			
12	Of Low-zonal *M. thoracifer*	*Rh. Cu.*	Branscombe.	Rowe.
13	Of Mid-zonal *M. Parkinsoni*	*M. ca.* ¾.	Hants.	Brydone.
14	„	*O. p.*	Wilts.	Blackmore.
15	Of High-Zonal *M. tumidus*	*B. muc.* "U."	Rügen.	G-p.M., Berlin
16	„ *M. mammillatus*	Danian.	Annetorp.	Lund. Mus.
	(*d*) Actinal view of Infero-marginalia.			
17	Of Mid-zonal *M. exsculptus*	*M. ca.* ¾.	Hants.	Brydone.
	Metopaster undulatus series (pp. 118, 119).			
18	Abactinal view of a broken specimen of *M. decipiens*, Spencer	*A. q.*	Wilts.	Blackmore.
19	Abactinal view of reconstructed margin of *M. undulatus*, Spencer	*B. muc.* "U."	Rügen.	Brit. Mus.
20	Abactinal view of Terminal Supero-marginal of rugose var. of *M. undulatus*	*B. muc.* "M."	Weybourne.	Brydone.
	Mitraster Hunteri, Forbes (p. 117).			
21	Abactinal view of specimen (6/7 of nat. size) . .	*B. muc.*	Meudon.	Janet.
22	A pair of terminal Supero-marginalia of same specimen			
23	A pair of terminal Supero-marginalia	*M. ca.* ¾.	Hants.	Brydone.

All the figures, except where otherwise stated, are magnified three diameters.

The contractions used for the zones are readily intelligible if reference be made to the zonal table, p. 104. *M. ca.* ¼ = lower quarter; *M. ca.* ¾ = upper three-quarters of zone of *M. cor-anguinum*.

A full list of the collections is given, pp. 99, 100. The contraction used (Plate 10, fig. 15) indicates the Geologisch-palæontologisches Museum, Berlin.

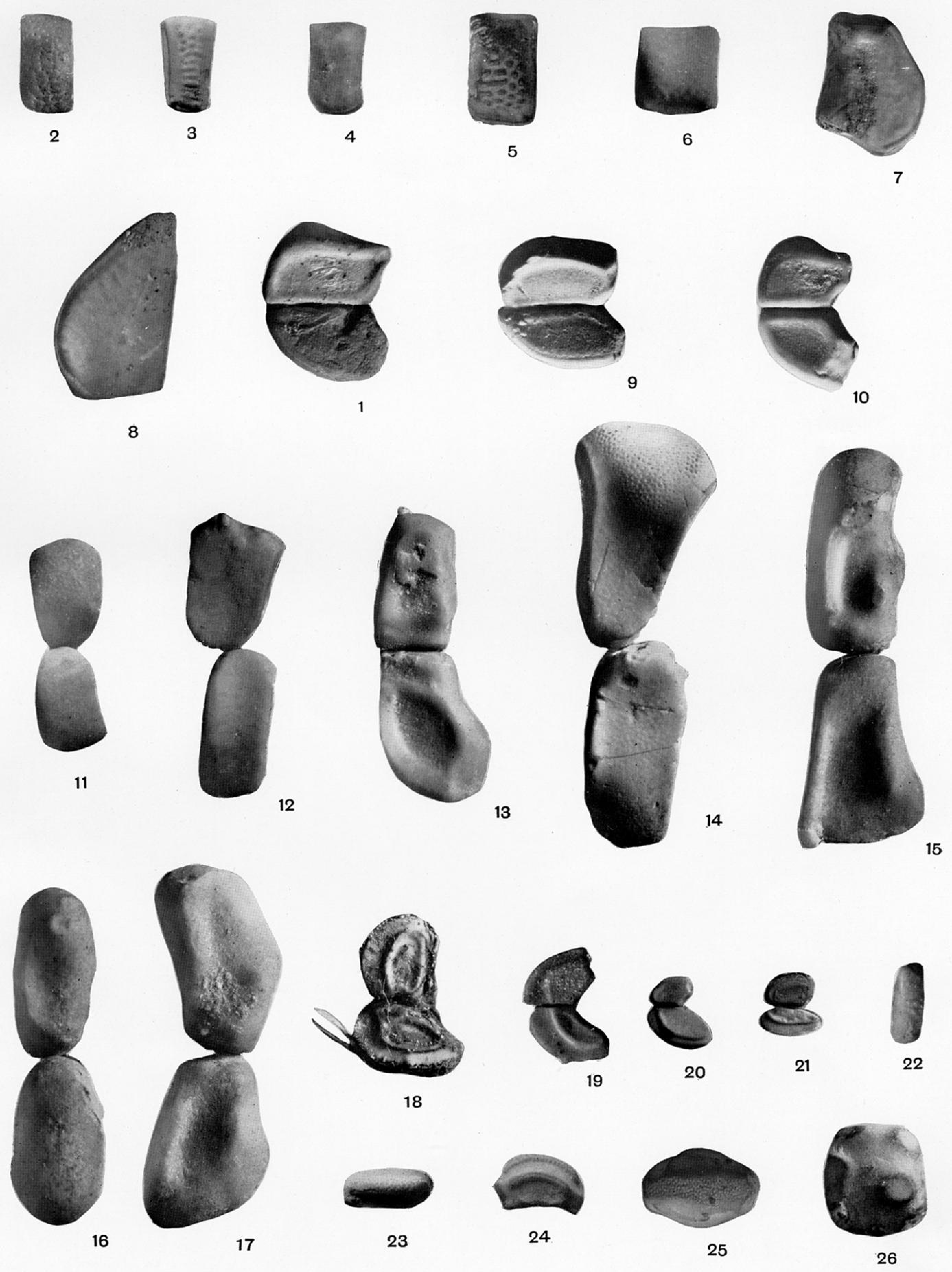


PLATE 11.

Fig.		Zone.	Locality.	Collection.
	Mitraster Hunteri, Forbes (p. 117).			
1	Profile view of Marginalia	*B. muc.*	I. of Wight.	Rowe.
2	Abactinal view of a Supero-marginal	*B. muc.* "U."	Rügen.	Brit. Mus.
	Mitraster rugatus, Forbes (p. 117).			
3	Abactinal view of a Supero-marginal	*M. ca.* $\frac{3}{4}$	Hants.	Brydone.
	Metopaster uncatus series (p. 116).			
	(*a*) Abactinal view of Supero-marginalia.			
4	Of early Mid-zonal form of *M. uncatus*	*M. ca.* $\frac{3}{4}$	,,	,,
5	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
6	,, ,, *M. quadratus*	*B. muc.* "L."	,,	,,
	(*b*) Abactinal views of terminal Supero-marginalia.			
7	Of Mid-zonal form of *M. quadratus* (partially broken down)	*O. pilula*	,,	,,
8	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
	(*c*) Profile views of Marginalia.			
9	Of Mid-zonal form of *M. uncatus*	*M. ca.* $\frac{3}{4}$	,,	,,
10	Of High-zonal form of *M. uncatus*	*A. q.*	,,	,,
	Pycinaster series (pp. 124, 125).			
11	Lateral view of marginalia of *Py. humilis* . . .	*Rh. Cu.*	Branscombe.	Rowe.
12	,, ,, ,, *Py. angustatus* . . .	Marsup.	Margate.	Brydone.
13	Profile ,, ,, same species . . .	,,	,,	,,
14	Lateral ,, ,, *Py. magnificus* . . .	*A. q.*	Hants.	,,
15	Profile ,, ,, same species . . .	,,	,,	,,
16	Lateral ,, ,, *Py. crassus* . . .	*B. muc.* "U."	Trimingham.	,,
17	Profile ,, ,, same species . . .	,,	,,	,,
	Lophidiaster series (p. 139).			
	(*a*) Profile views of Marginalia.			
18	Of a modern species of Astropecten.			
19	Of *Lophidiaster ornatus*	*P. asper.*	Hooken.	,,
20	Of *L. pygmæus*	*B. muc.* "U."	Rügen.	Brit. Mus.
21	,, ,, ...	,,	St. Pierre.	Brussels.
22	(*b*) Actinal view of marginal of *L. ornatus*	*P. asper.*	Hooken.	Brydone.
	Arthraster cristatus, Spencer (p. 140).			
23	Abactinal view of plate of arm ?	*M. ca.* $\frac{3}{4}$	Hants.	,,
24	Profile view of same.			
	Hadranderaster simplex, Geinitz (p. 137).			
25	Outer view of a marginal	Marsup.	,,	,,
26	Profile view of same.			

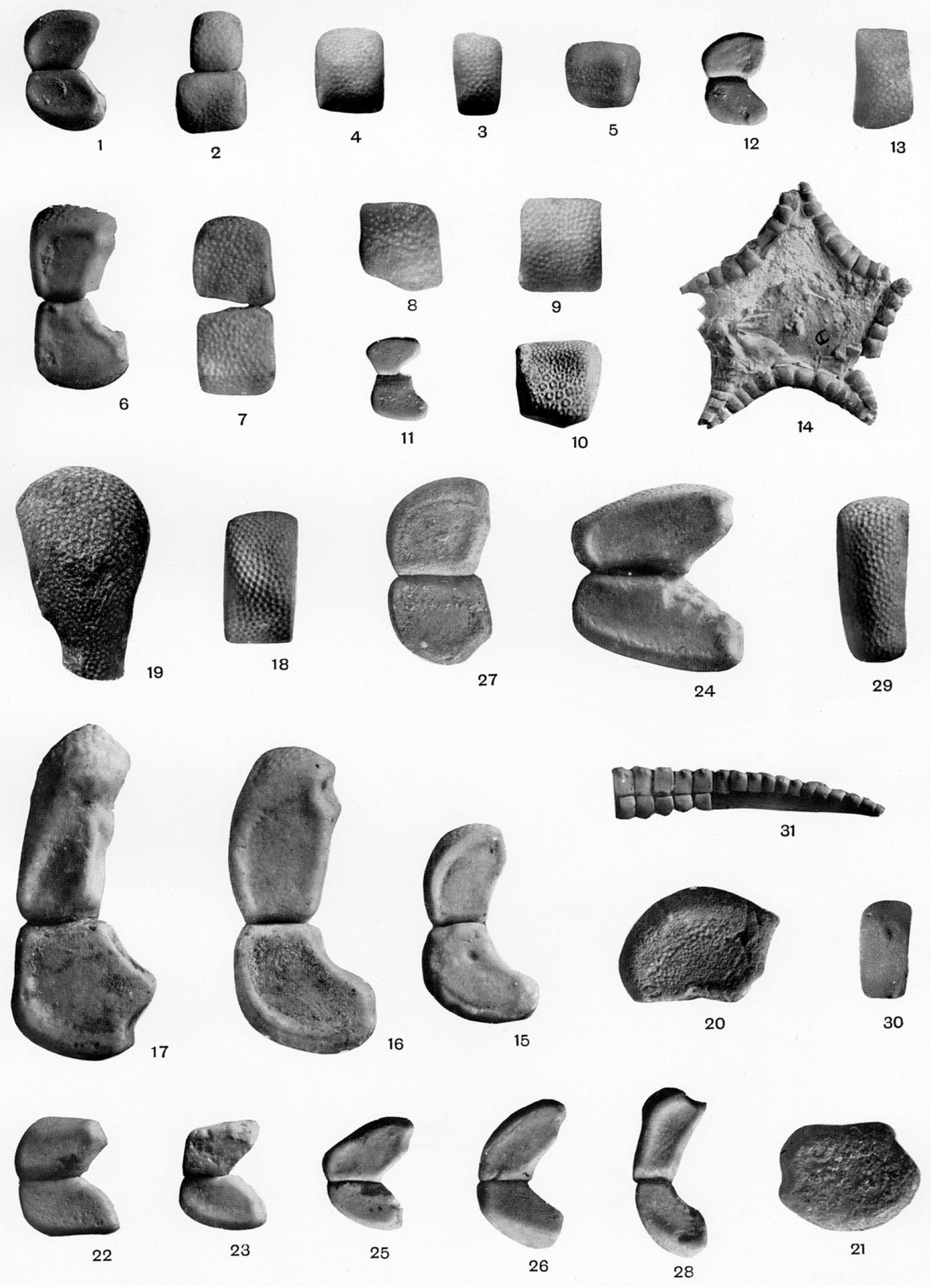


PLATE 12.

Fig.		Zone.	Locality.	Collection.
	Crateraster-Teichaster series (pp. 120–123).			
	(*a*) Views of Low-zonal forms (*Crateraster quinqueloba*).			
1	Profile view of Marginalia	*Rh. Cu.*	Branscombe.	Rowe.
2	Lateral view of same.			
3	Abactinal view of the Supero-marginal.			
4	Actinal view of the Infero-marginal.			
5	Lateral view of an Infero-marginal	*T. l.*	Devon.	„
	(*b*) Views of Mid-zonal forms (*C. quinqueloba*).			
6	Profile view of Marginalia	Marsup.	Hants.	Brydone.
7	Lateral view of same.			
8	Abactinal view of the Supero-marginal.			
9	Actinal view of the Infero-marginal.			
10	Lateral view of another Supero-marginal . .	„	„	„
11	Profile view of Marginalia of var. *depressus* . .	*O. pilula.*	„	„
	(*c*) Views of High-zonal forms of (1) *C. quinqueloba.*			
12	Profile view of Marginalia	*B. muc.* "M."	Studland.	„
13	Abactinal view of a Supero-Marginal	*B. muc.* "L."	I. of Wight.	Rowe.
	(2) *Teichaster favosus.*			
14	Abactinal view of a restored specimen (6/7 nat. size)	„	„	Brit. Mus.
15	Profile view of Marginalia	*B. muc.* "M."	Studland.	Brydone.
16	„ „ „	*B. muc.* "U."	Rügen.	Brit. Mus.
17	„ „ „ (var. *retiformis*) . .	Danian.	Annetorp.	Lund. Mus.
18	Lateral view of a Supero-marginal	*B. muc.* "U."	Trimingham.	Brydone.
19	Lateral view of a Supero-marginal (var. *retiformis*)	Danian.	Annetorp.	Lund. Mus.
	Calliderma-Chomataster series (pp. 126–129).			
	(*a*) Profile views of Marginalia.			
20–21	Of Low-zonal *Tylaster jurensis*	*P. asper.* ?	Warminster ?	Mus. Prac. Geol.
22	„ *Calliderma Smithiæ*	*Rh. Cu.*	Branscombe.	Rowe.
23	„ „ „	*H. p.*	I. of Wight.	Brydone.
24	Of High-zonal „ „	*A. q.*	Hants.	„
25	„ „ „	*B. muc.* "L."	Norfolk.	Rowe.
26	„ *Chomataster præcursor*	*B. muc.* "M."	Studland.	„
27	„ „ „	„	Köpinge.	Lund. Mus.
28	„ „ *acules*	*B. muc.* "U."	Rügen.	Brit. Mus.
	(*b*) Abactinal views of Supero-marginalia.			
29	Of High-zonal form of *C. Smithiæ*	*A. q.*	Hants.	Brydone.
30	Of *Ch. præcursor*	*B. muc.* "M."	Studland.	„
31	(*c*) Lateral view of reconstructed arm of *Ch. acules* (slightly less than natural size)	*B. muc.* "U."	Rügen.	Brit. Mus.

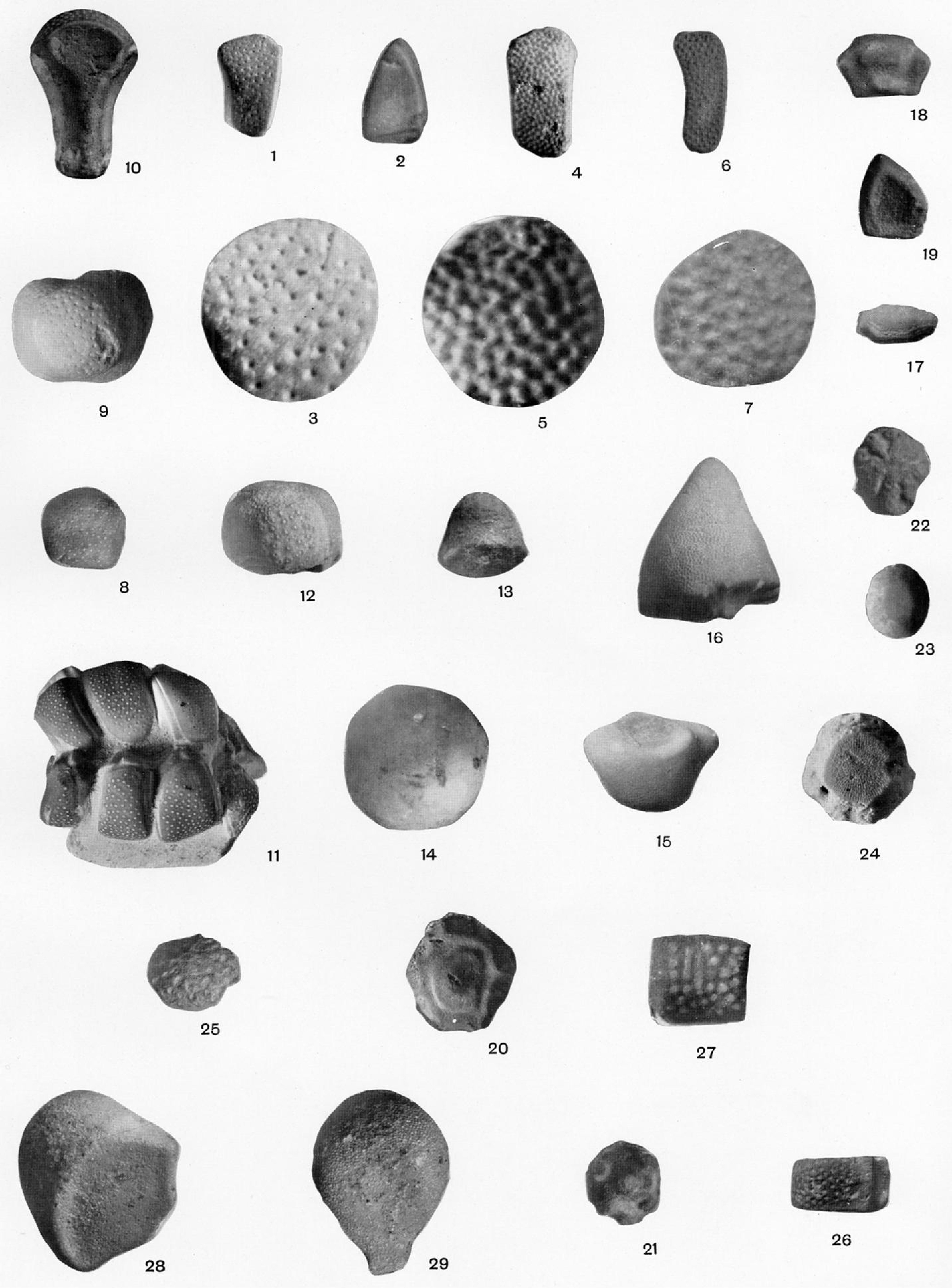
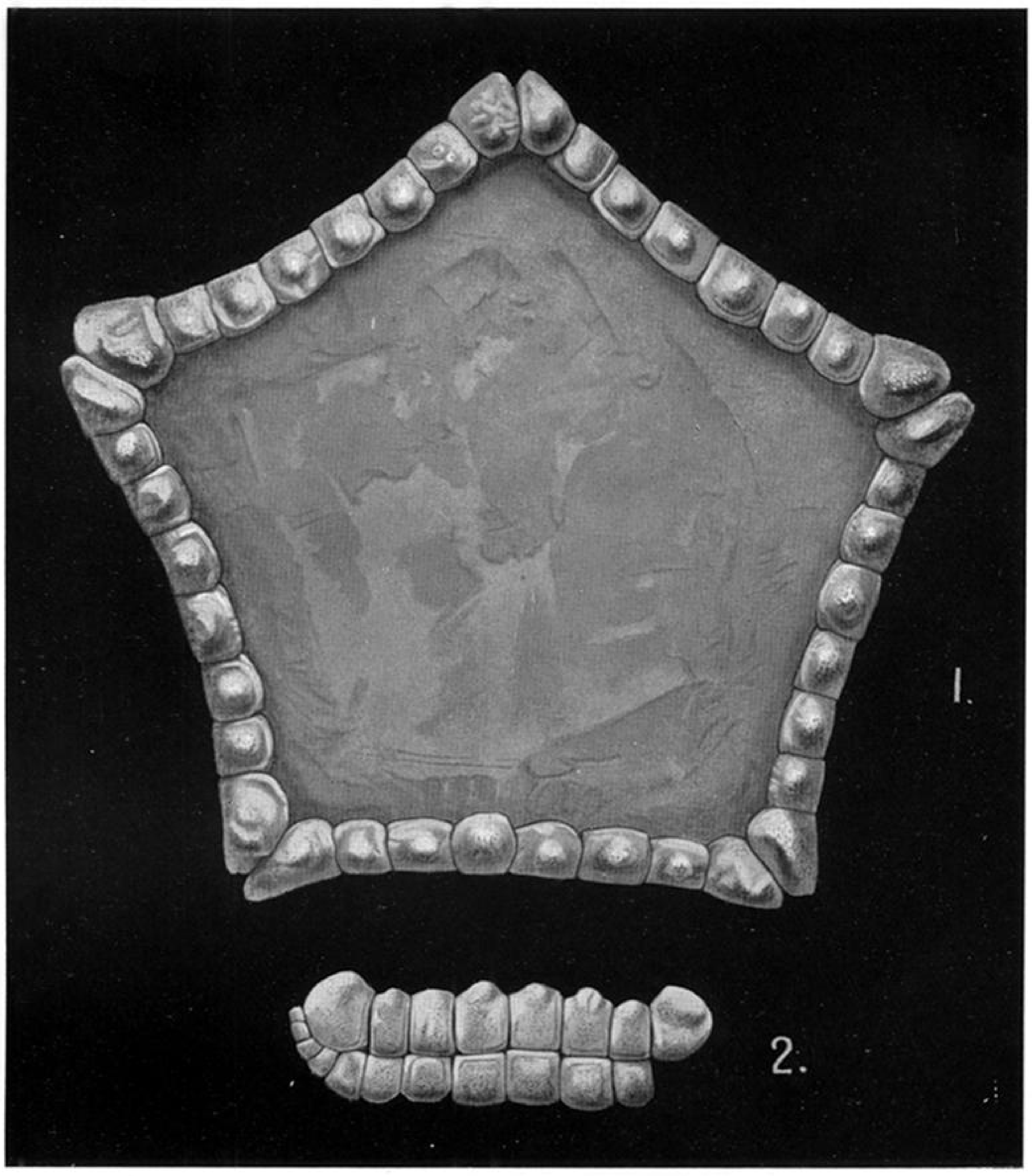


PLATE 13.

Fig.		Zone.	Locality.	Collection.
	Stauranderaster bulbiferus, Forbes (p. 133).			
	(*a*) Series to show ornament on Supero-marginalia near extremity of arm.			
1	Of Low-zonal form	*M. ca.* ¼	Whitchurch.	Brit. Mus.
2	Profile view of same.			
3	Portion of surface of same × 18.			
4	Of Mid-zonal form.	*M. ca.* ¾.	Hants.	Brydone.
5	Portion of surface of same × 18.			
6	Of High-zonal form	*B. muc.*	I. of Wight.	Rowe.
7	Portion of surface of same × 18.			
	(*b*) Abactinal views of the primary Radialia.			
8	Of Low-zonal form	*Rh. Cu.*	Branscombe.	,,
9	Of High-zonal form	*A. q.*	Hants.	Brydone.
	(*c*) Profile view of distal radial of arm.			
10	Of High-zonal form	,,	,,	,,
	Stauranderaster Boysii series (pp. 134, 135).			
11	Fragment of extremity of arm of Mid-zonal *S. gibbosus*, Spencer.	*O. pilula.*	Sussex.	Faber.
12	Abactinal view of primary Radialia of High-zonal *S. gibbosus*, var. *pyramidalis.*	Danian.	Stevns.	Copenhagen Mus.
13	Profile view of same ossicle.			
	(*c*) Primary Radial of *S. senonensis*, Valette.			
14	Abactinal view	*A. q.*	Hants.	Brydone.
15	Marginal of *S. senonensis*	,,	,,	,,
	Stauranderaster pistilliferus, Forbes (p. 135).			
16	A primary Radial	*M. ca.* ¾	Dieppe.	Janet.
17	Abactinal view of radial	,,	,,	,,
18	Profile view of radial	,,	,,	,,
19	,, ,, a marginal	,,	,,	,,
	Stauranderaster ? decoratus, Geinitz (p. 136).			
20	Outer view of marginal	Cenomanian.	Gamighügel.	Munich.
21	,, ,, ...	,,	Cap de la Héve.	Janet.
	Tholaster series (pp. 137, 138).			
22	Outer view of marginal of *Th. argus*, Spencer . .	*M. ca.* ¾	Dieppe.	,,
23	,, ,, ,, ,,	*M. ct.*	Seaford.	Rowe.
24	,, ,, *Th. ocellatus*, Forbes . .	*O. pilula.*	Hants.	,,
25	,, ,, *Tholaster* sp.	Cenomanian.	Gamighügel.	Munich.
	Ophryaster oligoplax, Sladen (p. 130).			
26	Abactinal view of a Supero-marginal	*B. muc.* "U."	Trimingham.	Brydone.
	Trachyaster radiatus, Spencer (p. 131).			
27	Abactinal view of a marginal × 18	*Sch. varians.*	Cambridge.	Brit. Mus.
	Phocidaster grandis, Spencer (p. 140).			
28	View of marginal	*P. asper. ?*	?	Mus. Pract. Geol.
29	Lateral view of another marginal	,,	?	,,



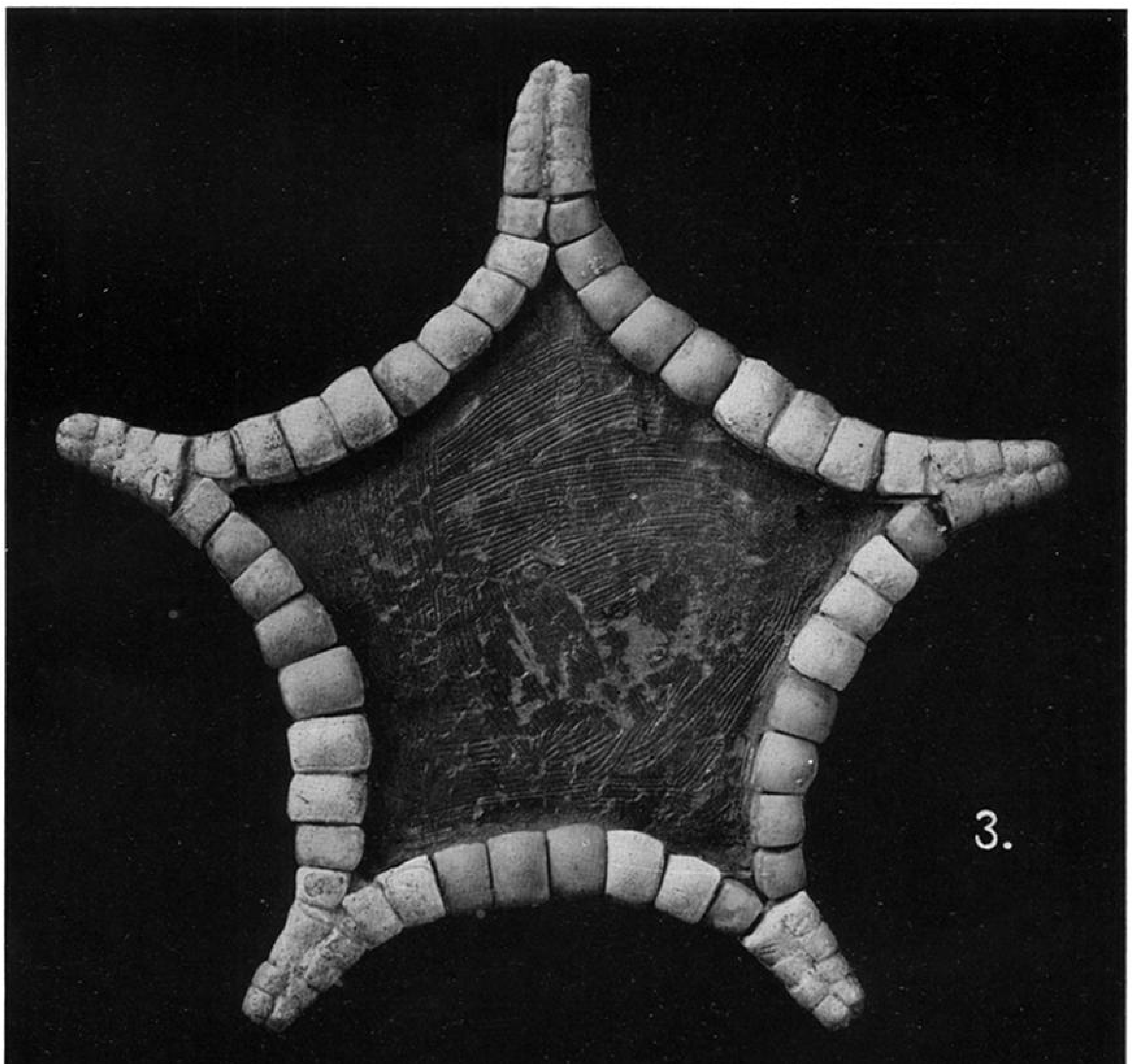


Plate 14.

Fig. 1.—An abactinal view of a reconstruction of the margin of *Metopaster tumidus*, Spencer. The ossicles which compose this reconstruction were chosen from a large collection of ossicles washed out of the "upper *mucronata*" chalk of the Island of Rügen. The reconstruction is in the collection of the British Museum (Natural History), p. 113.

Fig. 2.—A side view of a partial reconstruction of the margin of one side of the disc of the same species. (Material as above.) Coll. Brit. Mus., p. 113.

Fig. 3.—An abactinal view of a reconstruction of the margin of the radiate variety of *Metopaster tumidus*. The ossicles from which the reconstruction was made were obtained from the "upper *mucronata*" chalk of Trimingham, Norfolk, by Mr. Brydone. Portions of two rays were found, as also sufficient associated material to complete one half of an interradius. Mr. Barlow, of the British Museum, made casts from this material, and reconstructed a complete margin. The original set of ossicles is in the collection of Mr. Brydone.

The photos are by Mr. Herring, of the British Museum, p. 113.

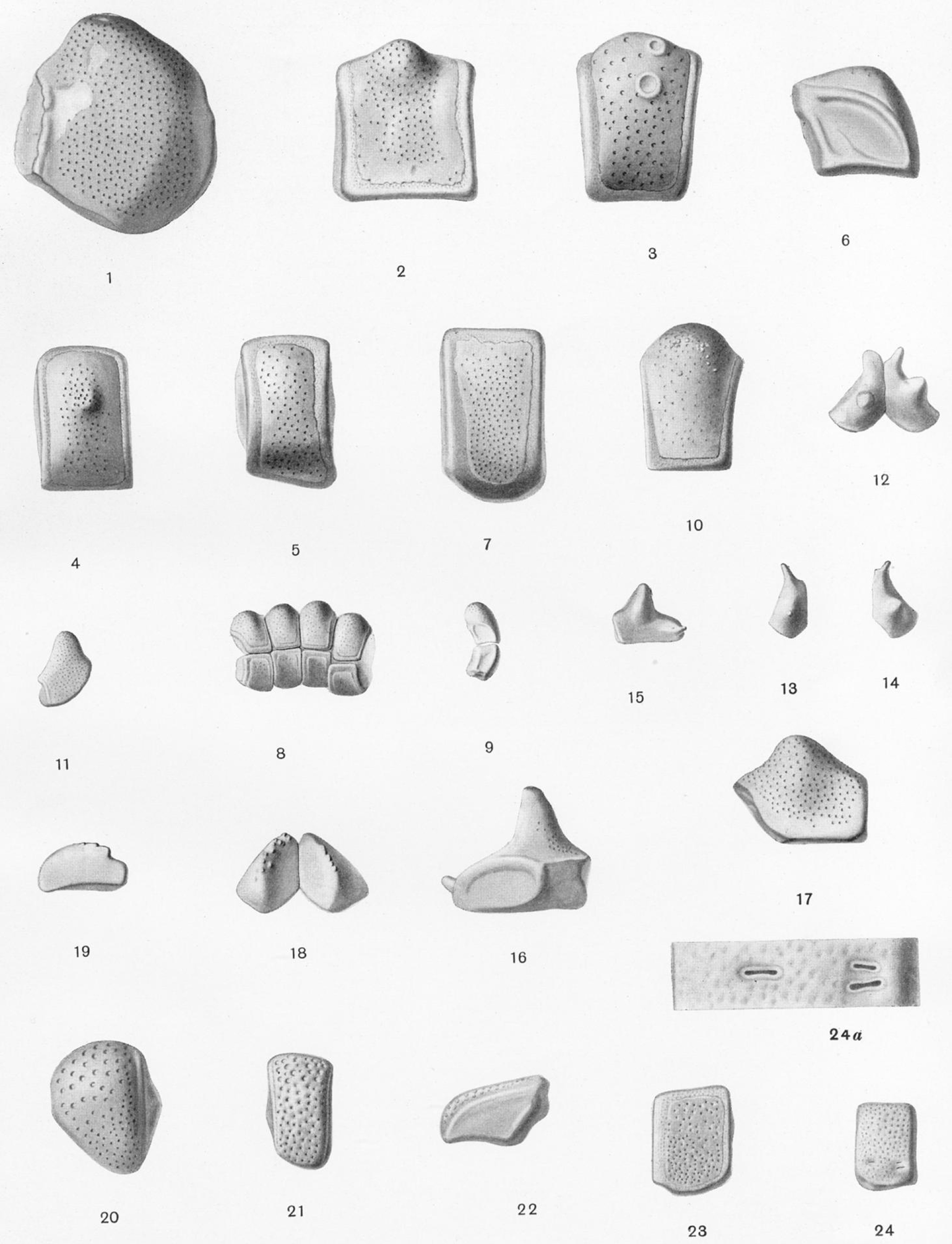


Plate 15.

Except when otherwise stated the ossicles figured on this plate are from the zone of *B. muc.* "U" of the Island of Rügen and are preserved in the British Museum of Natural History.

Metopaster tumidus, Spencer (pp. 113, 114).

Fig. 1.—Lateral view of a Terminal Supero-marginal. × 3.
Fig. 2.— „ „ Supero-marginal. × 3.
Fig. 3.— „ „ second Supero-marginal. × 3.
Fig. 4.—Abactinal view of a third Supero-marginal. × 3.
Fig. 5.—Lateral view of a fourth Supero-marginal (probably var. *radiatus*). × 3.
Fig. 6.—Profile view of a Supero-marginal. × 3.
Fig. 7.—Actinal view of an Infero-marginal. × 3.

Metopaster mammillatus, Gabb (pp. 114, 115).

Ossicles figured 8, 9 and 10 are from the Danian (Saltholmskalk) of Denmark. Coll. Copenhagen Mus.

Fig. 8.—Lateral view of a fragment. Nat. size.
Fig. 9.—Profile view of two end ossicles of fragment. Nat. size.
Fig. 10.—Lateral view of one of the Supero-marginalia. × 3.
Fig. 11.—A Terminal Supero-marginal from the Danian Limsten of Stevns. Nat. size. Coll. Brünnich Nielsen.

Metopaster Parkinsoni, var. *calcar* (pp. 119, 120).

All the ossicles figured are from the Trümmerkreide of N.E. Scania.

Fig. 12.—A pair of Terminal Supero-marginalia. Nat. size. Coll. Lund. Mus.
Figs. 13 & 14.—A pair of Terminal Supero-marginalia. Nat. size. Coll. Brit. Mus.
Fig. 15.—Lateral view of ossicle figured fig. 14. Nat. size.
Fig. 16.—Inner view of same. × 2.
Fig. 17.—Lateral view of a Supero-marginal. × 3. Coll. Lund. Mus.

Metopaster crista-galli, Spencer (p. 120).

From the Trümmerkreide of N.E. Scania. Coll. Lund. Mus.

Fig. 18.—A pair of Terminal Supero-marginalia. Nat. size.
Fig. 19.—Lateral view of one of above. Nat. size.

Metopaster undulatus, Spencer (pp. 118, 119).

Fig. 20.—Abactinal view of a Terminal Supero-marginal. × 3.
Fig. 21.— „ „ Supero-marginal. × 3.
Fig. 22.—Lateral view of same. × 3.
Fig. 23.—Actinal view of an Infero-marginal. × 3.
Fig. 24.—An Infero-marginal showing pedicellaria. × 3.
Fig. 24*a*.—Portion of surface of same highly magnified (× 12) to show shape of pedicellaria.

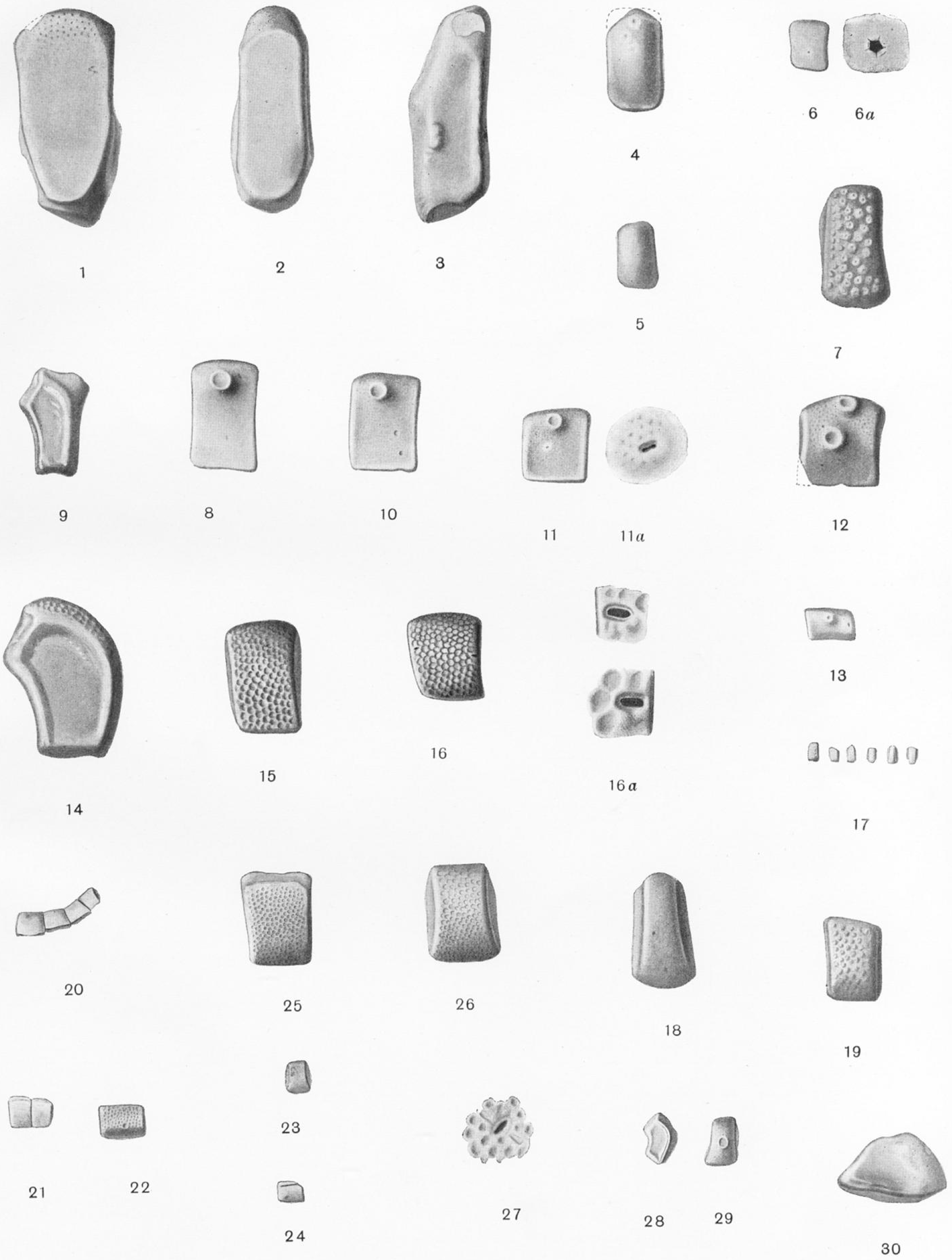


Plate 16.

All the ossicles figured on this plate, with the exception of those figured 28 and 29, are from the zone of *B. muc.* "U" of the Island of Rügen. They are preserved in the British Museum (Natural History).

Pycinaster crassus, Spencer (p. 125).

Fig. 1.—Lateral view of a Supero-marginal. × 3.
Fig. 2.— „ another Supero-marginal. × 3.
Fig. 3.—Profile view of an Infero-marginal. × 3.
Figs. 4 & 5.—Lateral views of small Supero-marginalia. × 3.
Fig. 6.—A small Marginal which possesses a pedicellaria. × 3.
Fig. 6*a*.—The pedicellaria highly magnified.

Arthraster cristatus, Spencer (p. 140).

Fig. 7.—Outer view of a Marginal. × 6.

Chomataster acules, Spencer (p. 126).

Fig. 8.—Lateral view of a Supero-marginal. × 3.
Fig. 9.—Profile view of same. × 3.
Fig. 10.—Lateral view of another Supero-marginal. × 3.
Fig. 11.— „ a third Supero-marginal showing pedicellaria.
Fig. 11*a*.—Portion of surface of same highly magnified to show shape of pedicellaria.
Fig. 12.—A Supero-marginal with two large spine pits. × 3.
Fig. 13.— „ from near extremity of arm. × 3.

Teichaster favosus, Spencer (p. 122).

Fig. 14.—Profile view of a Supero-marginal. × 3.
Fig. 15.—Lateral view of another Supero-marginal. × 3.
Fig. 16.— „ a third Supero-marginal to show pedicellaria. × 3.
Fig. 16*a*.—Portions of surface of same magnified to show shape of pedicellaria.

Lophidiaster pygmæus, von Hagenow, M.S. (p. 139).

Fig. 17.—Six Marginals. Nat. size.
Fig. 18.—A smooth Supero-marginal. × 6.
Fig. 19.—A rugose Supero-marginal. × 6.

Ophryaster magnus, Spencer (p. 130).

Fig. 20.—Four Supero-marginalia in abactinal view. Nat. size.
Fig. 21.—Two Infero-marginalia in actinal view. Nat. size.
Fig. 22.—Supero-marginal from near extremity of arm, showing a large spine pit. × 3.
Fig. 23.—Abactinal view of a Supero-marginal. Nat. size.
Fig. 24.—An Infero-marginal showing a valvate pedicellaria. Nat. size.
Fig. 25.—Abactinal view of a Supero-marginal. × 3.
Fig. 26.— „ another Supero-marginal. × 3.
Fig. 27.—Portion of surface of a Supero-marginal highly magnified (× 12) to show shape of pedicellaria.

Chomataster præcursor, Spencer (p. 126).
From the *B. mucronata* Greensand of Köpinge, Sweden.

Fig. 28.—Profile view of a Supero-marginal. Nat. size. Coll. Lund. Mus.
Fig. 29.—Lateral view of same.

Stauranderaster gibbosus, var. *pyramidalis*, Spencer (p. 134).

Fig. 30.—Lateral view of an abactinal ossicle. × 3.