

DET KONGELIGE DANSKE VIDENSKABERNES SELSKAB

BIOLOGISKE SKRIFTER, BIND II, NR. 5

THE ASTEROIDS OF
THE SENONIAN AND DANIAN
DEPOSITS OF DENMARK

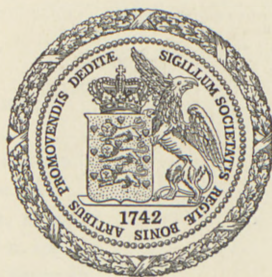
BY

K. BRÜNNICH NIELSEN

OPUS POSTHUMUM

EDITED BY

TH. MORTENSEN AND ALFRED ROSENKRANTZ



KØBENHAVN

I KOMMISSION HOS EJNAR MUNKSGAARD

1943

DET KONGELIGE DANSKE VIDEENSKABERNS Selskab
HISTORISKE ERHVERVSMUSEUM

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DR. H. H. HEDBERG AND ALFRED ROSENKRANTZ



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PREFACE

The death of Dr. K. BRÜNNICH NIELSEN in the spring of this year was a grievous loss to Danish palæontological and geological science. For many years Dr. BRÜNNICH NIELSEN had devoted himself to the study of the Senonian and Danian fossils, the results of which investigations were embodied in a long series of valuable publications. He was an extremely energetic collector, and by means of his thorough methods he succeeded in calling attention to a huge quantity of fossils, among others a great number of forms, the presence of which in our strata had until then been unnoticed, in some cases even entirely unexpected. Dr. BRÜNNICH NIELSEN was possessed of a superior power of combination which enabled him to reconstruct a number of species, the remains of which were found scattered throughout the strata. Here particular attention should be called to his arduous work with the Crinoids, which i. a. resulted in the very much appreciated reconstruction of *Cyathidium holopus*. In the last years of his life Dr. BRÜNNICH NIELSEN was particularly occupied by the study of the Asteroids, an animal group whose greatly scattered remains play a very important part in the composition of the Danish Senonian and Danian faunas. A manuscript on this subject had been prepared and accepted for publication in the memoirs of this Academy, but had not been made ready for print before the death of the author. It was the wish of Dr. BRÜNNICH NIELSEN that this paper should be published in English, the translation having been undertaken by Mrs. ASLAUG MIKKELSEN M. A. The editors beg to thank Dr. C. CROSSLAND for kindly undertaking a technical revision of the English MS.

København, November 1942.

TH. MORTENSEN

ALFRED ROSENKRANTZ

INTRODUCTION

The remains of Asteroids found in the Senonian and Danian deposits of Denmark are very numerous. The plates practically always occur isolated, and only in rare cases it has proved possible to find plates belonging to a single specimen and, in very rare cases, plates remaining in the original connection. In this respect the White Chalk of the Senonian seems more favourable than the Danian sediments, from which only four such cases are known.

The determination of these remains is, therefore, a very difficult and precarious task.

When an attempt is now made to give a survey of the remains found in Denmark, it is more particularly in order to call attention to these very frequently occurring fossils, so that they may be used e. g. for stratigraphical purposes. The fact that it is possible to reduce these conditions to some sort of order is due to the fundamental works by SLADEN and SPENCER (7) and by SPENCER (8), which give a good account of the plate forms characteristic of the English species. In recent times a treatise has been published by JEAN MERCIER (5) with the object of reducing to order the remains of Asteroids from the Basin de Paris. MERCIER, who has had the same difficulties to contend with as myself, has erroneously referred to SPENCER's species such forms which, both as regards form and ornaments, differ so greatly from SPENCER's illustrations that they do not in the least resemble the remains of plates, which have been found in Denmark and which, partly by SPENCER himself, have been determined as belonging to the species described by him. I have arrived at the conclusion that, when comparing two forms, there must be a close agreement, both in the shape and the ornament of their plates, if they are to be placed within the same species. However, it is true that in this manner the great variability disappears, which makes the species-series of SPENCER so comprehensive.

If the knowledge of these plates is to be of any use from a stratigraphical point of view, it is necessary to claim full agreement between the plates found and those described in the literature on the subject. If this is done, these animals will be very useful to the field geologist, as affording points of support for a more accurate division of the deposits. A great number of the remains found must, however, for the time being, be put aside as undeterminable.

GENERAL REMARKS

As it is difficult to reconstruct individuals in such a manner as to get a specimen with all its plates for description, this paper will first deal with the various plate forms found in the sediments, seeing that part of them cannot be referred to any particular species and must, therefore, be treated separately as isolated plates. Where plates have been found in connection, all the plate forms in the find will naturally be dealt with collectively in the descriptions of the species.

The following plate forms can be distinguished:

- a. Marginal plates or marginalia
- b. Terminal supero-marginalia¹
- c. Terminal infero-marginalia
- d. Terminal plates of the arm or terminalia
- e. Arm plates
- f. Adambulacralia
- g. Ambulacralia
- h. Mouth plates
- i. Dorsal plates
- j. Madreporites
- k. Neighbouring plates of the madreporite
- l. Interradial plates
- m. Pedicellariae

a. Marginalia.

In most of the Asteroids the margin of the animal, both on the arm and on the disc, has been covered with two rows of plates, supero- and infero-marginalia. These marginalia constitute the greater part of the finds in the sediments, and are consequently the most important for the determination of the species.

Thus from a systematic point of view the remains belong to the *Phanerozonia*, but this does not exclude the possibility of *Cryptozonia* having been of frequent occurrence in the same sediments.

¹ See note p. 14.

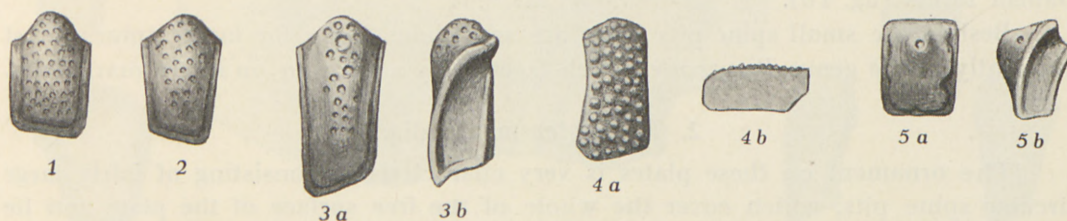
The ornaments of these marginalia are one of the distinguishing characteristics which, in connection with the general form of the plates, permit the division into genera.

The following plate forms may be distinguished:

1. Marginalia with *Metopaster* ornament
2. *Teichaster* marginalia
3. *Pycinaster* marginalia
4. *Chomataster* marginalia
5. *Ophryaster* marginalia
6. *Astropecten* marginalia
7. *Stauranderaster* marginalia

1. Marginalia with *Metopaster* ornament.

Most of the marginalia found have a "*Metopaster* ornament" such as described by SPENCER (8). The free surface of the plate has along the border a narrow,



Figs. 1—5. Fig. 1. *Metopaster* sp. Supero-marginal plate. Younger Danian. Fakse. $\frac{3}{1}$. Fig. 2. *Recurvaster* sp. Supero-marginal plate. Younger Danian. Fakse. $\frac{3}{1}$. Fig. 3. *Recurvaster* sp. Supero-marginal plate. Younger Danian. Herfølge. $\frac{3}{1}$. a. Outer side. b. Articular face. Fig. 4. *Metopaster uncutus* FORBES. Supero-marginal plate. Senonian. Båstad, Scania. $\frac{3}{1}$. a. Outer side. b. Profile. Fig. 5. *Metopaster* sp. Supero-marginal plate. Younger Danian. Herfølge. $\frac{3}{1}$. a. Outer side. b. Articular face. ST. HENTZE del.

slightly depressed zone, which may be crowded with minute, close-set spine pits, and a slightly raised, central area, which is smooth, provided with circular, distinctly separated, more or less regular spine pits (fig. 1). SPENCER refers this ornament to *Metopaster* and regards it as a main character of this genus, remarking at the same time that a very similar ornament may occur in *Stauranderaster*, the marginalia of which are, however, easily distinguishable from *Metopaster* by their different shape.

These considerations, which have resulted in SPENCER'S having added a variety "*radiatus*" to two of his species of *Metopaster* do, however, not hold good as far as Danish species are concerned. A couple of fortunate finds prove that this ornament occurs in an identical form both in a typical *Metopaster* with a large terminal supero-marginal plate, and in a form which has nothing to do either with the typical *Metopaster* or with the radiate variety of SPENCER, but belongs to a new genus: *Recurvaster* (fig. 2). Another find of plates in connection proves that the same ornament recurs in another new genus: *Ravniaster*.

Within the Danish deposits this ornament may consequently be found on the plates of four different genera.

The ornament may be subject to changes, according to SPENCER by a evolutionary process; the area between the spine pits may become rugose (fig. 3), and then the spine pits may disappear, the plate becoming rugose without pits (fig. 4). This particularly applies to *Mitraster*. Another development may take place, the pits disappearing without the surface becoming rugose. The central area is then quite smooth, and the *Metopaster* ornament can only be identified by means of the narrow, depressed border along the margin (fig. 5).

These plates differ greatly in shape. The profile may show that the margin of the animal was very high, the lateral surface of the marginalia being very large and merging into the smaller dorsal surface, which often carries tumidities. The lateral surfaces of the supero- and infero-marginal plates sometimes lie in continuity (plate I, fig. 13), frequently forming an angle (plate II, fig. 5). In other plates the lateral surface is very low, whereas the dorsal surface is very large. The profile then becomes what SPENCER calls the "uncatus" profile, which occurs in several Danish forms (fig. 4b).

Besides the small spine pits there are sometimes facets for larger spines, most frequently in the genus *Recurvaster*. Such facets may also occur on infero-marginalia.

2. *Teichaster* marginalia.

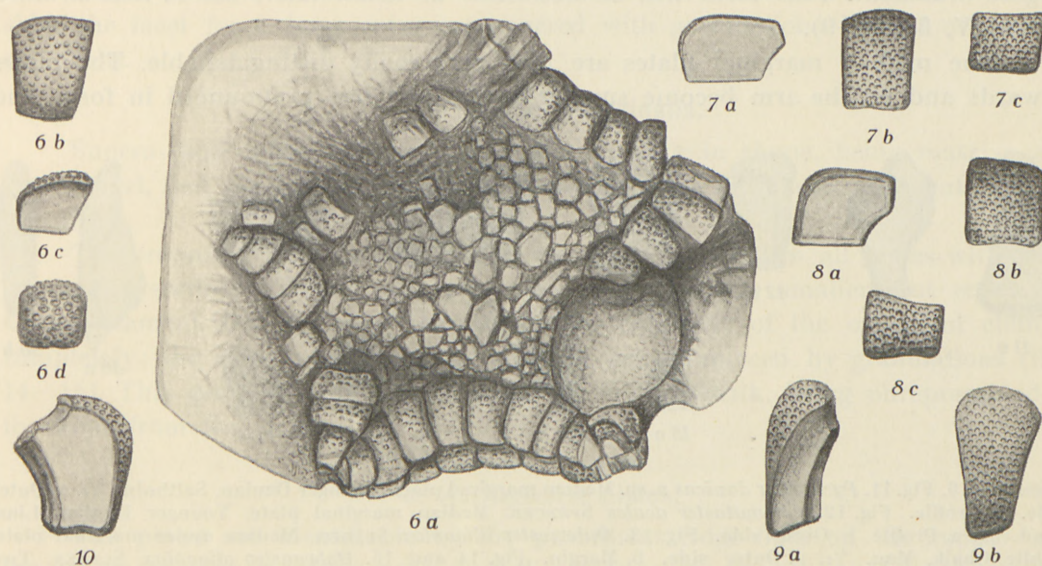
The ornament on these plates is very characteristic, consisting of fairly large circular spine pits, which cover the whole of the free surface of the plate and lie like the cells of a honeycomb, frequently with a small interspace between the individual pits, thus producing a hexagonal pattern. Sometimes this interspace may be slightly rugose and prominent. The crater-shaped pits, known in the closely related *Crateraster*, do not occur in the Danish forms of *Teichaster*. The most pronounced characteristics of these plates are, however, the robust shape and the sharp distinction between the lateral and dorsal parts of the plate (figs. 6 a—b).

In the White Chalk of Denmark these plates are not common, and the plates found are different from one locality to another. On a plate from the island of Møn the dorsal part of the supero-marginal is, as SPENCER describes it, covered by closely placed, nearly hexagonal spine pits, while the lateral face is covered by more scattered circular spine pits (fig. 7). Another supero-marginal plate from the White Chalk at Stevns Klint (♁: the cliffs of Stevns) has a coarsely granulated dorsal face, whereas the lateral face carries circular spine pits (fig. 8). On a third the dorsal face is ornamented with coarse hexagonal spine pits, whereas the lateral face is coarsely granulated. This plate was also found in Stevns Klint. Finally, there are from the same locality some plates with uniformly shaped circular spine pits scattered over both faces.

In Older Danian Bryozoan limestone there is a form with an ornament of a honeycomb appearance, which covers the whole of the free surface of the plate,

both the lateral and the dorsal side. The large circular spine pits lie rather close to one another, so that the intermediate face projects somewhat between the pits. The most characteristic feature of this species is, however, the shape of the marginal plate, the lateral being twice the size of the dorsal side. These plates are described in greater detail under *Teichaster anchylus* (fig. 9).

In the Younger Danian there are only a few plates which may be referred to this genus (Bryozoan limestone, Fakse). The supero-marginalia are peculiar in that



Figs. 6—10. Fig. 6. *Crateraster quinqueloba* GOLDFUSS. English White Chalk. a. Specimen with many plates in their original connection. $\frac{3}{2}$. b. Median marginal plate. Upper side. c. Same. Profile. d. Same. Lateral side. b—d $\frac{2}{1}$. Fig. 7. *Teichaster favosus* SPENCER. Median marginal plate. White Chalk. Møn. $\frac{3}{1}$. a. Profile. b. Upper side. c. Lateral side. Fig. 8. *Teichaster favosus* SPENCER. Median marginal plate. White Chalk. Stevns. $\frac{3}{1}$. a. Profile. b. Upper side. c. Lateral side. Fig. 9. *Teichaster anchylus* n. sp. Median marginal plate. Older Danian. Stevns. $\frac{3}{1}$. a. Profile. b. Outer side. Fig. 10. *Teichaster reliformis* SPENCER. Infero-marginal plate. Profile. Younger Danian. Lime sand. $\frac{3}{1}$. ST. HENTZE del.

the boundary line between the lateral and the dorsal faces is very close to the articular face between the supero- and infero-marginalia, the dorsal face, which is not horizontal, being considerably larger than the lateral one. The profile of the infero-marginal plate and the ornament is the same as in the preceding plates.

In the Younger Danian lime sand deposits there is a form which is distinguished by the great depth of the infero-marginalia. This form was named by SPENCER *Teichaster reliformis* (fig. 10).

3. *Pycinaster* marginalia.

The median supero-marginalia are easily distinguishable by their general forms. They are very high and wedge-shaped. In profile they are easily recognised by

the tumidity showing towards the body cavity and by the backwards curving outer surface (fig. 11). The ornament is very variable in the Danish forms. In the White Chalk and the Older Danian the comparatively few plates are nearly smooth, or covered only with a faintly visible ornament consisting of large, circular spine pits (plate III, figs. 22—23). In Younger Danian there are some plates with facets for larger spines. These are described as a separate species: *P. danicus* (fig. 11). In certain localities of Younger Danian (lime sand facies) there is a species with a pronounced rugose ornament. This form will be described in detail later, see *P. Rosenkrantzii* (plate IV, figs. 6—9).

The median marginal plates are thus very easily distinguishable. The plates towards and on the arm become smaller in size and less pronounced in form, and



Figs. 11—16. Fig. 11. *Pycinaster danicus* n. sp. Median marginal plate. Younger Danian. Saltholm. $\frac{3}{1}$. a. Outer side. b. Profile. Fig. 12. *Chomataster acules* SPENCER. Median marginal plate. Younger Danian. Lime sand. $\frac{3}{1}$. a. Profile. b. Outer side. Fig. 13. *Ophryaster oligoplax* SLADEN. Median upper marginal plate. White Chalk. Møn. $\frac{3}{1}$. a. Outer side. b. Margin. Fig. 14 and 15. *Ophryaster oligoplax* SLADEN. Two arm plates. $\frac{3}{1}$. Outer side and profile. Fig. 16. *Lophidiaster ornatus* SPENCER. Median marginal plate. Senonian. Båstad, Scania. $\frac{3}{2}$. a. Profile. b. Outer side. ST. HENTZE del.

as no collective find has been made, which might supply material for comparison, they are often included among the remainder of asteroid plates which, in every find, must be put by as indeterminate.

4. *Chomataster* marginalia.

The ornament is more or less pronounced, with very closely placed, small, circular spine pits. The large median supero-marginalia, which are most easily identifiable by their profiles, are thin with a vertical lateral face, terminating in a prominent tumidity forming the base of a strong spine. The lateral face forms a right angle with the short dorsal face (fig. 12). No find consisting of plates in connection is known from the Danish deposits. All plates belonging here are referred to SPENCER'S two species, viz. *C. acules* with the large spine, mentioned above, on the median supero-marginalia and *C. præcursor*, which is devoid of such a spine.

As in the preceding genus the median supero-marginalia are easily identifiable, whereas the infero-marginalia farther out towards the arm are difficult to determine.

From the White Chalk only few plates are found which belong here (Stevns, Møn, Aalborg). Most of them have a large spine facet, whereas a single one has two large facets. However, they all deviate from SPENCER'S description of the species, the whole of the surface being covered with circular spine pits. The Danish forms are low.

From Older Danian a number of large plates is known. Also here the whole of the surface is covered with distinct circular spine pits.

In the Younger Danian (lime sand) a number of small forms occur, which besides the facet for a large spine are covered with granulations instead of circular spine pits.

5. *Ophryaster marginalia*.

Supero- and infero-marginalia are almost alike in shape, being massive and very robust, and the lateral face gently rounds off into the dorsal and ventral faces, (fig. 13).

The ornament consists of scattered circular spine pits on all plates within the interradiation section. Towards the arms the plates become smaller, but retain the same ornament. On the arms themselves the character of the ornament changes completely; the spine pits disappear entirely, being replaced by granulations (figs. 14—15). This genus is only known from the White Chalk, being unrepresented in the finds from the Danian.

6. *Astropecten* plates.

The plates are identifiable by the prominent ridge both on the supero- and the infero-marginalia. The surface of this ridge may be sharp (*Lophidiaster*) or broad (*Astropecten*). The ornament on the surface of the ridge may vary greatly. The surface may be 1) quite smooth or supplied with scattered spine pits, or 2) it may be supplied with granulations, which may either be of the same or of a different size, so that on plates of this kind there are both large and small granules (fig. 16).

The genus *Lophidiaster* is evenly represented throughout all Danish deposits from Senonian to Danian.

7. *Stauranderaster marginalia*.

These plates are generally small, and there is very little difference between the upper and lower ones. Their distinguishing characteristic is the articular faces on the dorsal and ventral sides, supporting, the large dorsal and ventral plates which, in this genus, are developed in a peculiar manner (plate IV, figs. 26—28).

The ornament may, as mentioned, be very similar to that of *Metopaster*, consisting of a narrow, slightly depressed border and a central area with scattered spine pits.

b. Terminal supra-marginalia.¹

In most Asteroids the marginalia become smaller and smaller towards the end of the arm, and the last are narrow and disc-shaped. Only in *Metopaster* (and *Mitraster*) the last of the supero-marginalia presents definite characteristics. It has always a peculiar, easily distinguishable shape and may either be considerably larger than the median marginalia or smaller than the latter. Since by their special form these plates supply much information as to the general appearance of the animal, they deserve to be described in detail.

If one looks at the proximal margin of the plate, there is here an articular face, which connects this plate with the corresponding articular facet of the first median marginal plate (fig. 17 a). From this facet it is possible to determine the curve of the margin, the angle between the supero- and infero-marginalia and also the height of the median marginalia.

When turning the plate so that the under side faces upwards, the above-mentioned facet is seen to continue in a row of four-edged facets which, constantly decreasing in size, in an even curve reach the front margin of the plate, where there is a smaller or larger semicircular facet for the terminal unpaired plate of the arm (fig. 17 b).

The portion of the plate, which formed the outward boundary of the animal (the free part of the plate), has a part facing upwards and one facing outwards. The part facing outwards is generally trilateral, with a straight side facing backwards and a curved side facing upwards, which latter may be more or less deformed by a frequently occurring tumidity. The third side of the triangle faces downwards, and is seen in profile as a broken line corresponding with the facets of the outermost infero-marginalia (fig. 17 c). Seen from above the part of the free surface turning upwards is nearly four-sided. Towards the median line of the arm there is a straight line corresponding with the junction of the corresponding terminal supero-marginal plate from the other side of the arm. This line passes posteriorly at an obtuse angle into a face, which varies in length and marks the part of the margin connected with the covering plates of the dorsal surface. At an angle of about 90° is the third side of the quadrangle, this face corresponding with the junction of the nearest median upper marginal plate. Finally, the fourth side of the plate is formed by the free surface (fig. 17 d). The inner side of the plate has two smooth faces, the foremost as a rule oval in shape and marking the junction with the corresponding terminal supero-marginal plate from the other side of the arm. The proximal face, which is somewhat curved and sometimes slightly hollowed, faces the body cavity of the animal and is very variable in size (fig. 17 b).

¹ The designation "terminal supra- (and infra-) marginalia" is rather unfortunate, because it may lead to confusion with the terminalia proper, the unpaired plate found at the end of each arm. It would have been highly preferable to distinguish those plates as distal or distalmost supra- or infra-marginalia. Since, however, the first mentioned term is generally used in the literature on fossil Asteroids, the editors did not like to introduce the change of this term in a posthumous work.

The features of this plate which constitutes the characteristics of various species are the following:

I. The appearance of the free surface; smooth, dotted, rugose, with or without tumidity.

II. The angle between the free surface and its inward junction with the neighbouring terminal supero-marginal. This angle may vary greatly, from 35° — 90° . Upon it depends the shape of the whole circumference of the animal. If the angle is narrow, the arm becomes protracted and pointed, whereas a wide angle makes the circumference of the animal more or less circular (figs. 18—19).

III. The size of the proximal inward face may vary greatly. If this face is large, it means that the arm projects very little, seeing that it is only represented by part of the supero-marginal plate (fig. 17 b); if on the other hand it is small, the whole plate goes to form the arm.

IV. The proximal facet which shows the shape of the median supero-marginalia may, as mentioned, vary considerably.

V. The anterior and distal, small, semicircular facet, which fits with the small unpaired terminal plate, may also vary considerably in size and thus supply a useful characteristic.

Such characteristic terminal supero-marginalia occur rather frequently in all deposits both of the Senonian and the Older and Younger Danian.

The variety "*radiatus*" mentioned by SPENCER has not as yet been identified with certainty in the deposits of Denmark, but there are a few terminal marginalia, which may possibly be referred to it. According to SPENCER'S figure (8, plate 14, fig. 3) the arm is seen to terminate in a comparatively large, rounded terminal marginal plate. The arm, as seen from the dorsal side, consists of four marginal plates, very nearly equal in size. The ornament on these plates cannot be distinguished on the figure. The terminal plate is not larger than the others and is gently rounded. It has a face showing towards the first proximal arm plate and a lateral face at right angles to the said face and connecting the plate with the corresponding plate from the other side of the arm. A single terminal marginal plate of this kind is known from Danish deposits, so it is justifiable to suppose that also this "radiate" form is found in Denmark. SPENCER'S type specimen of four connected marginal plates from Saltholm (8, plate 15, fig. 8) perhaps contains the remains of such a form, and also the plate shown in fig. 20 a—e may be placed here. The dimensions of this terminal marginal plate are the following:

Length: 5 mm.

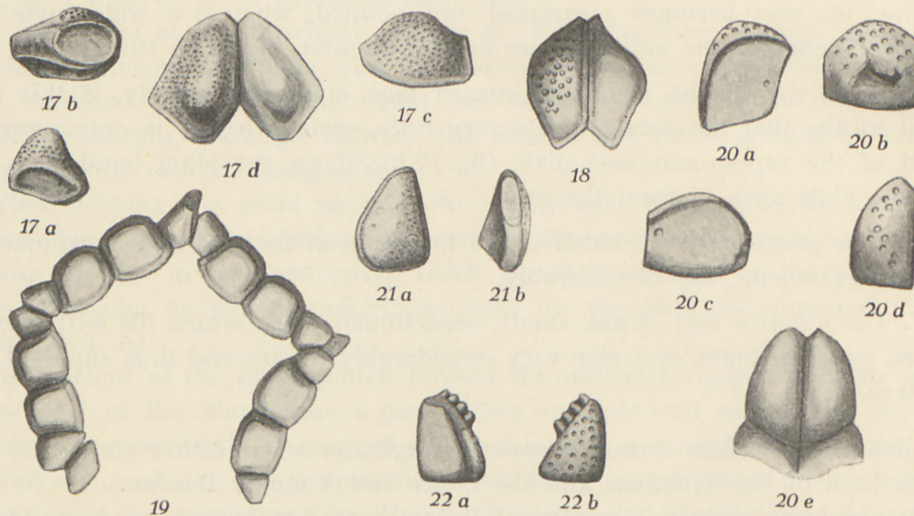
Height: 5 mm.

Height of facet towards adjacent upper marginal plate: 3 mm.

Depth - - - - - : 3 mm.

The free surface is shaped rather like part of a sphere, there being a slight tumidity which turns upwards and passes evenly into the margin of the plate. Scattered over the whole surface there are sparse circular spine pits of equal size. The boundary between the narrow border and the central area is sharp. The anterior angle of the plate is about 40° , the total angle of the arm thus being about 80° .

The proximal interior facet has disappeared entirely, the distal facet passing directly into the facet for the adjoining supero-marginal plate. The posterior facet



Figs. 17—22. Fig. 17. *Metopaster tumidus* SPENCER. Terminal supero-marginal plate. Senonian. Båstad, Scania. $\frac{3}{1}$. a. Median articular face. b. Inner side. c. Outer side. d. Upper side. Fig. 18. Two united terminal supero-marginalia. $\frac{3}{1}$. Fig. 19. *Ravnaster simplex* n. sp. Reconstruction, seen from above. $\frac{4}{1}$. Fig. 20. *Metopaster* (var. *radiatus*?). Terminal supero-marginal plate. Older Danian. Kagstrup. $\frac{6}{1}$. a. Articular face. b. Outer side. c. Inner side. d. Upper side. e. Extremity of the arm. Fig. 21. *Recurvaster planus* n. sp. Supero-marginal plate. Danian. $\frac{5}{1}$. a. Outer side. b. Inner side. Fig. 22. *Recurvaster planus* n. sp. Infero-marginal plate with remains of ambulacralia. Danian. $\frac{5}{1}$. a. Upper side. b. Under side. ST. HENTZE del.

shows that the profile of the arm had only a faint curvature, and that the supero-marginalia were very nearly equal in height and depth. The under side shows three small facets for lower marginalia. The facet for the terminal plate of the arm is proportionally large.

c. Terminal infero-marginalia.

Among other Asteroids from Egypt, which have been described by DE LORIO (4), SPENCER (8, p. 151) mentions a *Metopaster Teilhardii*, describing it as follows:

"*M. 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”.

Several forms with such large terminal infero-marginalia are known from the Danish deposits, and they will be referred to a new genus: *Ravniaster*. Like SPENCER, I am of the opinion that these forms cannot be referred to the genus *Metopaster*, even though the ornament in most of them is exactly the same as in *Metopaster*.

The large, terminal infero-marginal plate is as a rule flattened, triangular with a smooth face showing upwards, which serves for the attachment of the corresponding terminal supero-marginal plate. The face showing towards the ambulacral furrow is either straight or curved, and frequently carries impressions of the short, rod-shaped ambulacralia. The free surface showing downwards and outwards may have a typical *Metopaster* ornament; it may also be quite smooth or covered with small protuberances (figs. 21—22).

In the White Chalk a couple of forms occur, which belong here. The Danian contains a very frequently occurring form, which is found throughout all horizons. This form is widely distributed outside Denmark; thus I possess some plates belonging to it from the Turonian of France (Chatellerault).

d. Terminal plates.

At the extremity of each arm, or rather as a distal termination of each ambulacral furrow, there is an unpaired, terminal plate.

On the under side of this plate there is a furrow, which terminates the ambulacral furrow of the arm and ends in a small oval depression, where the feeler with the eye was situated. This depression as a rule faces dorsally. The free dorsal side is frequently ornamented, either with fine granules or with facets for large spines, of which there may be one to three. Most of the terminal plates found belong to the *Pentagonasteridae*, having the truncated oblique lateral surfaces, which correspond with the outermost facets of the last (distalmost) supero-marginalia. Thanks to the finds of plates in connection made in Denmark some of them may be referred to species of *Metopaster*, but most of them are found isolated and can only in some cases be determined (figs. 23—24).

Besides these terminalia with sharply cut facets there are a number which entirely lack articular facets, but are evenly rounded along the margin. Part of those are greatly swollen, others are small, broad and low and exactly resemble terminalia from recent cryptozoiate Asteroids (fig. 25). There is no doubt that these terminalia may be referred to cryptozoiate Asteroids, a group which had not been identified in Mesozoic deposits, until in 1935 MERCIER (5) described and figured such plates from Jurassic and Older Cretaceous deposits under the generic name of *Asterias*. In support of my supposition it may be mentioned that I have succeeded in finding a few typical star-shaped dorsal plates, completely corresponding with dorsal plates from recent species of *Asterias*.

I have undertaken a series of examinations of the terminalia of the Asteroids, thinking that these plates may be used for specific or generic diagnoses. However, the result obtained shows that there is no possibility of using them in this way, though the plates may with certainty indicate the presence of cryptozoniata Asteroids.

It is more particularly in the White Chalk that the large swollen plates occur. The Older Danian is rich in the massive, spine-bearing plates; they may, however, also occur in the Younger Danian, in which have also been found some plates with large protuberances resembling eyebrows.

e. Arm plates.

With the exception of supero- and infero-marginalia there are as a rule no characteristic plates in the arms of the Cretaceous Asteroids. Only the genus *Stauranderaster* has distinct rows of plates on the dorsal side of the arms, a middle row, by SPENCER called radialia [in recent sea-stars usually designated as carinalia], and possibly a couple of lateral rows, adradialia, which, in connection with the marginalia, form a solid armature for the arm, all the rows of plates being articulated with each other. These radials or dorsals may be of a peculiar shape, which makes it possible to identify them when found isolated. SPENCER figures such a plate of *Stauranderaster bulbiferus* (plate 12, fig. 10), but gives only one figure, which shows the profile of the plate. From this figure and his description it is, however, rather difficult to gather the meaning. With the kind permission of Dr. TH. MØRTENSEN I may here give a description of the arm of a *S. Boysii* (plate IV, fig. 24). The dorsal plate is club-shaped with a dorsally swollen area, which bears the ornament characteristic of the species, viz. a smooth surface with scattered punctiform spine pits. The four oblique lateral facets form articular faces, partly with the supero-marginalia, partly with the adjoining dorsals. The lowermost small face is square, facing the cavity of the arm. The supero-marginalia form articular faces towards these dorsals, the length of which is the height of the club-shaped dorsal.

In the Danish material this club-shaped dorsal is somewhat reduced; it is not so high as to be actually club-shaped, but only truncate-conical with the smaller face showing downwards. The articular faces on the oblique lateral faces are very well defined and make the plate identifiable with certainty (plate IV, figs. 26—27).

These plates are evenly distributed in the Senonian and the Danian.

f. Adambulacralia.

The Adambulacralia are cubical or parallelepipedic plates, which form a solid border along the two sides of the ambulacral furrow and serve to support the ambulacralia. They have a free margin, which may bear one or more rows of spine pits. When found isolated they are of no importance, even though they play a considerable part in the systematics of recent Asteroids (plate I, fig. 7).

g. Ambulacralia.

These plates, which constitute the sides and the bottom of the ambulacral furrow, are not very characteristic, but easily identified. When found isolated they are of no great importance, as they are rather alike in all the forms represented in the finds.

h. Mouth plates.

The strong mouth plates consist of the two proximal ambulacralia (Amb. I and II) in connection with the two proximal adambulacralia (Adamb. I and II) in each row. The oral skeleton then consists of twice two ambulacral and twice two adambulacral plates, or eight plates in all off each ambulacral furrow. In the whole of the mouth there are thus forty plates forming twenty pairs, the ambulacralia and adambulacralia having coalesced two and two.

There are two forms of mouth armature, depending upon the ambulacralia or the adambulacralia being most strongly developed.

Seen from the under side of the animal the adambulacral mouth is shaped like a strong five-rayed star, whereas the ambulacral mouth is apparently much less robust, the adambulacralia not being so close-fitting and more leaf-shaped. These structures are of importance in the classification of recent Asteroids (figs. 26—27).

In the Danish deposits both forms are represented, but only in very few cases have they been found in connection with other remains of the same specimen.

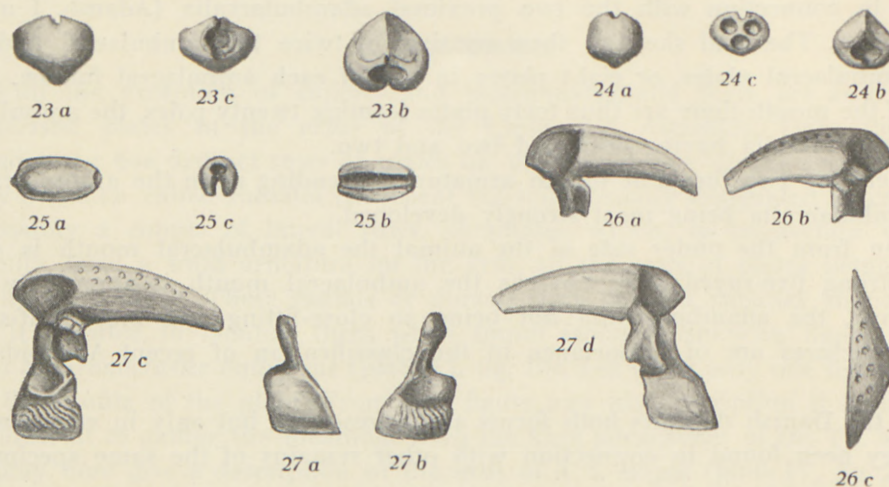
i. Dorsal plates.

In most of the Asteroids found in the Danish deposits the dorsal area within the marginalia is filled with a close-fitting pavement of angular plates; only in the radial papular zone the plates have a particular shape, becoming thicker and bearing upon their margins impressions of the elastic bands, which unite the individual plates and permit of some mobility. The surface bears an ornament corresponding with those of the marginalia, circular spine pits, small knobs or the like. Sometimes they carry pedicellariae. The main form is a regular hexagon of inconsiderable height. The border of the plate frequently has a groove surrounding all its six sides and serving to attach the elastic band (plate I, fig. 15). The lower border is sometimes protracted at the six corners, the plate thus becoming star-shaped. In a few cases these plates are very high, and instead of a single furrow running along the border six deep vertical grooves have been formed, the plate consequently presenting the appearance of a lantern (plate IV, fig. 32).

Such plates have been found in fairly large quantities in the Upper Grey Chalk from Trimmingham. The marginal plate most frequently found together with this was *Teichaster favosus*, and it is therefore a likely supposition that the peculiar dorsal plate belongs to this species. In the Danish deposits a few specimens were found

in the White Chalk of the cliffs of Møn and Stevns (a single specimen has been found at Båstad, Scania).

Special forms of dorsal plates are found in *Stauranderaster* and *Vallettaster* (SPENCER's *Tholaster*). In *Stauranderaster* there is in the centre of the dorsal side a large swollen plate, designated the centrale. At some distance from the latter five swollen plates, designated interradialia, are placed in a circle. From the centre of the disk a series of plates extends as far as the extremity of the arm, viz. the radialia or dorsalia (carinalia). The first of these, which belongs to the same circular



Figs. 23—27. Figs. 23 and 24. Terminal plates. Two isolated finds from Younger Danian. Saltholm. $\frac{6}{1}$. Fig. 25. *Asterias* sp. Terminal plate. White Chalk. Møn. $\frac{6}{1}$. Figs. 26 and 27. *Recurvaster stevensensis* n. sp. Mouth plates. White Chalk. Stevns. An ambulacral plate 1 and 2, separate and united. $\frac{5}{2}$. ST. HENTZE del.

row as the interradialia, is also swollen. All these plates bear the same ornament as the marginalia; this may consist of a small depressed border and a central area with scattered spine pits as in *Metopaster*, or it may be quite smooth or covered with small knobs.

Besides these easily identifiable plates there may also be others, presumably originating from that part of the dorsal side of the disc, which is not filled with the above-mentioned rows of plates. Thus a plate of quite a different appearance has been found in a specimen of *S. Boysii* from the English Chalk. This plate is polygonal, rounded, with a very small, free dorsal face, which bears the ornament characteristic of the species. The ventral side of this plate is considerably larger than the dorsal, the lateral margins being cut off very obliquely. These lateral faces have irregular articular surfaces, frequently with punctiform depressions (plate IV, fig. 25). This form of dorsal plates, which has hitherto been regarded as characteristic of the genus *Vallettaster*, as described by SPENCER, makes it very difficult, when only isolated plates are at hand, to distinguish between these two genera, as there is risk of referring *Stauranderaster* plates to *Vallettaster*.

The genus *Valettaster*, the species of which are described as bell-shaped and vaulted with an unbroken border without arms, have dorsal plates distinguished by a very small, irregularly shaped free dorsal face, with or without ornament, and a much larger ventral face, which is irregularly wavy and has an irregularly rounded angular circumference. The lateral face of these plates is cut off very obliquely, with a greater or smaller number of articular faces, which may be either smooth or supplied with punctiform holes. The ornament on the small, free dorsal face may consist of more or less prominent meandering lines. It may also be absent, so that the plate is smooth (plate IV, fig. 29).

Finally there are—though rarely—some dorsal plates, which greatly resemble the star-shaped dorsal plates known from recent cryptozoniata Asteroids, often with a central circular facet for at spine. These plates may be supposed to belong to the same form as the formerly mentioned terminal plates. MERCIER (5) designated a form possessing such dorsal plates by the name of *Asterias* (plate IV, fig. 30).

j. Madreporite.

Where madreporites have been found, they have, as in recent forms, a regularly triangular circumference and are supplied with the well-known intertwined, closely joined fine grooves on the surface. The three lateral surfaces are very obliquely cut off, the ventral surface being considerably smaller than the dorsal.

k. Neighbouring plates of the madreporite.

Round the madreporite there are three plates of a rather peculiar appearance. Facing the madreporite those plates have a straight side, which is cut off obliquely so as to form a support for the madreporite resting on it. On the side facing the madreporite these three plates have a deep groove with a corresponding vaulting outwards on the free surface of the plate.

l. Ventral interradial plates.

These plates present no very characteristic features. They all have a free surface with ornaments of various kinds. The lateral faces are obliquely cut off, the plates in their original position being imbricated (plate I, fig. 4).

m. Pedicellariae.

In the material at hand the following forms of pedicellariae have been found:
Bivalved, elongated pedicellariae. They are particularly frequent in the infero-marginal of *Ophryaster* (plate IV, figs. 12, 13, 14, 15).

Bivalved, elongated pedicellariae with an extension in the middle.

Five-valved circular pedicellariae, which according to SPENCER are a distinguishing character of the genus *Pycinaster*.

SYSTEMATICS

The material at hand only in a very slight degree lends itself to classificatory remarks. Therefore, in this paper the classification of SPENCER (2) will in the main be followed, with only some small alterations and additions. SPENCER's generic name *Tholaster* is preoccupied and should be replaced by *Vallettaster*¹. As an addition is introduced the order *Forcipulata* with the genus *Asterias*, to which are referred the rare finds of some dorsal and terminal plates.

Finally, two new genera, *Recurvaster* and *Ravniaster*, have been established to include some greatly specialized forms with *Metopaster* ornament, one genus without the special terminal supero-marginal of the genus *Metopaster*, the other with the particularly developed terminal infero-marginalia and a greatly reduced number of plates in the row of marginalia.

When dealing with the genus *Metopaster*, the marginalia of which are easily identifiable by their characteristic ornament, it appears from the study of the specimens figured in the literature of the subject and of the few finds of plates in connection that all median marginalia in the same individual have the same appearance and are very nearly of the same size, only the terminal supero- and infero-marginalia deviating. If on the strength of this observation, one wishes to reconstruct an individual from the isolated plates at hand, it turns out that it is only possible to make quite a small number of plates fit together, and further that the number of different forms becomes very large.

According to SLADEN and SPENCER (7) the distinguishing characteristic of the genus *Metopaster* is the ornament on the marginal plates and, more particularly, the peculiarity that the terminal supero-marginal plate has a peculiar form and is frequently the largest in the series. Subsequently SPENCER changed this diagnosis to the effect that the main characteristic becomes the above-mentioned ornament, whereas the terminal supero-marginalia play no part from a systematic point of view (8), p. 108. He states that in catagenetic varieties these plates may be broken down into their primitive constituent ossicles. In this manner the variety "*radiatus*" appeared, which he finds both in *M. tumidus* and in *M. mammillatus*.

¹ Editors' note: This name was proposed by LAMBERT: *Révue de Paléozoologie*. 1914, p. 27; cf. VALETTE (9), p. 57.

In the Danish deposits there are numerous plates with a *Metopaster* ornament, partly typical forms with a peculiarly shaped terminal supero-marginal plate, partly plates of a form which, according to SPENCER, should be classed with the variety "radiatus", their two lateral faces differing in size. But as, owing to a fortunate accident, a considerable number of ossicles belonging to one individual have been found, it can be proved that part of these plates have no connection, neither with *M. tumidus* and *M. mammillatus* nor with their varieties. They belong to an entirely different genus, which is closely related to the recent genus *Ceramaster*. As to the Danish forms there is consequently no reason to modify the original diagnosis of the genus, which is based upon the ornament in connection with the peculiarly shaped terminal supero-marginalia, and it is thus more particularly the latter which, by their differences, may serve to distinguish the various species.

As to the varieties of *M. tumidus* and *M. mammillatus*, which SPENCER (8) named "radiatus", it is peculiar that it bears no resemblance whatsoever to the main form. The arms, which are straightly extended, without a curvature at the extremity, have four brachial joints in the row of supero-marginalia. They are very nearly of the same size and terminate in a comparatively large supero-marginal plate, the shape of which is like the fourth part of a sphere. The most prominent feature is that the terminal marginal plate is separated from the adjacent arm plate by a section at right angles to the direction of the arm. If one imagines these four plates as being fused into a single terminal supero-marginal plate, its shape will be widely different from the terminal supero-marginal plate of the main form. The median marginalia are distinguishable by their size, which decreases in the direction of the arm, but it is difficult to understand, why the median marginalia should change character, because the terminal marginal plate has broken down.

There is evidence that a breaking down like the one mentioned may take place. We have before us the outer fragments of terminal marginalia of *Metopaster kagstrupensis* from Korporalskroen, and these fragments follow so exactly the appearance of the main form that it is possible to put together a complete plate and a fragment, in such a manner that the extremity of the arm becomes natural (plate I, fig. 15). The median marginalia of this species all have equally large lateral articular faces.¹

In SPENCER'S "radiatus" there is nothing to suggest the new genus *Recurvaster*, the arm plates of which become smaller and smaller and terminate in a thin, disc-shaped plate under the terminal plate.

In my opinion SPENCER'S "radiatus" forms belong to an entirely different species which may, however, with some stress be referred to the genus *Metopaster*,

¹ Editors' note: In the opinion of the editors the fragment shown on pl. I, fig. 15 does not afford evidence of a natural breaking down of the large distal supero-marginal into smaller plates; the small plate shown in the figure has all the appearance of being merely a fragment accidentally broken off a larger plate. A natural breaking down of originally large plates into a number of smaller ones, such as that supposed to have taken place in this "radiatus" form, is most improbable and has not been observed in any recent form.

as the terminal supero-marginal plate bears the characteristic shape of the latter. In the Danish deposits a single terminal supero-marginal plate has been found, which may have belonged to such a form, and has been mentioned in the preceding chapter. Owing to the scarcity of the material at hand I shall not enter into this question, but only give a warning against referring median marginalia with *Metopaster* ornaments to definite species of the genus *Metopaster*.

The new genus *Recurvaster* was established, because it appears from the specimen found with the arm plates in their original position that the structure of the arm in this form has nothing in common with the genus *Metopaster*. It is, therefore, impossible to make this form fit in with any of the definitions given of the genus *Metopaster*.

The other new genus *Ravniaster* includes Asteroids with a special construction of the arm, not only the terminal supero-, but also the terminal infero-marginal plate being large and formed in a special manner, which is unknown in *Metopaster*. SPENCER mentions an Egyptian form of this construction, saying that it cannot be referred to the genus *Metopaster*. Besides this peculiarity of the large infero-marginalia there is another, which is also very surprising. A find of plates belonging to one and the same individual proves that there are very few plates in the row of marginalia. In one species there is nothing but terminal marginalia, so that the number of plates in the row of supero-marginalia all along the border is only ten in all. The number of the infero-marginalia may also be reduced to ten, but there is some variation here, as the infero-terminal marginal plate may be divided. In other species there are four plates in the row of supero-marginalia, viz. two terminal and two median ones.

Apart from these few modifications it is possible to maintain the part of SPENCER's classification, which is of importance to the Danish forms.

Order *Granulosa*, PERRIER

Family *Pentagonasteridae*, PERRIER

Genus *Metopaster*, SLADEN

- » *Mitraster*, SLADEN
- » *Recurvaster*, n. g.
- » *Ravniaster*, n. g.
- » *Teichaster*, SPENCER
- » *Pycinaster*, SPENCER
- » *Chomataster*, SPENCER
- » *Ophryaster*, SPENCER

Family *Stauranderasteridae*, SPENCER

Genus *Stauranderaster*, SPENCER

Order *Spinulosa*, PERRIER

Family *Sphaerasteridae*, SCHÖNDORF

Genus *Vallettaster*, LAMBERT

Order *Paxillosa*, PERRIER
 Family *Astropectinidae*, GRAY
 Genus *Lophidiaster*, SPENCER
 Order *Forcipulata*, SPENCER
 Genus *Asterias*, LINNÉ

Order GRANULOSA, Perrier.

Family *Pentagonasteridae*, Perrier.

• Genus METOPASTER, Sladen.

The species belonging to this genus all have a peculiarly shaped terminal supero-marginal plate, as has been described by SPENCER (8).

The Danish species are approximately divided according to the beds in which they were found, so that it is natural to describe them in three groups: the species of the Senonian White Chalk, the species of the Older Danian and the species of the Younger Danian.

The species of the White Chalk.

The species described below, which are identified by means of their terminal supero-marginal plates, may be referred to two of SPENCER's series, partly the *M. Parkinsonii* series and partly the *M. undulatus* series. The third *M. uncatu* series is not represented in its typical form in the Cretaceous deposits of Denmark.

From the Danish White Chalk the following species are known as belonging to the *M. Parkinsonii*, series:

1. *Metopaster tumidus*, SPENCER
2. *Metopaster Poulsenii*, n. sp.
3. *Metopaster stevensensis*, n. sp.
4. *Metopaster angulatus*, n. sp.

and to the *M. undulatus* series:

5. *Metopaster undulatus*, SPENCER
6. *Metopaster granulatus*, n. sp.

The plates of these two groups are distinguished from each other, in that the plates of the *M. Parkinsonii* series have spine pits, which are of the same size everywhere on the same plate, and the narrow border is distinctly separated from the central area, whereas the plates of the *undulatus* group have spine pits varying in size on the same plate, and the transition between border and central area is quite even.

1. *Metopaster tumidus*, SPENCER.

Plate I, figs. 1 a—d.

1913. *M. tumidus*. SPENCER: 8, p. 113, plate 10, figs. 8, 15; plate 14, figs. 1—2; plate 15, figs. 1—7.

The specific characters of this species are according to SPENCER (8. p. 113): "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 terminal supero-marginal plate figured (8, plate 15, fig. 1) is selected as the holotype of the species.

The terminal supero-marginal plate is very easily distinguishable by its great tumidity and the great lateral and dorsal face of the plate. After the reconstruction (8, plate 14, figs. 1 and 2) this terminal supero-marginal plate is much larger than the other supero-marginalia, of which there are six in each interradius. All the plates in the upper row of marginalia are of equal appearance and size. In so far everything seems to be in good order; but to the same species SPENCER also refers plate 10, fig. 8, which besides the distinctive dorsal tumidity has another and smaller, showing towards the extremity of the arm. Plate 10, fig. 15 shows the profile of a pair of connected supero- and infero-marginalia. They lie very nearly in continuity and show that the margin of the animal has practically been vertical. The tumidity is very pronounced. SPENCER's plate 15, figs. 2, 3 and 4 represent differently shaped supero-marginalia, which undoubtedly do not belong to the species described above, as each of them requires that adjacent plates should be of the same appearance. In the same manner SPENCER's plate 15, fig. 6 represents a profile, which does not correspond with the one shown on plate 10, fig. 15.

The terminal supero-marginal of SPENCER, figured on plate 15, fig. 1, the profile of plate 10, fig. 15 and the reconstructed individual plate 14, figs. 1—2 together give the impression of a well defined and well founded species, whereas the remaining plates, which SPENCER refers to *Metopaster tumidus*, should be referred to some other hitherto undescribed species.

The material from the Danish White Chalk contains a specimen which may be referred to this species, viz. a supero-marginal plate from Møn; in its shape and size it corresponds entirely with the holotype of SPENCER, whereas its ornament differs somewhat, only the tumidity possessing spine pits, while the remainder of the surface is quite smooth. SPENCER's holotype has spine pits scattered all over the surface (plate I, figs. 1 a—d).

This supero-marginal plate has the following dimensions:

Length: 11 mm.

Breadth: 11 mm.

Height of facet towards adjacent supero-marginal plate: 7 mm.

Depth - - - - - : 4 mm.

The free surface has a well defined, very pronounced tumidity, covered all over with closely placed, circular spine pits of unequal size, while the remaining part of the free surface is quite smooth, without holes.

The anterior angle of the plate is hardly 45° , the total angle of the arm thus being less than 90° .

The posterior inward face is large, as large as the one in front. The facet towards the arm shows that its profile has had a slight curvature, and that the heights of the median supero-marginalia have exceeded their depths.

The facet for the terminal plate of the arm is very small.

M. tumidus seems to be of rather rare occurrence in the White Chalk of Denmark, and then only in a single variety corresponding with SPENCER'S plate 15, fig. 1. The form figured on plate 14, fig. 1, which is distinguished by the angle at the extremity of the arm being comparatively small, somewhat less than 90° (both plates joined together), is not known from the Danish White Chalk, but from the limestone of Båstad in Scania (gravel limestone from the zone with *Belemnitella mucronata*), I have a terminal supero-marginal plate, which seems identical with SPENCER'S form from Rügen mentioned above. Text, fig. 17.

The dimensions of this plate are

Length: 11 mm.

Height: 11 mm.

Height of facet towards adjacent supero-marginal plate: 4 mm.

Depth - - - - - : 5 mm.

The free surface has a well defined, elongated, very pronounced tumidity. The whole of the free surface, also the tumidity, is covered with rather closely placed circular spine pits of equal size.

The anterior angle of the plate is hardly 45° , the total angle of the arm thus being less than 90° .

The inward, posterior face is about the same size as the one in front. The facet towards the arm shows that the profile of the arm has had a great curvature, and that the height of the median supero-marginalia has been less than the depth. The facet for the terminal plates of the arm is rather small.

JEAN MERCIER mentions this species from the Coniacian and Maastrichtian in the Basin de Paris, but description and figures (5, pp. 30—31, plate 1, figs. 17a—f) show that these plates probably have nothing to do with SPENCER'S species.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk. Møn.

2. *Metopaster Poulsenii*, n. sp.

Plate I, figs. 2—9.

By a fortunate find at Stevns Klint north of Kulsti Rende I have become possessed of an accumulation of plates of a *Metopaster*, which in many characters

differ greatly from *M. tumidus*. The plates were found pell-mell, but it proved that there was a sufficient number to reconstruct arm and supero-marginalia for two sides from the extremity of one angle to that of another. Besides there was a terminal plate, a single mouth plate, numerous ambulacral plates, adambulacral plates and ventral and dorsal covering plates.

The body forms a compact pentagon and is rather high (about 15 mm). The profile of the united supero- and infero-marginalia shows an evenly curved line; together they form an angle of about 120° . The profile of the supero-marginal plate quite resembles SPENCER's plate 15, fig. 6. The distance between two extremities of the arms is about 36 mm. From one extremity of the arm to another there were in all six plates. I arrived at this conclusion by joining the supero-marginalia in different manners. Only when using the number of six, I succeeded in producing a form, which might result in a regular pentagon. Later on JOH. TROELSEN, M. Sc. presented me with another specimen, which he had found at Stevns Klint and for which I tender him my best thanks. This specimen had nearly three sides with plates in the original connection, and here also there were six plates from one extremity of an arm to another (plate I, fig. 9).

The terminal supero-marginal plate has the following dimensions (plate I, fig. 2):

Length: 10 mm.

Height: 6 mm.

Height of facet towards adjacent supero-marginal plate: 4 mm.

Depth - - - - - : 6 mm.

The free surface has a smaller flattened tumidity, the surface of which is crowded with circular spine pits of equal size. The remaining part of the free surface is smooth.

The anterior angle of the plate is 45° , the total angle of the arm thus being 90° and only very little pronounced. The posterior inward face is small, about one fourth of the anterior oval surface. The backward facet shows that the profile of the arm had a considerable curvature. The facet for the terminal plate of the arm is comparatively large.

The terminal supero-marginal plate shows clearly by its form that it belonged to a *Metopaster*, but, as contrasted with *M. tumidus*, it is smaller than the other supero-marginalia, the extremity of the arm thus becoming somewhat truncated (plate I, fig. 9).

The adjacent supero-marginal plate in the row is easily identifiable, the two faces which show towards the neighbouring plates not being parallel, as the face towards the terminal supero-marginal plate curves somewhat behind it (plate I, fig. 3). The third supero-marginal plate is the largest of them all, and is nearly symmetrical (plate I, fig. 3).

The supero-marginalia have a ridge-shaped tumidity, which occupies about a third of the breadth of the plate. The tumidity is distinguishable on all the plates,

though it decreases somewhat from the third to the terminal plate. The spine pits are most closely placed on the ridge-shaped tumidity, there being an area devoid of pores on each side of the latter.

The infero-marginalia are all asymmetrical, the ventral margin retreating somewhat from the nearest extremity of the arm (plate I, fig. 3a). Each row has twelve infero-marginalia, there being four lower plates corresponding with each terminal supero-marginal plate. The spine pits are evenly distributed over the whole surface within the granulated border.

The terminal plate is comparatively small, corresponding with the two small, rounded facets on the tip of the terminal supero-marginal plate. The shape is the usual one, with two small, facets showing upwards, whereas the ventral part of the plate has a furrow which is a continuation of the ambulacral furrow; it ends in a small rounded face, where the eye was placed. The upper free surface is raised into a small ridge and bears no marks of spines.

The ambulacralia, which are of the usual *Metopaster* shape, were alternating and are comparatively small, the largest measuring about 4 mm in length. (The largest infero-marginal plate measures 10 mm in length).

The adambulacralia are also of the usual *Metopaster* shape; on the free surface there are two oblique rows of well developed spine pits, the spines of which have covered the ambulacral furrow (plate I, fig. 7). The dorsal covering plates which were arranged radially, i. e. in the papular zone, are prismatic in structure, very nearly hexagonal in outline; the dorsal face has no distinct spine pits, but is crowded with numerous irregular granulations. The ventral face is not so regularly hexagonal, but incised along the margin so as to be nearly stellate. The edges are supplied with grooves for the attachment of the muscular and tendinous ligaments, which keep the plates together (plate I, fig. 5).

The other covering plates do not seem to present any characteristic features. Pedicellariæ have not been found.

This form is so fully illustrated that it cannot very well be mistaken for any other species of *Metopaster*, and it will be possible without great difficulty to identify even isolated plates.

This species has been named in honour of Dr. CHR. POULSEN, Keeper of the Palæontological Department of the Mineralogical and Geological Museum at Copenhagen.

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk. Stevns. Eerslev.

Besides the above species of *Metopaster*, which can be identified with certainty, there are in the Danish White Chalk several others, of which until now only the terminal supero-marginal plate is known; this plate, however, is so characteristic that it is possible from its different facets to deduce many details regarding the

height, slant and ornament of the marginalia. These terminal plates being constant without transition forms, it is possible by this means to distinguish several species, which seem fairly natural.

3. *Metopaster stevensensis* n. sp.

Plate I, fig 10.

The terminal supero-marginal plate has the following dimensions:

Length: 13 mm.

Height: 11 mm.

Height of facet towards adjacent supero-marginal plate: 7 mm.

Breadth - - - - - : 4 mm.

The free surface has a rather considerable, elongated tumidity which passes gradually into its surroundings. The whole of the free surface is crowded with circular spine pits of equal size.

The anterior angle of the plate is small, about 40° , the total angle of the arm having been considerably less than 90° . The posterior inward face is large, as large as the anterior face, only this latter having taken part in the formation of the arm. The posterior backward facet shows that the outer side of the arm had only a slight curvature, the supero- and infero-marginalia having nearly formed the continuation of each other. The supero-marginalia have a large tumidity, and their height exceeds their depth. The facet for the terminal plate is only small. The under side shows four facets for the infero-marginalia.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk. Stevns Klint.

4. *Metopaster angulatus* n. sp.

Plate I, fig. 11.

The terminal supero-marginal plate has the following dimensions:

Length: 7 mm.

Height: 4 mm.

Height of facet towards adjacent supero-marginal plate: 2 mm.

Depth - - - - - : 1 mm.

The free surface has no tumidities but is concave.

Scattered over the whole of the surface there are circular spine pits of equal size, but unevenly distributed, so that there are rather large, smooth areas between the pits.

The anterior angle of the plate is small, about 30° , the total angle of the arm being 60° .

The posterior inward face is very large, about $1\frac{1}{2}$ times the size of the anterior oval one. The facet towards the arm shows that its profile had a consider-

able curvature, and that the height of the supero-marginalia by far exceeded their depth. The facet for the terminal plate of the arm is comparatively large. The under side shows five facets for infero-marginalia.

Horizon and locality. Upper Senonian Zone with *Belemnitella mucronata*. White Chalk. Enegaard (Præstø),

5. *Metopaster undulatus* SPENCER.

1913, SPENCER. 8, pp. 118-119, plate 10, figs. 19-20; plate 15, figs. 20-24.

1935, MERCIER. 5, p. 29, plate 1, figs. 15 a-b.

This species forms the main group within the *Metopaster undulatus* series of SPENCER, which is distinguished from the *Metopaster Parkinsonii* 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 Danish material belonging here is found in the older parts of the White Chalk from Møn and Aalborg, but seems to be entirely absent at Stevns Klint. Part of it corresponds fairly well with the English material, but some of it deviates so greatly that it should be distinguished as a species apart.

A terminal supero-marginal plate from Møn has the following dimensions:

Length: 4 mm.

Height: 3 mm.

Height of facet towards adjacent supero-marginal plate: 3 mm.

Depth - - - - - : 5 mm.

The free surface is evenly vaulted without tumidity. There is no distinct boundary between the border and the central area, and the spine pits are unequal in size. Towards the upper border of the plate the spine pits are lacking, and here there are a number of small granules, just as on SPENCER's plate 10, fig. 20.

The anterior angle of the plate is large, about 90°, the total angle of the arm thus becoming about 180°, which means that the animal had an evenly rounded outline.

The posterior inward face is very small, smaller than a fourth of the anterior large, almost square face. The facet showing towards the arm proves that the profile of the latter was strongly curved, and that the height of the supero-marginalia was very small compared with the depth. The facet for the terminal plate of the arm is comparatively large. The under side shows four facets for infero-marginal plates.

As appears from this description, this plate agrees with SPENCER's *M. undulatus* (8, pl. 15, figs. 21-22).

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk. Aalborg, Møn.

6. *Metopaster granulatus n. sp.*

Plate I, fig. 12.

In the White Chalk of Aalborg, Jutland, are often found the remains of a small *Metopaster*, which is closely related to *M. undulatus*.

The terminal supero-marginal plate has the following dimensions:

Length: 4 mm.

Height: 3 mm.

Height of facet towards adjacent supero-marginal plate: 2 mm.

Depth - - - - - : 3 mm.

The free surface is very uneven, the spine pits being of various sizes, and towards the upper margin of the plate they are replaced by small granulations. The transition between the border and the central area is even.

The anterior angle of the plate is very large, larger than in *M. undulatus*. It measures about 100°, so that the margin of the animal is rather drawn in at the place where the extremity of the arm was.

The posterior surface facing inwards is quite small, like *M. undulatus*. The facet towards the arm shows that its profile was strongly curved, and that the height of the supero-marginalia was very small compared to their depth. Corresponding with these requirements there are a number of supero-marginalia, which undoubtedly belong to the same individual as the terminal supero-marginal plate described above.

The median marginal plate nearest it is distinguished by the fact that one of its lateral faces curves behind the terminal one. The free surface of this plate has also a number of fine granulations in its upper part. The adjacent supero-marginal plate has parallel lateral faces, but otherwise resembles the preceding one.

The difference between the supero-marginalia indicates that there were more than two median supero-marginalia. I am inclined to think that there have been four.

In shape this species is very like *M. undulatus*, though easily distinguishable from the latter, the extremity of the arm being drawn in.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk. Aalborg.

The species of the Danian.

When considering the *Metopasters* from the Danian we immediately encounter the difficulty that only in very few cases are we possessed of several plates from the same individual, and in by far the greater number of cases we are consequently compelled to guess at the connection between the plates found. One of the few cases where plates, belonging to the same animal, have been found in connection are the supero- and infero-marginalia from Saltholm, which have been mentioned

and figured by SPENCER. He regards them as typical of the species *Metopaster mammillatus* GABB. and is of opinion that the figured remains belonged to a radiate form, but mentions no less than three forms of terminal supero-marginalia, which he reckons as belonging to *M. mammillatus*. The one (SPENCER's plate 15, fig. 11), originating from the Older Danian in Kagstrup, I have referred to a new species *M. Spencerii*; the other, likewise from the Older Danian in Kagstrup, is said greatly to resemble a corresponding plate from *M. tumidus*; this plate I have likewise referred to a new species *M. kagstrupensis*. The third plate-type originates from Annetorp in Scania and Rejstrup in the island of Funen, viz. from the Younger Danian, and is here named *M. elevatus*. Their shape and the appearance of the facets show that these three types have nothing to do with the connected plates from Saltholm; they must be established as types of three different species. The only plates left to represent *M. mammillatus* are then those from Saltholm, which according to the shape of their facets belonged to a form with produced arms, and therefore should be removed from the genus *Metopaster* (see *Recurvaster* p. 39).

That the above-mentioned terminal supero-marginalia are not varieties of or represent different stages of development of the same species, appears clearly from the fact that many specimens of each form have been found of different sizes, but even the smallest are of exactly the same shape as the largest.

The arrangement adopted in the description of the *Metopaster* forms of the Danian is as follows: the forms of the Older Danian (Stevns Klint and Kagstrup) are mentioned first, as they form a group apart, which is somewhat different from the forms of the Younger Danian and rather closely associated with the forms of the White Chalk.

From the Older Danian the following forms are described:

7. *M. kagstrupensis*, n. sp.
8. *M. Spencerii*, n. sp.

7. *Metopaster kagstrupensis*, n. sp.

Plate I, figs. 13, 14 and 15.

1913. *M. mammillatus*, SPENCER (8), p. 115.

This species, which is one of the most frequently occurring Asteroids in the Older Danian, is also among the best known forms in the Danish deposits. At Stevns Klint Docent ROSENKRANTZ found a specimen with a whole row of plates in their original position, these plates extending from one extremity of the arm to the other. This unique find makes it possible to determine the number of marginalia and gives other information of importance. Further, the find shows part of the dorsal surface of the supero-marginalia with the tumidity (plate I, fig. 13).

It turns out that there were only four median plates, the whole row thus only counting six plates. The distance between two neighbouring extremities of the arms

is 44 mm. The height of the margin of the median marginalia, measured on the inner side of the plates, is 20 mm, of which the upper plate takes up 8 mm and the lower 12 mm, there being a difference of 4 mm in the height of the two plates.

This form very nearly approaches the *M. Poulsenii* found in the White Chalk, where it has been proved by experiments of reconstruction that there are also only four median supero-marginalia in the row. The difference between these two species is in the form of the terminal supero-marginal plate.

When comparing the plates found in their original connection with the isolated ones, it is possible to identify the terminal supero- and the first and the second median marginalia, both in the upper and lower row of plates, the first and the second being reckoned from the middle of the interradius, so that the second median supero-marginal plate is the one nearest the terminal marginal plate.

The terminal marginal plate has the following dimensions:

Length: 10 mm.

Height: 11 mm.

Height of facet towards adjacent supero-marginal plate: 9 mm.

Depth - - - - - : 7 mm.

The free surface has a rather considerable tumidity facing upwards and is closely covered by circular spine pits of equal size. The boundary between the border and the central area is sharp.

The anterior angle of the plate is about 40°, the total angle of the arm thus being about 80°. The posterior face showing inwards is small, only one third of the anterior oval one. The backward facet shows that the outer side of the arm was only slightly curved, the supero- and infero-marginalia having been in prolongation of each other. The tumidity has turned dorsally, and it has not occupied the whole breadth of the plate. The under side shows four facets for infero-marginalia. The facet for the terminal plate of the arm is small (plate I, fig. 14e).

The ample material from Korporalskroen includes a few supero-marginalia, which have been divided into their original constituents. In particular there is the outer (distal) fragment, which is of exactly the same appearance as the outermost portion of a complete supero-terminal marginal plate, without the slightest tendency to alter its shape or to increase the length of the arms, and without influence on the appearance of the median plates (plate I, fig. 15). (Cf. note p. 22).

The first median supero-marginal plate is very nearly cubical, the depth of the plate being almost equal to the breadth, whereas the height is somewhat greater. The outer (lateral) free surface passes evenly into the upper face, where there is a tumidity which does not occupy the whole breadth of the plate, but starts on the lateral side as a ridge, on the dorsal face passing into a rounded conical projection. The free surface has the well-known *Melopaster* ornament with a rather broad, finely dotted depressed border and a smooth central area with more or less scattered spine pits.

Seen from the lateral side the line between the row of supero- and infero-marginalia is slightly zig-zag, the distal edge of the lower first median marginal plate projecting into the row of supero-marginalia.

The second median supero-marginal plate resembles the first, but is slightly asymmetrical, as it curves a little behind the terminal supero-marginal plate.

The first median infero-marginal plate is, as mentioned above, considerably higher than the corresponding supero-marginal plate. It is asymmetrical, the distal articular face being somewhat smaller than the proximal one, although it projects somewhat into the row of supero-marginalia.

The second median infero-marginal plate is also rather asymmetrical, the distal articular face being considerably smaller than the proximal one.

These plates are easily distinguishable from marginalia belonging to another species, *M. Spencerii*, found in the same beds. The marginalia of the latter are not cubical, their depth being considerably smaller than their breadth. It is possible to distinguish the marginalia of these two species, even when found isolated.

Horizon and localities. Older Danian: Stevns Klint. Kagstrup. Korporalskroen.

8. *Metopaster Spencerii*, n. sp.

Plate I, figs. 16—17; Plate II, fig. 1.

1913. *M. mammillatus*, SPENCER, 8, pp. 114—115, plate 15, fig. 11.

The terminal supero-marginal plate has the following dimensions:

Length: 10 mm.

Height: 9 mm.

Height of facet towards adjacent supero-marginal plate: 4 mm.

Depth - - - - - : 3 mm.

On the upper margin of the free surface, far towards the front margin of the plate, there is a horn-shaped tumidity, which is covered with circular spine pits of the same size, evenly distributed over the whole of the surface. The line of demarcation between border and central area is sharp.

The anterior angle of the plate is very small, the total angle of the arm thus being only about 30°.

The posterior inward face is very small, about one fifth of the anterior one, which latter is very characteristic, in that it occupies not merely the greater part of the inward face, but also extends over the posterior part of the tumidity. If two neighbouring plates are joined, only one tumidity is formed with two small horns. The backward facet shows that the arm was faintly curved, and that the depth of the marginalia exceeded the height. The facet for the terminal plate of the arm is rather large (plate I, fig. 16). The under side shows four elongated facets for infero-marginalia.

If from this one tries to draw any conclusion as to the appearance of the supero-marginalia, one must expect to find low and deep plates with a horn-shaped tumidity turning upwards.

Supero-marginalia of this appearance are rather numerous in the same beds, in which the terminal plates were found, and it is interesting to see how well and naturally they fit together (plate II, fig. 1).

Infero-marginalia which in size and ornament fit in with these supero-marginalia have been found in the same beds.

This *Metopaster* form, which is easily identifiable and very characteristic, deviates considerably from the other forms belonging to the *M. Parkinsonii* group, e. g. by the particularly large terminal marginalia. The *Metopaster*, whose terminal supero-marginalia come nearest in shape to the plate described is the *M. Parkinsonii* var. *calcar.* of SPENCER known from Swedish Senonian deposits, both from the zone with *Actinocamax mammillatus* and the Zone with *Belemnitella mucronata*.

Horizon and localities. Older Danian: Stevns Klint. Kagstrup. Korporalskroen.

When comparing the *Metopaster* forms proper from the Younger Danian with those from the Older Danian, the decrease in number is striking; moreover, the species are different. Most of the marginalia found in the Younger Danian possessing a *Metopaster* ornament are forms with produced arms.

The only species which can be established from the Younger Danian is:

9. *Metopaster elevatus, n. sp.*

Plate II, fig. 2.

1913. *Metopaster mammillatus*. SPENCER, 8, p. 114, plate 10, fig. 9.

SPENCER describes this terminal supero-marginal plate in the following manner:

"The terminal supero-marginalia from Annetorp (Sweden) and Rejstrup (Denmark) differ again, as they are high and narrow with a prominent abactinal tumidity."

The terminal supero-marginal plate which is figured on plate II, fig. 2 has the following dimensions:

Length: 7 mm.

Height: 12 mm.

Height of facet towards adjacent supero-marginal plate: 6 mm.

Depth - - - - - : 4 mm.

On the upper margin of the surface, which is very high and narrow, there is a large upwardly directed tumidity, evenly rounding off the whole of the upper part of the plate. The whole surface is crowded with circular spine pits, all of

which are nearly of the same size, being only somewhat coarser right above the border, and the central area is sharp.

The anterior angle of the plate is about 45° , the total angle of the arm being about 90° . The posterior inward face is small in comparison with the large anterior one, which forms an upright oval figure.

The posterior facet shows that the outer side of the arm in profile was only faintly curved, the supero- and infero-marginalia having been in continuity. From this it can be concluded that the supero-marginalia had a considerable tumidity occupying the whole of the breadth of the plate. The height was somewhat greater than the depth. Upper plates of a corresponding shape have been found in the same beds. The facet for the terminal plate of the arm is comparatively large. The under side shows three facets for infero-marginalia. The facet for the terminal plate of the arm is comparatively large.

This terminal supero-marginalia plate is of rather frequent occurrence in the Younger Danian.

Horizon and localities. Younger Danian: Fakse (Bryozoan limestone). Rejstrup. It is also known from Limhamn (Sweden).

Genus MITRASTER, Sladen.

In the material from Danish localities, which SPENCER had at his disposal for study, he also found some isolated plates belonging to the genus *Mitraster*. He referred them all to *M. Hunterii*, and they occurred both in the White Chalk and the Danian (both Older and Younger Danian). In both formations they are of rather rare occurrence.

In SPENCER'S "Evolution" (8) plate 10, fig. 21 is figured a specimen of *M. Hunterii* from Meudon with four median supero-marginalia, i. e. six plates in each row and with comparatively large terminal supero-marginalia, which in any case are of the same size as the median supero-marginalia.

According to SPENCER (8, p. 117) "the genus must have branched off, in early times. The forms show ancestral relationships with the "low-zonal" forms of *Metopaster Parkinsonii* in (a) the limited number of median supero-marginalia (never more than two on each side of the 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."

It is probable that there are two species series within the genus:

- 1) The *M. Hunterii* series,
- 2) The *M. compactus* and *M. rugatus* series.

The series which interests us is the former, the only one of which remains are found in Danish deposits. As to this SPENCER writes (8, p. 117):

"*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 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 punctuations 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)."

As to the relation between the two genera, *Metopaster* and *Mitraster*, SPENCER writes (8, p. 108):

"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."

The Danish material, which has in part been determined by SPENCER, is very scarce and chiefly consists of isolated supero-marginalia with the characteristic "*uncatus*" profile, and with a more or less coarsely granulated ornament without spine pits.

1. *Mitraster Hunterii*, SPENCER, var. *laevis* n. var.

1891—1907. *M. Hunteri*. SLADEN & SPENCER, 7, pp. 59—68.

1913 » SPENCER, 8, p. 117, plate 10, figs. 21—23; plate 11, figs. 1—2.

The material from the Danish White Chalk includes a number of supero-marginalia which, by their ornament and their "*uncatus*" profile, show that they belong here; some of the plates SPENCER has determined as *Mitraster Hunterii*. The shape of these plates shows that the number of supero-marginalia exceeded two. No terminal supero-marginal plate has been found with the same ornament as these plates, but from the White Chalk at Stevns Klint a couple of terminal supero-marginalia are known, which have the shape of *Mitraster*, but are quite smooth on the free surface. It is therefore natural to unite these plates, the result being a new variety of SPENCER's species. In his mention of the *Mitraster* forms SPENCER observes that in the Upper *Mucronata* Chalk they have a tendency to become smooth.

The outline of the animal is cycloidal-pentagonal, with faintly projecting extremities. The number of marginalia is not known, any more than the form and ornamentation of the infero-marginalia.

The terminal supero-marginal plate has the following dimensions:

Length: 5 mm.

Height: 7 mm.

Height of facet towards adjacent supero-marginal plate: 2 mm.

Depth - - - - - : 5 mm.

The free surface is evenly vaulted, shows no tumidity and no spine pits. The anterior angle of the plate is large, about 60° , the total angle of the arm becoming about 120° , the circumference of the animal having thus been fairly evenly rounded.

The posterior inward face is very small, less than a fourth of the anterior large oval one. The facet towards the arm shows that its profile has been strongly curved, and that the height of the supero-marginalia has been very small in proportion to the depth. The facet for the terminal plate of the arm is comparatively small. The under side shows three facets for the infero-marginalia plates.

As described by SPENCER the median supero-marginalia are low, with an *uncatus* profile and a faint granulated ornament without spine pits. From the Danian there are similar plates in small numbers, but from here no terminal supero-marginalia are known, so it is extremely doubtful whether these plates really belong to the genus *Mitraster*. The ornament on these Danian plates is frequently more pronounced than on the Senonian examples.

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk (Terminal supero-marginalia): Møn. Stevns Klint.

?Older Danian (median marginalia): Stevns Klint. Kagstrup.

?Younger Danian (median marginalia): Saltholm. Fakse.

Genus RECURVASTER, n. g.

The species belonging to this genus all have the *Metopaster* ornament, and their arms are comparatively long and dorsally curved. As genotype is taken *R. stevensensis*, of which are known a complete arm, marginalia, dorsal plates, terminal plate, ventral plates, ambulacral, and adambulacral plates, and mouth plates. Finds of isolated plates comprise median supero-marginalia with tumidity and lateral articular faces of unequal size, and also supero-marginalia of a special shape originating from the arm.

This genus is common in the Danish White Chalk and Danian.

The following species are described:

From the White Chalk:

1. *Recurvaster stevensensis*, n. sp.
2. *Recurvaster echinatus*, n. sp.

and from the Danian:

3. *Recurvaster mammillatus*, (GABB).
4. *Recurvaster communis*, n. sp.

1. *Recurvaster stevensensis*, n. sp.

Plate II, fig. 3. Text, fig. 28.

By a fortunate find in the White Chalk of Stevns Klint, a little to the north of Kulsti Rende, I have become possessed of a great number of plates originating from the same individual and belonging to the genus *Recurvaster*.

Most of the plates were unconnected, but one of the upwardly bending extremities of the arms was preserved in situ, so that it was possible to remove the individual plates from the White Chalk and again join them together. Starting from this safe foundation I succeeded in reconstructing two extremities of arms nearly complete and an interjacent interradius in a fairly probable way. This reconstruction forms the basis of my description, the only thing of which I am in doubt being the length of the interradius. I have used six median supero-marginalia as the most

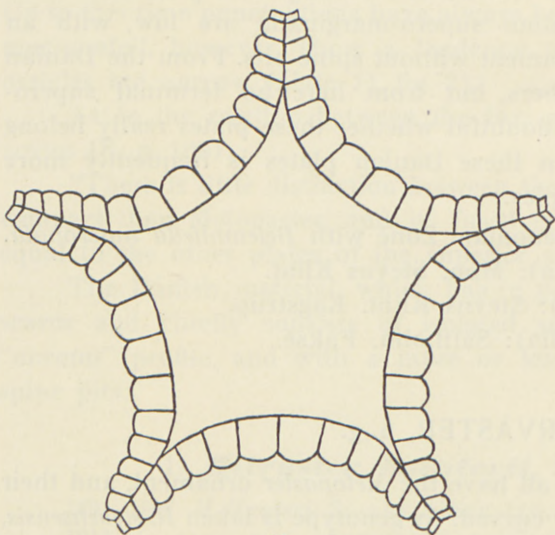


Fig. 28. *Recurvaster stevensensis* n. sp. Reconstruction.

probable number, but it is possible that this number is wrong (text, figure 28). The body is a five-rayed star, the arms of which are produced and bent upwards. The body is high, 15 mm. The profile of the joined supero- and infero-marginalia forms an evenly curved line, the axis of the two plates forming an angle of about 135° . The distance between the two reconstructed extremities of arms is 56 mm. The margin has four supero-marginalia + four plates belonging to the arm, as well as six median plates, that is fourteen plates in all.

There is a considerable difference in shape between the individual plates in the row of supero-marginalia. The two midmost of the six median plates are the largest in the whole row; they

are asymmetrical, their dorsal, mammillate tumidity pointing towards the extremity of the arm; the two adjacent ones are also asymmetrical and their tumidity less; the two outermost lack tumidity, and their lateral faces are not parallel, as the curvature of the arm begins here.

As in the genus *Metopaster* the ornament consists of a narrow border, which follows the free surface of the whole plate and is covered with small, closely touching circular facets and a smooth face with scattered spine pits, very nearly equal in size. This species has the peculiarity that these spine pits in a few places are fused into short lines.

The four median infero-marginalia have the same ornament; the border, however, is broader, and so the central area becomes more pronounced, and the spine pits are also here frequently fused.

The four supero-marginalia of the arm have no tumidity; only the proximal one is faintly dotted with spine pits in the dorsal part, and they all lack the distinctly separated marginal area. They decrease evenly in size towards the extremity of the arm, where a new formation of plates seems to take place, seeing that there

is a beginning of a fifth plate on top of the fourth, viz. a very thin plate supporting the terminal plate.

The infero-marginalia of the arm also decrease in size towards its extremity, and they all lack the narrow, faceted border. The scattered spine pits are present, sparsely on the largest one, and then greatly decreasing in number towards the extremity of the arm.

The terminal plate, which is comparatively large, has two smooth faces joining at obtuse angles, these faces corresponding with those of the smallest supero-marginalia facing towards the extremity of the arm. The free surface has three large circular facets, each of which carried a short conical, strong spine.

The ambulacral plates have been of the usual shape and alternating, the largest up to 7 mm. in size; towards the arm they become smaller and gradually change their shape, losing their various facets and becoming small, oblong, flat plates.

The adambulacral plates are of the usual shape; on the free surface there are three rows of strong spine pits.

The adambulacral and the ambulacral plates, which form the boundary of the mouth, are very stout, of the structure usual for an "ambulacral" mouth, without any distinguishing characteristics.

The dorsal covering plates from the papular zone are prismatic, the free surface being crowded with small roundish facets; the basal part is stellate, and the lateral edges are slightly hollowed.

The madreporite is a large equilateral triangular plate with bevelled edges. The adjacent covering plates are of a peculiar structure; they send forth an edge in under the bevelled sides of the madreporites and are deeply grooved.

The other covering plates present no special characteristics, being of the usual shape.

This form is very characteristic, and most of the details are well elucidated, but the description shows that only the median supero-marginalia can be recognized as isolated plates, whereas the arm plates and the terminal plate can afford only generic characters.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*, White Chalk: Stevns Klint.

2. *Recurvaster echinatus*, n. sp.

Plate II, figs. 4—9.

A find of connected plates originates from the White Chalk of Stevns Klint, and curiously enough also from the locality north of Kulsti. The White Chalk is here of a somewhat different nature, compared with that of other parts of Stevns Klint. It is much more homogeneous and seems to have been deposited under quieter conditions, as the remains of the animals are much better preserved. The

Echinoids are not crushed; the large, frequently thin-shelled, Rhynchonellas are most frequently undamaged, and the Lamellibranchs are comparatively well preserved. *Belemnitella mucronata* has been found in its normal form, whereas the otherwise in the White Chalk so frequently occurring *Thecidium papillatum* and *Th. recurvirostre* are lacking. The Bryozoan fauna also shows a number of deviations, and here it is interesting to see that LEVINSEN's easily identifiable form *Puncturiella gudumensis* which, in this country, had been found only in certain localities in Jutland: Gudumlund and Nørre-Uttrup, but which has also been found by myself in the Upper Grey Chalk from Trimmingham, likewise recurs in these beds north of Kulsti. These observations seem to suggest that the lower beds of the White Chalk in the northern part of this cliff are older than those of the southern part at Rødvig, which result I have already arrived at in other ways (6). The plates found were all unconnected, so that it was not possible to undertake any reasonable reconstruction. However, it appeared fairly distinctly from the characters of the marginalia that we are here dealing with a form with arms of some extension.

The find of the arm of *Recurvaster stevensensis*, however, led me once more to try to reconstruct the new form, taking *R. stevensensis* as my example, and it soon proved that the two forms were very closely related. The arms also in this case proved to have the characteristic strong upward bend. I am unable to give any measurement of the distance between the extremities of the arms, as I cannot prove with certainty that the number of median supero-marginalia assumed by me is correct.

The form of the animal is that of a five-rayed star with produced arms, strongly bent upwards. The height of the border measured at the largest median marginalia about 12 mm.

The joined supero- and infero-marginalia have in profile an evenly rounded outer side. The two marginalia form an angle of about 110° .

The arm is comparatively longer in this species than in the preceding. It numbers six supero- and six infero-marginalia. In all probability there have been six median marginalia, the total number of supero-marginalia having probably been five times eighteen.

In this species also there is a considerable difference between the size of the median marginalia, the size decreasing towards the arm. The lack of symmetry of the plates is the same as that of the preceding species.

The supero-marginalia have a dorsal tumidity, shaped like an evenly rounded elevation extending over the breadth of the whole plate. The ornament is the usual one, a narrow, finely faceted border round a slightly elevated face with equally distributed, equal-sized spine pits. In the middle of this tumidity there is, on the four median plates, a smooth circular facet for a strong spine. On the first arm plate the ornament becomes less pronounced, and the last supero-marginalia are quite smooth. The spine pits are always distinctly separated and are never fused into small furrows.

The infero-marginalia decrease in size towards the arm. The median free surface is slightly grooved with a broad, indistinct furrow, which begins at the dorsal margin and disappears approximately in the middle of the plate. The ornament continues in part right to the last arm plate; only the narrow faceted margin soon disappears, so that the whole of the surface forms a single undivided plate.

The terminal plate is comparatively large, shaped like that of *R. stevensensis*, though it differs from it by lacking the three large articular faces for spines; but it has a rather irregular free surface with scattered facets for small spines.

The ambulacralia are alternating, comparatively large, up to about 5 mm. Towards the extremity of the arm they become small and smooth, without facets. The adambulacralia (plate II, figs. 6 a—b) have on their free surface four strong oblique furrows for spine pits. The mouth plates are robust, of the usual shape, without any characteristic features.

The dorsal covering plates from the papular zone are of exactly the same shape as in *R. stevensensis*, the free surface being covered with closely touching circular facets (plate II, fig. 7). The madreporite is unknown, but one of its neighbouring plates has been found, quite like the corresponding one in *R. stevensensis*. The other covering plates offer no points of interest.

This species is very characteristic and well known in details. The median marginalia and the adambulacralia are easily identifiable among isolated plates, whereas the other plates are not characteristic.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns Klint.

3. *Recurvaster mammillatus*. (GABB.).

Plate II, figs. 10—14.

1876. *Goniaster mammillata*. W. M. GABB. 2, pp. 178, 179, figs. 2, 2a, 2b.

1893. *Goniaster mammillata*. CLARK, W. B. 1, p. 32; plate V, figs. 1a—h.

1891—1907. *Pycinaster mammillatus*. SLADEN & SPENCER. 7, p. 119, plate 3, figs 2, 3.

1913. *Metopaster mammillatus*. SPENCER. 8, pp. 114, 123, plate 10, fig. 16; plate 15, figs. 8, 9, 10.

SPENCER gives as specific characteristics the high body form, the pronouncedly asymmetric supero-marginalia, generally with a prominent tumidity, which stretches well over the dorsal surface and occupies the whole of the dorsal surface of the ossicles and, finally, the coarse ornament, which, on the supero-marginalia, is frequently confined to the tumid portion of the ossicle.

According to SPENCER (8) the specimens figured are typical of the species. The specimen of plate 15, fig. 8 comes from Saltholm; it consists of four supero- and four infero-marginalia, all in their original positions. The broad tumidity, which characterizes the species, is figured on plate 15, fig. 9.

It is much more difficult to get a clear idea of the paired, terminal supero-marginalia. SPENCER says that they vary very much according to the locality in

which they are found. Specimens from Kagstrup greatly resemble the corresponding plates of *Metopaster tumidus* (here described as *Metopaster kagstrupensis*). Other specimens from Kagstrup and Stevns Klint have the tumidity situated at the distal end of the plate. A specimen of this kind is figured by SPENCER on plate 15, fig. 11. This specimen must consequently be taken as a holotype (here described as *Metopaster Spenceri*). The terminal supero-marginalia from Annetorp and Rejstrup again deviate from these, being tall and narrow with a prominent dorsal tumidity. This form is figured on plate 10, fig. 9 and must also be taken as a holotype (here described as *Metopaster elevatus*).

In conclusion SPENCER remarks that the great majority of specimens, in all probability, had extended arms on account of the breaking down of the large terminal supero-marginalia (cf. note p. 23). He concludes as follows (8, p. 115): "In fact no large terminal supero-marginalia are found in the higher beds of the Danian."

In reality, terminal supero-marginalia occur rather frequently in the Younger Danian. SPENCER's plate 10, fig. 9 is of an example from Annetorp, a typical Younger Danian locality.

When the three terminal supero-marginalia are removed from the species, all that remains of *Metopaster mammillatus* is the marginal fragment from Saltholm with the four supero- and the four infero-marginalia described by SPENCER. If one considers this fragment with the marginalia decreasing in size and the proportionally small distal articular face, it cannot be denied that they most closely resemble the corresponding portion of the two species of *Recurvaster*, known from the White Chalk; at any rate it can hardly be a *Metopaster*. As the isolated *Metopaster* plates, so frequently found in the Younger Danian, may be identified by their tumidity, which occupies the whole of the plate, and by the different sizes of the lateral articular faces of the plates, it has been necessary to move these remains to the genus *Recurvaster*.

The isolated supero-marginalia occur rather frequently in the various localities of the Younger Danian, where they are among the most frequent finds. These supero-marginalia are, as mentioned, identifiable by the great mammillate tumidity, which occupies the breadth of the whole plate and the unequally large, lateral, articular face.

The ornament may vary very considerably. It may be identical with those of the *Metopasters*, or smooth with very few scattered spine pits, and there is often a tendency to form large, circular facets for larger spines, as a rule one, but not rarely two or more.

The infero-marginalia are also asymmetrical, but are very like the infero-marginalia of the *Metopasters* and are, consequently, difficult to distinguish when found isolated. The plates from the arm are rather frequently found as slightly curved plates without ornament. They cannot originate from *Metopaster*, any more than from other asteroids found in this locality, but are very little differentiated.

In spite of the great variation in the supero-marginalia, it is not possible to distinguish between different species, until better results can be obtained by finds of connected plates. This group of isolated plates is the largest in the whole of the Younger Danian, to which division the species is restricted.

Horizon and localities. Younger Danian: Fakse. Thorslunde. Frederiksholm Lille Skensved. Saltholm. Rejstrup. Holckenhavn. Mønsted and other localities in Jutland.

4. *Recurvaster communis*, n. sp.

Plate IV, fig. 33.

Marginalia of a special shape very frequently occur in various deposits of the Danian. They have the *Metopaster* ornament with scattered spine pits in the central area, though sometimes this area is smooth without spine pits. They have an "uncatus" profile, that is, they are low but very deep. The supero-marginalia generally show a very slight tumidity; the lateral faces are of unequal size, but the difference is very slight. There is no terminal supero-marginal plate to be fitted in with these plates. I have therefore chosen to refer them to the genus *Recurvaster*, until some one succeeds in finding plates in their original position, which may perhaps alter the present view of them.

The plates occur rather frequently in all the deposits of the Danian, both Older and Younger.

One of the largest median supero-marginalia has the following dimensions:

Length measured on the dorsal side:	4 mm.
Breadth - - - - - :	3 mm.
Height of the plate:	2 mm.

The plate is flattened, and the transition between the dorsal and the lateral faces is even. There is a slight tumidity.

One of the largest median infero-marginalia has the following dimensions:

Length measured on the dorsal side:	4 mm.
Breadth - - - - - :	3 mm.
Height of the plate:	2 mm.

The plate is flat, with a distinct line of demarcation between the margin and the central area. The ornament consists of scattered spine pits.

Horizon and localities. Older Danian: Stevns Klint. Kagstrup. Korporalskroen.

Younger Danian: Rejstrup. Herfølge.

Genus RAVNIASTER, n. g.

The species belonging to this genus all have the *Metopaster* ornament in several of its different forms, either the usual one with scattered spine pits or granules, or with a smooth central area. Common to all the species of this genus is the peculiarity that a large terminal infero-marginal plate has been developed corresponding with the large terminal supero-marginal plate. Furthermore, the genus is distinguished by having only very few or no median marginal plates. The margin between two extremities of arms has thus from two to four supero-marginalia.

As genotype is taken *Ravniaster planus*, a specimen of which has been found with the marginalia in their original position, forming two entire rows.

The genus is common in Senonian and Danian deposits. Six species have been found in Denmark, viz.:

From the White Chalk:

1. *Ravniaster simplex*, n. sp.
2. *Ravniaster lævis*, n. sp.
3. *Ravniaster virgineus*, n. sp.

From the Danian:

4. *Ravniaster maculatus*, n. sp.
5. *Ravniaster planus*, n. sp.
6. *Ravniaster carinatus*, n. sp.

1. *Ravniaster simplex*, n. sp.

Plate III, figs. 1—2.

In the White Chalk at Stevns Klint I have collected a number of connected marginalia, which permit a very detailed reconstruction of this species.

The form is a depressed and rounded pentagon without projecting extremities of arms. The number of supero-marginalia to each side of the arm is only four, and there is the peculiarity about them that the four median flat marginalia are considerably larger than the two terminal ones. The number of infero-marginalia at each side of the arm is also only four. The border is thus of a very simple construction, seeing that there are only forty marginalia in the entire border.

The dimensions of the restored specimen show that the distance from the extremity of one arm to the adjacent one is about 8 mm, the result thus being a diameter of about 14 mm.

The terminal supero-marginal plate has the following dimensions:

Length: $1\frac{1}{2}$ mm.

Height: $3\frac{1}{2}$ mm.

Height of facet towards adjacent supero-marginal plate: $1\frac{1}{2}$ mm.

Depth - - - - - : 3 mm.

The free surface is evenly rounded, smooth, without spine pits and without distinction between border and central area. On the smooth surface there are a

number of slight, granulated elevations. The anterior angle is between 80° and 90° . The posterior, inward face is entirely lacking. The face towards the arm shows that the margin of the body was evenly rounded, and that the supero-marginalia have a great depth. The facet for the terminal plate of the arm is very large. The under side shows a large facet for the terminal infero-marginal plate, and a smaller one for the distal part of the median infero-marginal plate.

The median supero-marginal plate has only a small height, but a great depth; otherwise, when seen from above, it is rather rectangular in shape, the narrow sides, however, being convex and sloping in the direction of the extremity of the arm. The two long sides are thus different in length, the distal being the shorter. The long side is quite straight, whereas the shorter is somewhat curved. On the free surface there is a distinction between margin and central area.

When joining the four plates, which form the one side of the animal, the result becomes a very characteristic figure, seeing that the inner boundary towards the disc and also the free margin form regular arched lines.

The terminal infero-marginal plate is a rather long, triangular plate with an articular face fitting with the median infero-marginal plate, a triangular smooth upward face fitting the terminal supero-marginal plate, a likewise triangular face towards the median line of the arm, which on closer inspection proves to have parallel stripes, where the ambulacralia were situated; it has a free surface showing downwards, which is evenly vaulted and quite smooth. The pointed end of this pyramid-shaped plate in some cases bears marks of the terminal plate of the arm.

The median infero-marginal plate is low and approximately square; however, the side towards the disc is cut off obliquely and shows a curved surface, the side towards the terminal plate thus becoming smaller than the one towards the other median face. The free surface is smaller, without pits. The plate is broader than the corresponding supero-marginal, so that it extends over the whole of the median supero-marginal and a small portion of the terminal supero-marginal plate.

When joining four plates belonging together, a similar figure is obtained as in the case of the supero-marginalia.

The shape of the animal and the ornament on the supero-marginalia suggest the genus *Mitraster* and the very closely related *Metopaster undulatus* group, but it is unique in the small terminal supero-marginal plate and the characteristic terminal infero-marginal plate.

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns. Eskelund.

2. *Ravniaster levis*, n. sp.

Plate III, fig. 8.

In the White Chalk at Stevns Klint I have found a series of connected marginalia, which make it possible to reconstruct a form, closely related to the preceding species and, therefore, referred to the genus *Ravniaster*.

The form is depressed, pentagonal, with slightly projecting corners. In the row of supero-marginalia there are only four plates, two terminal and two median ones. Exactly the same is the case with the row of infero-marginalia.

The dimensions of the restored animal is 10 mm from the extremity of one arm to the middle of the interradius facing it. The distance between two extremities of arms is 5 mm. The height of the margin is 2 mm.

The terminal supero-marginal plate has the following dimensions:

Length: 1 mm.

Height: 1 mm.

Height of facet towards adjacent supero-marginal: 1 mm.

Depth - - - - - : 2 mm.

The free surface is evenly rounded and quite smooth, without spine pits or elevations of any kind. The margin and the lateral area are, however, distinctly separated. The anterior angle of the plate is a little more than 45° , the total angle of the arm thus somewhat exceeding 90° . The posterior inner face is quite narrow. The facet for the terminal plate of the arm is comparatively large. The under side shows a large facet for the triangular terminal infero-marginal plate and quite a narrow one for the outermost portion of the median infero-marginal plate.

The median supero-marginal plate is quite low, with a very great depth. The face towards the terminal supero-marginal plate is somewhat curved and smaller than the face towards the other median supero-marginal plate. In consequence the margins of all the supero-marginalia turning towards the disc become more or less parallel with the one facing outwards and slightly curved. The free surface is slightly vaulted; it distinctly shows the boundary between margin and central area and is quite smooth.

The terminal infero-marginal plate is greater than the supero-marginal one. The surface is quite smooth, the shape triangular, one side facing towards the furrow of the arm, the other corresponding with the outer margin of the animal, and the third, which is smaller than the other two, showing towards the median infero-marginal plate.

The median infero-marginal plate greatly resembles the supero-marginal one, but is somewhat broader, leaving a narrow facet on the terminal supero-marginal plate. The outer and inner margins of the plate are nearly equal in size and parallel. The two side margins of the plate are also nearly parallel, but the margin facing towards the terminal plate is somewhat smaller than the other one and slightly curved.

Thirty-two of the forty marginalia of the specimen described are preserved and can be joined to a whole, which shows that the animal was shaped like a regular pentagon with slightly produced extremities of arms, as opposed to the preceding species, where the angles of the arm are evenly rounded.

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns. Møn. Aalborg.

3. *Ravniaster virgineus n. sp.*

Plate III, figs. 3—7; text, fig. 29.

From the White Chalk in Møns Klint I have four connected supero-marginalia of a species closely related to the two last mentioned. The number of plates between two extremities of arms is also here four, and in the same manner there is a large terminal infero-marginal plate.

The shape of the whole row of plates shows that the animal was shaped like a regular pentagon with extremities of angles of about 108° , that is without projecting extremities of arms. (Text, fig. 29).

The distance between two extremities of arms is about 8 mm, which corresponds to a diameter of about 14 mm.

The terminal supero-marginal plate has the following dimensions:

Length: 1 mm.

Height: $1\frac{1}{2}$ mm.

Height of facet towards adjacent supero-marginal: 1 mm.

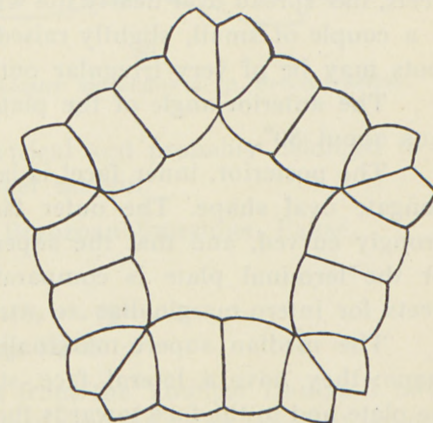
Depth - - - - - : 2 mm.

The free surface is evenly rounded without tumidities, but crowded with close-set, small protuberances. Margin and central area are rather distinctly separated. The anterior angle of the plate is slightly over 50° , the total angle of the arm thus being about 108° . The posterior, inward face is very narrow; the surface towards the arm shows a distinct "uncatus" profile. The facet for the terminal plate of the arm is very large. The under side shows a broad facet for the large terminal infero-marginal plate and a narrow one for the distal portion of the median infero-marginal plate.

The median supero-marginal plate is very depressed; when seen from above, it is rectangular in shape, the face towards the terminal supero-marginal plate, however, being somewhat curved. The free surface is covered with closely placed small protuberances.

The infero-marginalia are not known, but from the appearance of the terminal supero-marginal plate it may be concluded that there was a large terminal infero-marginal, and that the median infero-marginal was broader than the median supero-marginal plate.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*.
White Chalk: Møns Klint.



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Fig. 29. *Ravniaster virgineus n. sp.*
Reconstruction.

That these three last mentioned forms are not variations of the same species is clear from the fact that no transitions between them have been found. The rather numerous isolated plates of *Ravniaster laevis* have been found in the same beds as those of *R. simplex*, but the plates of these two forms are very easily distinguishable and show no intermediate forms. *R. laevis* and *R. virgineus* resemble each other very much, but are sharply distinguished by the ornament of the plate.

4. *Ravniaster maculatus*, n. sp.

Plate III, figs. 5—7; text, fig. 30.

There is a number of plates, chiefly originating from Bryozoan limestone in Fakse, which it seems possible to refer to the genus *Ravniaster*. The plates consist of terminal supero- and infero-marginalia and median infero- and supero-marginalia.

The terminal supero-marginal plate has the following dimensions:

Length: 8 mm.

Height: 4 mm.

Height of facet towards adjacent supero-marginal plate: 2 mm.

Depth - - - - - : 3 mm.

The free surface has no tumidity, but is evenly rounded, the boundary between the portions of the free surface, which show upwards and outwards, being effaced. There are none of the usual circular spine pits, but the border ornament, which is like the characteristic *Metopaster* ornament, viz. fine, closely placed, hexagonal facets, has spread over nearly the whole surface, the central area being thus restricted to a couple of small, slightly raised spots, smooth or with scattered spine pits. The spots may be of very irregular outline.

The anterior angle of the plate is about 40°, the total angle of the arm being thus about 80°.

The posterior, inner facet is large, as large as the anterior one, which is of an elongate oval shape. The outer facet shows that the outer side of the arm was strongly curved, and that the supero-marginalia were low and very deep. The facet for the terminal plate is comparatively small. The under side shows 1—3 large facets for infero-marginalia.

The median supero-marginalia, plate III, fig. 7, are very nearly of the same shape; they have a lateral face, standing at right angles both to the free end of the plate and to the face towards the infero-marginal plate, and serve to connect them with the other median supero-marginal plate; the other lateral face, which is smaller, is curved somewhat downwards towards the terminal supero-marginal plate.

The terminal infero-marginalia are large, triangular and as a rule unconnected, and they very much resemble the supero-marginalia, but the best distinguishing mark is the fact that the surface of the infero-marginal, which faces towards the furrow, shows a number of parallel impressions originating from the small, rod-shaped, distal ambulacral plates.

Attempted reconstruction of a specimen, based upon the plates available, results in a sea-star of a flat, depressed shape, which forms a regular pentagon with slightly projecting extremities of arms. Text fig. 30.

The distinguishing feature of the plates is the broad outer portion, which is very finely dotted, and the small, smooth, central area with the scattered spine pits, the ornament otherwise characteristic of *Metopaster*. This central area may be very variable in shape: square, rounded, oval or irregular. On a few plates it may have disappeared entirely, the plate being finely dotted over the whole of its surface.

The same ornament, or at any rate a simpler one, is described for *Metopaster exsculptus*, which according to SPENCER (8, plate 10, fig. 17) only existed for a short time in the mid-zones of the English Chalk. This form possesses a greater number of plates, and the infero-marginalia are entirely lacking the smooth, central area.

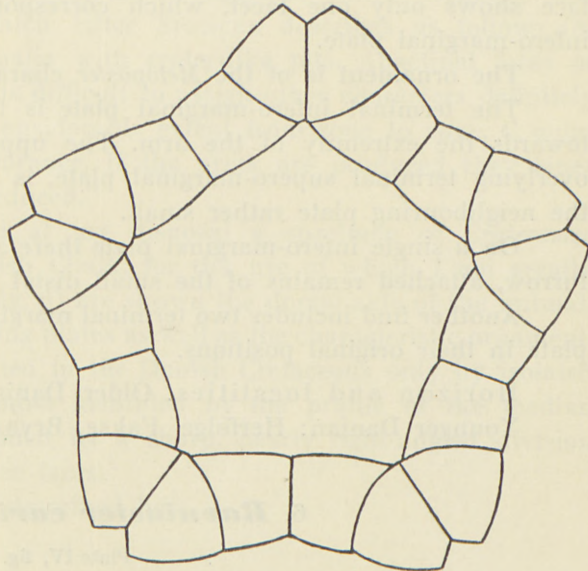
From other Younger Danian beds there are isolated plates with a similar ornament, as e. g. from Rejstrup and Herfølge (Bryozoan limestone), but these plates do not resemble those from Fakse, as they are asymmetrical and probably belonged to a species with several plates in the row of the upper margin.

Horizon and locality. Younger Danian. Bryozoan limestone. Fakse.

5. *Ravniaster planus*, n. sp.

Plate III, figs. 9—13; text, figs. 21, 22.

In deposits from the Older, and partly also from the Younger Danian I have found a great number of plates, which bear distinct signs of being terminal supero- and infero-marginalia. My attempts to combine them with median marginalia found in the same localities were so unsuccessful that I gave up the attempt. I then tried to join them without median plates, and in this manner I succeeded in producing a form with only two marginal plates from one extremity of the arm to another. As this solution seemed to me to be improbable, I abandoned the attempt of reconstruction. My surprise was great, when one day in the Older Danian near Korporalskroen I found a small specimen with three extremities of arms preserved,



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Fig. 30. *Ravniaster maculatus* n. sp. Reconstruction.

all of them possessing both infero- and supero-marginalia. This specimen had in each margin only two marginal plates, both of them terminal, and this applied to the supero- as well as to the infero-marginal plates. This find caused me to establish the genus *Ravniaster*, and I very soon succeeded in finding more forms of this genus.

The terminal supero-marginal plate is flattened with a longitudinal, faintly pronounced ridge from the extremity of the arm to the articular face. The downward face shows only one facet, which corresponds with the equally large terminal infero-marginal plate.

The ornament is of the *Metopaster* character.

The terminal infero-marginal plate is triangular with a rather sharp angle towards the extremity of the arm. The upper face, which corresponds with the overlying terminal supero-marginal plate, is even, and the articular face towards the neighbouring plate rather small.

On a single infero-marginal plate there are, corresponding with the ambulacral furrow, attached remains of the small distal ambulacral plates.

Another find includes two terminal marginalia, a supero- and an infero-marginal plate in their original positions.

Horizon and localities. Older Danian: Kagstrup. Stevns. Korporalskroen. Younger Danian: Herfølge. Fakse, Bryozoa limestone.

6. *Ravniaster carinatus*, n. sp.

Plate IV, fig. 34.

A number of terminal supero-marginalia have a special ornament, for which reason I have considered it desirable to give it a special name.

One of the largest terminal supero-marginalia has the following dimensions:

Length: 3 mm.

Height: $1\frac{1}{2}$ mm.

Height of facet towards median supero-marginal plate: 1 mm.

Depth - - - - - : 2 mm.

The free surface is divided by a longitudinal ridge into one portion facing upwards and another facing outwards. On the ridge there are circular spine pits, evenly distributed and of equal size. The remaining part of the surface is smooth, and margin and central area are separated by a sharp line of demarcation.

The anterior angle of the plate is about 40° , the total angle of the arm thus becoming 80° . The posterior inward facet shows that the profile of the arm was strongly curved, and that the height of supero-marginalia was considerably less than the depth. The facet for the terminal plate is comparatively large. The under side shows two oblong facets for infero-marginalia.

Horizon and localities. Younger Danian: Saltholm, Herfølge, Rejstrup.

Genus TEICHAster, Spencer.

SPENCER mentions the following generic characters (8, p. 122): "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."—It is the absence of rugosities which separates this genus from the genus *Crateraster*, which latter SPENCER describes as follows (8, p. 121): "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."

Dr. TH. MORTENSEN has placed at my disposal a specimen of *Crateraster quinqueloba* GOLDFUSS from the English Chalk, for the use of which I am greatly indebted to him. In the figures (text, fig. 6) are shown the dorsal side of the animal, the ambulacral plate and its neighbouring plates as well as the characteristic ornament.

The genus *Teichaster* is represented in the Danish Cretaceous only by isolated plates. The latter are first and foremost identified by the profile of the median supero-marginalia, which is distinguished by a sharp, nearly right-angled division between the lateral and the dorsal free faces.

The following species are to be described here.

From the White Chalk:

1. *Teichaster favosus*, SPENCER

From the Danian:

2. *Teichaster cf. favosus*, SPENCER
3. *Teichaster anchylus* n. sp.
4. *Teichaster retiformis*, SPENCER

Besides the plates which have been determined as to species, there is a not inconsiderable number of isolated plates, which at the present moment yield no point of support for a determination of the species. The fact is that arm plates are of little importance for the identification, and these plates are particularly numerous. The plates determined as to species originate from the margin of the disc, and are so characteristic that it is possible to determine them, though they cannot give much information about the general appearance of the animal. The determination is, therefore, exclusively based upon isolated median marginalia.

1. *Teichaster favosus*, SPENCER.

Plate III, fig. 16; text, figs. 7—8.

1913 *T. favosus*, SPENCER, 8, pp. 122—123, plate 12, figs. 14—19, plate 16, figs. 14—16.

This species is very common in the Senonian White Chalk, particularly on Rügen, and it also occurs in Denmark, but is not particularly common.

In the single case where several plates belonging to the same individual, though unconnected, have been found, the marginalia are low. The ornaments of the dorsal and the ventral faces consist of hexagonal, circular spine pits and a very faint granulation, whereas the lateral side has hexagonal spine pits.

One specimen from Stevns Klint, Mandehoved, is shown in text, fig. 8. Remains are found of a produced arm, which has had at least five plates, rapidly decreasing in size. The remaining material, originating from the Danish White Chalk, is very variable. On some plates there are, as mentioned by SPENCER, close-set, very nearly hexagonal spine pits on the dorsal faces of the supero-marginal plates, whereas the lateral face has more scattered, circular spine pits. (One specimen, text, fig. 7 e (Møn). On another supero-marginal plate the dorsal face is coarsely granulated, whereas the lateral face has circular spine pits. On a third the dorsal face is tumid with coarse, hexagonal spine pits, whereas the lateral face is coarsely granulated. Others have circular spine pits of the same shape scattered over both faces.

Whether all these plates can be regarded as variations of SPENCER'S *T. favosus* is, indeed, very doubtful. As already mentioned, connected plates have only been found in one case, and these show no variation. With the material at hand there seems to be no possibility of dividing it into more species.

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn. Stevns. Aalborg. Enegaarde.

2. *Teichaster cf. favosus*, SPENCER.

In the Younger Danian there are a few high plates, which show similarities to SPENCER'S species, but the greater part of the marginalia have the peculiarity that the line of demarcation between the lateral and dorsal surfaces on the supero-marginalia is very close to the articular surfaces towards the infero-marginalia, the dorsal face, which is not horizontal, thus becoming larger than the lateral. The ornament on these plates is the same on the dorsal as on the lateral side. It will in all probability be necessary to regard it as a separate species, but as long as no better material is at hand, it is preferable to keep these plates together under the above designation.

Horizon and localities. Younger Danian: Thorslunde. Saltholm. Fakse. Herfølge. Holckenhavn. Daugbjerg. Mønsted.

3. *Teichaster anchylus*, n. sp.

Plate III, figs. 14—15, 17; text, fig. 9.

This form is of very frequent occurrence in the Older Danian, and its median supero-marginalia are so characteristic that it must be regarded as a distinct species.

The ornament is reticulate, the entire surface of the plate, both the lateral, the dorsal and the ventral faces having the same ornament, viz. circular spine pits, which are so close-set as to produce a honey-combed surface. The greatest pecu-

liarity about this form is, however, the shape of the median supero-marginalia. They are more than twice as high as they are broad, and the dorsal face is only half the size of the lateral. Some of the supero-marginalia are symmetrically built with a slightly tumid dorsal face, the articular faces towards the neighbouring plates being equal in size. Others are asymmetrically built with oblique articular faces. The two lateral articular faces are thus of different size, so that it appears that the margin of the animal was high right between two arms, but decreased gradually in height in the direction of the arms.

The infero-marginalia have the same ornament as the supero-marginalia, but the lateral and ventral lateral faces merge more evenly into each other than in *T. retiformis*. Towards the arm there is no line of demarcation between the two faces, which are gradually fused so that the plate has a characteristic triangular appearance in cross section. On the margin of these plates which faces towards the ambulacral furrow, parallel impressions of the ambulacralia are to be seen.

This form differs so much from *T. retiformis*, both in the shape of the marginalia and in the ornament that it seems natural to consider it as an independent species, all the more as it apparently does not vary.

Horizon and localities. Older Danian: Stevns. Kagstrup. Korporalskroen.

4. *Teichaster retiformis*, SPENCER.

Plate III, figs. 18—19; text, fig. 10.

1913. *T. favosus* var. *retiformis*, SPENCER, 8, p. 122, plate 12, figs. 17 and 19.

As a variety of *T. favosus* SPENCER mentions a form from the Danian, which he calls var. *retiformis*. He describes it as follows:

“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”, “... the infero-marginalia are extremely thick and unmistakably distinct from all other Asteroid ossicles in the Chalk. The ornament has largely disappeared from the lateral faces”.

This characteristic is naturally not very valuable, but when looking at SPENCER'S plate 12, fig. 19 one nevertheless gets the impression of a definite form. The supero-marginal plate has, on the dorsal face, which is very short, a pronounced tumid vaulting. As is rarely the case, the most characteristic feature is, however, the lower marginal plate, which has a very marked profile. The lateral and the ventral faces are almost equal in size, and merge into each other with a comparatively sharp, almost right-angled curvature.

The plate is very thick. On the lateral face there is a shallow furrow running parallel with the lower horizontal edge of the plate.

Such characteristic infero-marginalia have only been found in certain beds of lime sand in the Younger Danian.

Horizon and localities. Younger Danian: Saltholm. South harbour of Copenhagen. (Limhamn).

Genus PYCINASTER, Spencer.

SPENCER describes this genus in the following manner (8, p. 123):

"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 principal difference between the species of this genus consists in their varying size and height. A dorsal tumidity may be developed. The supero-marginalia may easily be distinguished from infero-marginalia by their shape and by the prominent knob serving for attachment of 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 and as a rule wedge-shaped. The median infero-marginalia are oblong with parallel sides and the height is greater than the length. Near the distal part of the arm the plates become square. The pedicellariæ are, when present, usually found in that part of the plate which is nearest the boundary between the supero- and infero-marginalia.

MERCIER (5), who has a number of species belonging to this genus, observes that his plates are not smooth, but on the contrary covered with rugose papillæ. This means that the general shape of the plates, not their ornament, is the main character of the genus.

The material available from our deposits is rather abundant, but only isolated plates have been found, so that it is not possible to describe the general shape of the animals, but only a few characteristic plates.

The following species will be described:

From the White Chalk and the Older Danian

1. *Pycinaster crassus*, SPENCER.

From the Danian

2. *Pycinaster danicus*, n. sp.
3. *Pycinaster Rosenkrantzii*, n. sp.

1. *Pycinaster crassus*, SPENCER.

Plate III, figs. 20, 21.

1913. *Pycinaster crassus*. SPENCER, 8, pp. 123—125. Plate 11, figs. 16—17; plate 16, figs. 1—6.

SPENCER mentions this form from the Senonian of England, Germany and Denmark. It has smooth plates without any ornament, for which reason MERCIER'S form (5, p. 12) bearing the same name can hardly be referred to it. The profile of the median supero-marginalia with the inward protuberance is that characteristic of the genus. The species is distinguished from the other (older) ones by the fact of the ossicles being larger and higher, and furthermore they have a dorsal tumidity. SPENCER records this form from the Danish White Chalk and Danian.

The material belonging here, for the greater part consisting of isolated plates, is distributed in the following manner:

In our White Chalk, where the form is not common, there are a few plates from the median part of the row of supero-marginalia. The plate is large, of a peculiar shape with a rather considerable tumidity and no ornament, so it is quite smooth. A find of some connected plates shows a few infero-marginalia and a number of dorsal and ventral plates with a faintly circular ornament. A few small marginalia have facets for larger spines.

From the Older Danian there are only a few supero-marginalia with faintly circular ornaments.

Horizons and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns Klint.

Older Danian: Kagstrup. Korporalskroen.

2. *Pycinaster danicus*, n. sp.

Plate IV, figs. 1—5.

From the Younger Danian there are a great many large supero-marginalia, which attract some attention. From Bryozoan limestone in Fakse there is a median supero-marginal plate, which is symmetrical and wedge-shaped. A dorsal tumidity takes up the whole of the breadth of the plate. On the margin of the latter are seen four projecting circular facets for large spines, arranged in a circle transversely to the plate. The surface is not smooth, but has closely placed circular spine pits. Corresponding in size with this type an asymmetrical plate has been found with a large articular face towards the median and a much smaller articular face towards the more distal plate. Also this plate is crowded with rather closely touching circular spine pits, which are particularly pronounced on the dorsal tumidity. The appearance of these two plates give the impression that the margin of the animal was high right between the arms, the height rapidly decreasing towards the arm.

From the lower beds of Herfølge there is a median supero-marginal plate, also covered with close-set circular spine pits, particularly on the lateral side. On the tumidity there is a single prominent circular facet and on the lateral side a similar one for large spines.

From Saltholm there is a similar, but smaller plate, with two large spine facets and a couple of infero-marginalia, one of which has two large facets, whereas the other one is without such large spines.

These finds show that in the Younger Danian there is a *Pycinaster* form which is very different from the *P. crassus* described by SPENCER, having had large spines both on the infero- and the supero-marginalia and being supplied with circular spine pits.

Horizon and localities. Younger Danian: Saltholm. Fakse. Herfølge. Frederiksholm. Thorslunde. Rejstrup. Holckenhavn. Mønsted.

3. *Pycinaster Rosenkrantzi*, n. sp.

Plate IV, figs. 6—9.

In a locality of younger Danian in the south harbour of Copenhagen Docent ROSENKRANTZ has found a great many remains of a *Pycinaster* form, which deviates so much from *P. danicus* that it ought to be regarded as a separate species. The shape is the same as in *P. danicus*, with the high interr radial margin and the abundance of facets for large spines. The difference is in the ornament, which in this form is hexagonal with very closely placed spine pits. The projecting margins of these pits lend a very characteristic, rugose appearance to the whole of the surface. Supero- and infero-marginalia are only very little displaced in relation to one another.

Horizon and locality. Younger Danian: Lime sand. Northern part of Tegholm, Copenhagen.

Genus CHOMATASTER, Spencer.

In the Danish deposits only isolated plates are found, and it is therefore possible to recognize them only by means of their particularly characteristic median supero-marginalia.

SPENCER (8) divides the genus into two groups:

a. The *Calliderma* group.

The variety of genera, which SPENCER refers to the *Calliderma* group, is very heterogeneous and hardly quite natural. The ornament of the plates is comparatively undifferentiated and consists of more or less hexagonal, close-set spine pits or of more scattered circular ones.

SPENCER divides this group into two subdivisions:

1. Forms with comparatively short arms and an interr radial arc. To this group is reckoned a series belonging to the genus *Calliderma*, which has not been found in Danish deposits, and the genus *Chomataster*.

2. Forms with long arms and a well-rounded interr radial arc. To this group SPENCER refers the genus *Ophryaster*.

b. The *Comptonia* group.

No Danish forms.

SPENCER describes the genus *Chomataster* in the following manner (8, p. 128):

“Body high. 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.”

In the Danish deposits there are only isolated plates, and it is therefore only possible to identify them by means of particularly pronounced plates, such as the median supero-marginalia.

Here a description will be given of:

1. *Chomataster præcursor*, SPENCER
2. *Chomataster acules*, SPENCER

1. *Chomataster præcursor*, SPENCER.

1913. *Chomataster præcursor*, SPENCER, p. 129, plate 12, figs. 26—27; plate 16, figs. 28—29.

The spine pits are arranged in a fine hexagonal pattern.

There are several isolated plates from the Danish White Chalk, one of which has been determined by SPENCER.

Horizons and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn. Aalborg.

2. *Chomataster acules*, SPENCER.

Text, fig. 12.

1913. *Chomataster acules*, SPENCER, 8, p. 129, plate 12, figs. 28 and 31; plate 16, figs. 8—13.

The distinguishing character of the species is the fact that the supero-median marginalia have a large spine pit for a strong spine, but are otherwise smooth.

In the Danish White Chalk this form is rare. There are a number of supero-marginalia, most of which have a large facet for a strong spine, but a single example has two. However, they all deviate from the description given by SPENCER, there being besides the large facets scattered circular spine pits over the whole of the surface. The Danish form is low.

From the Older Danian there are a number of strong supero-marginalia, the height of which is twice the breadth, and which bear a very strong facet for a spine, and the whole of the surface is covered with circular spine pits.

From the Younger Danian there are a number of small plates, which indicate that the margin was low. Part of these plates have, besides a large spine facet, granules instead of spine pits. The material being very scarce, the whole of it is classed together under the name of *C. acules*.

Horizons and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn. Stevns. Aalborg.

Older Danian: Stevns. Kagstrup.

Younger Danian: Saltholm. Fakse. Rejstrup.

Genus OPHRYASTER, Spencer.

The genus is diagnosed as follows (8, p. 129): "General form depressed. Arms long, interbrachial arcs well rounded. Spine pits often circular and well separated. Inner margin of supero-marginalia often brow-like."

To this genus SPENCER refers three species, one of which occurs in the Danish White Chalk.

Most of the material at hand originates from a find of plates belonging to the same specimen, none of which, however, were found in their original position.

Further, some isolated plates have been found. Of these the median marginalia are identifiable by their profile forming a right-angled triangle, the one side, which corresponds with the free surface, forming a regular circular arc.

The material found most nearly resembles the species described by SPENCER, *O. oligoplax*, SLADEN.

1. *Ophryaster oligoplax*, SLADEN.

Plate IV, figs. 10—23; text, figs. 13—15.

1891—1907. *Ophryaster oligoplax*, SLADEN & SPENCER, 7, pp. 19—21.

1913. - - - , SPENCER, 8, p. 130, plate 13, fig. 26.

The distinguishing mark of the ossicles of this species is the presence of a narrow area without spine pits on the inner margin of the supero-marginalia.

A number of plates belonging to this species have been found in the Danish White Chalk.

By a lucky find at Møns Klint I have secured a number of plates from a single individual, and by means of this it has been possible to reconstruct at any rate one arm. The supero-marginalia from the interradial arc (median supero-marginalia) are very nearly square, being equally high and broad. In profile the plate is triangular, with two sides standing at right angles to each other and a third side, which forms a regular arc. The whole of the free surface is slightly tumid and covered with rather close-set, circular spine pits, only a small area on the inner side of the dorsal surface being devoid of spine pits. The infero-marginalia from the same part of the arm are of exactly the same size as the supero-marginalia. They are square, their height being equal to their breadth, triangular in profile with an even arc as a third side. They are not tumid. The whole of the surface is covered with scattered circular spine pits. Most of them have an elongated valvate pedicellaria near the upper margin, both valves being frequently found in situ. Towards the arm the character of the supero-marginalia changes, and they become low, the height being only half the breadth. The tumidity is unchanged, and the ornament is constant.

The infero-marginalia from the same region likewise become smaller, do not change character and retain the pedicellaria.

The arm itself consists of at least twelve supero- (six by six) and twelve infero-marginalia (six by six), which are closely joined and form a dorsalwards

curving arm extremity. The arm decreases only slightly in thickness from the base to the extremity. The ornament on these arm plates deviates very much from the ornament on the median marginalia. The spine pits disappear entirely and are replaced by rather pronounced granulations, confined to the slightly tumid central area both in the supero- and the infero-marginalia. The shape also becomes different, the plates narrowing so that the height becomes about twice the breadth.

If such plates are found isolated, it is impossible to imagine that marginalia from the disc and the arm belong to the same species, even to the same genus. Besides these marginalia from arm and disc, plates from the dorsal side (the papular zone) are present from the same individual.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn.

Family Stauranderasteridæ, Spencer.

Genus STAURANDERASTER, Spencer.

The genus was established to include some White Chalk asteroids with breast-plate shaped marginalia and a circlet of prominent tumid ossicles on the dorsal surface of the disc (see SPENCER'S description, 8, p. 132).

At the bases of the arms there are several rows of plates, radialia, supero- and infero-marginalia, which are very alike in appearance. They are thin, with imbricating edges and distinctly breast-plate shaped. The rabbet edge and the raised central area are clearly defined. The ossicles of the swollen part of the arm show considerable differences. The radialia are club-shaped with a swollen head, and the marginalia high and closely fitting. Both of these series have frequently a very indistinct rabbet edge. The swollen plates on the dorsal side consist of a central plate, situated in the middle of the dorsal side, and a circlet of plates which are named radialia and interradiania, ten in all. All of these eleven plates are generally tumid and may have a more or less extended base.

The central plate is often a very regular pentagon and this has caused several mistakes. For instance based upon such a central plate from the English Chalk GISLÉN (3, pp. 28—30, figs. 56—59) established a new Comatulid genus *Casterometra*, which he refers to the Palæantedonids. As there is no central cavity, he made a couple of sections through the plate to look for it, without any result, however; and in order to clear up the matter he must then have recourse to some theories on the fossilization process.

SPENCER has the following species:

S. bulbiferus, FORBES. The swollen plates have no extended bases in the early forms, whereas such are present in the later. The ornament changes from dotted to rugose.

S. Boysii, FORBES. Has a finer ornament and leads up to the smooth forms. It has no swollen arms.

S. senonensis, VALETTE. Resembles in shape *S. Boysii*, but is quite smooth.

S. gibbosus, SPENCER. General shape like *S. Boysii* with the exception that the distal portion of the arm is swollen. The spine pits frequently lipped.

From the *Mucronata* zone and the Danian he mentions the variety *pyramidalis* with large dorsal ossicles, which are more pyramidal than hemispheric in shape and may be quite smooth.

S. coronatus, FORBES. Is a smooth form.

S. pistilliferus, FORBES. Has plates with a small rabbet edge. The tumid central area is usually covered with close-set, granular spines.

S. decoratus, GEINITZ. Has ossicles of an irregular shape and frequently with wart-like protuberances.

MERCIER (5, p. 33 seq.) distinguishes two genera: *Stauraster* (VALETTE, 1928) and *Stauranderaster* (SPENCER, 1907). To *Stauraster* he refers some very thick dorsal plates, whereas to *Stauranderaster* he refers species with large central and inter-radial plates and also thick dorsal plates. There is for the present no use for this classification regarding the Danish forms, as only isolated plates have been found, and wherever thick dorsal plates are present in the beds there are also large central and interradial plates.

In Denmark the genus occurs only as isolated plates, a few of which, however, may be grouped according to the localities where they are found; it is consequently possible to establish various forms, and according to the principle "melius est distinguere quam confundere" the following species are proposed:

1. *Stauranderaster gibbosus*, SPENCER.
2. *Stauranderaster pyramidalis*, SPENCER
3. *Stauranderaster mixtus*, n. sp.
4. *Stauranderaster miliaris*, n. sp.
5. *Stauranderaster speculum*, n. sp.

1. *Stauranderaster gibbosus*, SPENCER.

1913. *Stauranderaster gibbosus*. SPENCER, 8, pp. 133—134, plate 13, figs. 11—12.

In the Danish White Chalk the species is, upon the whole, not of frequent occurrence. A few large dorsal plates (centrals) are found, but they are quite smooth, almost flat, and without extended bases. SPENCER himself has determined them as belonging to this species, even though the plates which lack extended bases ought to occur in older beds.

Horizon and locality. Upper Senonian. Zone with *Belemnittella mucronata*. White Chalk: Stevns.

2. *Stauranderaster pyramidalis*, SPENCER.

1913. *Stauranderaster gibbosus* var. *pyramidalis*, SPENCER, 8, p. 135, plate 16, fig. 30.

The species is not of frequent occurrence. There are some centrals, which have an extended base and a conical inflated dorsal part. The ornament on these faces varies considerably. The surface may be quite smooth, but may also have a finely granulated ornament, and finally comparatively large spine pits with lip-formed surroundings may occur.

Together with these large plates there are a number of large marginalia of a typical shape with a raised central area, with scattered, rather deep pits. No club-shaped radialia have been found, so nothing is known of the appearance of the arm.

Horizons and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns Klint.

Older Danian: Stevns Klint. Kagstrup. Korporalskroen,

3. *Stauranderaster mixtus*, n. sp.

Plate IV, figs. 26—28.

In a find of accumulated plates from the same individual it is possible to identify large supero-marginalia from the swollen part of the arm with corresponding club-shaped radial plates and a radial plate with typical articular faces. All of these are slightly tumid and have an almost smooth central area with very few scattered spine pits. Together with these arm plates have been found a couple of large plates from the dorsal side of the disc, in all probability primary radial plates. The surface is only slightly tumid. The ornament is of such a kind that within a broad marginal area there is a sharply defined, slightly raised area which is quite smooth. SPENCER states that this ornament is found in *S. decoratus*, but the special characters of this form are its irregular shape and the wart-like protuberances on the sides of the plates.

Horizon and locality. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns Klint.

4. *Stauranderaster miliaris*, n. sp.

Plate IV, fig. 35.

In Danian deposits, both older and younger, there are isolated plates of a *Stauranderaster*, which is easily identified by its peculiar ornament. The central area of the plates, which is surrounded by a rather broad rabbet edge, is raised and entirely covered by fine granulations.

The following plates are found:

1. A primary radial with a circular central area, surrounded by a rabbet edge. The circumference of the plate is oval, the sides are bevelled, with sharp edges.

2. Large supero-marginalia from the swollen part of the arm of a typical *Stauranderaster* form.

3. A dorsal plate (radial) from the swollen part of the arm, symmetrically built with bevelled articular faces on either side and broad articular faces on the front and backside.

4. Finally some bevelled, irregularly shaped marginalia with an extended ventral side and a granulated ornament on the dorsal tumidity.

The same ornament has been found by SPENCER in *S. pistilliferus*, but it is impossible to refer the Danish plates to this species, as the large dorsals are tumid and are without any projecting conus.

Horizons and localities. Older Danian: Stevns Klint. Kagstrup. Korporalskroen. Younger Danian: Saltholm. Rejstrup. Herfølge.

5. *Stauranderaster speculum*, n. sp.

Plate IV, fig. 35.

In the Younger Danian there are a number of plates with a special ornament.

The centrale is without any extended base; it is only tumid and has no pyramidal extension. The ornament is somewhat variable. The surface may be quite smooth, or with a granulated ornament, but no spine pits. Corresponding with these central plates there are small plates from the arm and the dorsal side with a sharply cut, smooth, glassy ornament.

Horizon and localities. Younger Danian: Rejstrup. Saltholm. Fakse. Herfølge.

Order SPINOLOSA, Perrier.

Family *Sphæraasteridæ* Schöndorf.

Genus VALETTASTER, Lambert.

[The name *Tholaster* SPENCER, as being preoccupied, was changed into *Valettaster* by LAMBERT (cf. above p. 22).]

This genus includes isolated plates of an irregular shape with a generally quite small free surface and bevelled edges, frequently with smooth articular faces bearing small pits. The outer surface is often so small that one gets the impression of a low, truncated conical plate. Some plates do not reach the surface of the animal and, therefore, lack the ornament which is to be found on the small free surface of the others.

SPENCER has divided his material into two species: *V. argus* and *V. ocellatus*; what distinguishes them from each other is that *V. ocellatus* has a madreporiform ornament, whereas *V. argus* is entirely without ornament.

In the Danish White Chalk and Danian isolated plates have been found, a single find comprising plates belonging to one individual, but not in their original connection. They can be divided into the following two species:

1. *Valettaster ocellatus* (SPENCER)
2. *Valettaster granulatus*, *n. sp.*

1. ***Valettaster ocellatus*** (SPENCER)

Plate IV, fig. 29.

1913. *Tholaster ocellatus*, SPENCER, 8, pp. 137—138, plate 13, fig. 24.

Plates belonging to this species are rather frequently found in the Danish deposits. They are fairly easily recognizable, but their irregular shape yields no points of support for the determination of the part of the animal, where they were originally located. The bell-shaped margin must, however, have had some marginalia. The ambulacral furrows must have had ambulacral plates and so on, but as to this nothing is known, and among the plates found there are none which show their function. For the determination of the species it is, therefore, only possible to use the sparse ornament on the small free surfaces of the plates. The ornament is somewhat variable; on some plates, originating from the White Chalk of Jutland, it consists of deeply incised furrows, whereas on others it consists of madreporiform, faintly curving furrows; finally, it may be so indistinct that it is only visible through a lens.

Horizons and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn. Aalborg.

Older and Younger Danian: Numerous localities.

2. ***Valettaster granulatus***, *n. sp.*

Plate IV, fig. 37.

In the Younger Danian there are a number of plates with an ornament, which differs entirely from that of the preceding species. The surface has no furrows or stripes, but the small, free surfaces are smooth, with scattered, rather prominent granules.

Horizon and locality. Younger Danian: Saltholm.

Order PAXILLOSA, Perrier.

Family *Astropectinidæ*, Gray.

Genus LOPHIDIASTER, Spencer.

To this genus SPENCER refers marginalia, which have a prominent ridge on the outer side and a characteristic profile, with evenly rounded outer sides. MERCIER divides the material belonging here into two genera: *Lophidiaster* and *Astropecten*,

but the Danish material agrees so well with the English that it can hardly be divided.

SPENCER gives the following generic characters (8, p. 138): "Marginal strongly ridged. Spines on marginalia either minute or absent". He mentions two species: *L. ornatus* and *L. pygmæus*. *L. ornatus* is thus described by SPENCER (8, p. 138): "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)". The figure shows that the surface was covered with small protuberances.

L. pygmæus is described as follows: "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".

The large marginalia of *L. ornatus* are not found in Danish deposits, but from the gravel limestone at Båstad (Scania) a number of marginalia are at hand of the same size and with a similar ornament (text, fig. 16).

Lophidiaster-marginalia are of very frequent occurrence both in the White Chalk and in the Danian. All the plates from the White Chalk are small and have a granulated ornament; only in rare cases they are smooth. The differences from SPENCER's description of *L. pygmæus* are so small that there is no reason to separate the Danish form from this species. The material from the Danian is abundant; however, like that from the White Chalk, it only consists of isolated plates. The Danian material shows plates which are somewhat larger than those from the White Chalk. The ridge is somewhat narrower, and the ornament always consists in rather deep and close-set spine pits, both on the supero- and infero-marginalia. These forms have been given a special name, *L. punctatus*.

The following forms are described:

From the White Chalk: 1. *Lophidiaster pygmæus*, (v. HAGENOW M. S.) SPENCER.

From the Danian: 2. *Lophidiaster punctatus*, n. sp.

1. *Lophidiaster pygmæus*, (v. HAGENOW M. S.) SPENCER.

Asterias pygmæa v. HAGENOW M. S.

1913. *Lophidiaster pygmæus*, SPENCER, 8, p. 139, plate 11, figs. 20—21; plate 16, figs. 17—19.

The marginalia of this species are small and rather broad, the ridge constituting about three fourths of the breadth of the plate. The ridge projects only a little, and as much in a dorsal as in a lateral direction, so that it forms no wings, as in *L. ornatus*.

The ornament is granulated, the granules frequently being of different sizes. There is no difference in the ornament on the supero- and infero-marginalia..

Horizon and localities. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Stevns Klint. Møn. Enegaarde. Aalborg. Mariager.

2. *Lophidiaster punctatus*, n. sp.

Plate IV, fig. 38.

This species includes all the *Lophidiaster* plates found both in the Older and Younger Danian. Common to them all is the rather narrow ridge with the characteristic ornament, which consists of scattered, rather deep spine pits.

Horizons and localities. Older Danian: Kagstrup. Korporalskroen.
Younger Danian: Saltholm. Frederiksholm. Fakse. Herfølge. Holckenhavn. Mønsted.

Order FORCIPULATA, Perrier.

Genus ASTERIAS, Linné.

1. *Asterias* sp.

Plate IV, figs. 30—32.

MERCIER (5, p. 46) has described a couple of Asteroids which were cryptozoniata, and the dorsal sides of which were covered with stellate, small plates, as is the case in many recent forms. One of his species was founded on a nearly complete specimen, whereas the other one is based upon isolated stellate dorsal plates. He refers both of them to the genus *Asterias*.

In the Danish deposits are found, but very rarely, similar stellate dorsal plates and some terminal plates from the extremity of the arm (plate IV, fig. 31). However, a much more detailed treatment of the subject is necessary, and these plates are only mentioned in order to call attention to them, when the opportunity offers for further research, and in order to show that there are cryptozoniata Asteroids in these mesozoic beds.

Horizons and localities. Terminal plates. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Møn. Aalborg.

Younger Danian: Fakse.

Dorsal plates. Upper Senonian. Zone with *Belemnitella mucronata*. White Chalk: Aalborg.

The Asteroid remains described in this treatise are preserved in the Mineralogical and Geological Museum of the University of Copenhagen.

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PLATES

Plate I.

- Fig. 1. *Metopaster tumidus* SPENCER. Terminal supero-marginal plate. c. $\frac{2}{1}$. White Chalk. Møn.
a. Median articular face. b. Inner side. c. Outer side. d. Viewed from above.
- 2. *Metopaster Poulsenii* n. sp. Terminal supero-marginal plate. c. $\frac{2}{1}$. White Chalk. Stevns.
a. Median articular face. b. Inner side. c. Outer side. d. Outer side.
 - 3. Same. Reconstruction. c. $\frac{1}{1}$. a. Angle of arm, front-view. b. Margin viewed from above. c. Margin. Lateral view.
 - 4. Same. Actinal covering plate. c. $\frac{4}{1}$. a. Viewed from above. b. Viewed from below.
 - 5. Same. Plate from the papular zone. c. $\frac{4}{1}$. a. Viewed from above. b. Lateral view. c. Viewed from below.
 - 6. Same. Third lower marginal plate. c. $\frac{3}{1}$. Viewed from without.
 - 7. Same. Ambulacral plate c. $\frac{4}{1}$. a. Viewed from the ambulacral furrow. b. Lateral view.
 - 8. Same. Terminal plate. c. $\frac{4}{1}$. a. Under side. b. Upper side. c. Viewed from the extremity of the arm.
 - 9. Same. A specimen with the plates found in their original connection. $\frac{4}{3}$. a. Viewed from above. b. Front view of the margin.
 - 10. *Metopaster stevensensis* n. sp. Terminal supero-marginal plate. c. $\frac{2}{1}$. White Chalk. Stevns. a. Median articular face. b. Inner side. c. Outer side. d. Viewed from above.
 - 11. *Metopaster angulatus* n. sp. Terminal supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Enegaarde. a. Median articular face. b. Inner side. c. Outer side. e. Viewed from above.
 - 12. *Metopaster granulatus* n. sp. Angle of the arm. c. $\frac{3}{1}$. White Chalk. Aalborg. a. Viewed from above. b. Viewed from the extremity.
 - 13. *Metopaster kagstrupensis* n. sp. Terminal supero-marginal plate. $\frac{4}{3}$. Older Danian. Stevns. Row of plates extending from one extremity of the arm to the other.
 - 14. Same. Terminal supero-marginal plate. $\frac{4}{3}$. Older Danian. Stevns. a. Median articular face. b. Inner side. c. Outer side. d. Viewed from above. e. Extremity of the arm.
 - 15. Same. Extremity of the arm with a whole and a "broken-down" terminal supero-marginal plate. $\frac{4}{3}$. Older Danian. Korporalskroen.
 - 16. *Metopaster Spencerii* n. sp. Terminal supero-marginal plate. $\frac{4}{3}$. Older Danian. Stevns. a. Outer side. b. Inner side. c. Viewed from above.
 - 17. Same. Reconstruction of the extremity of an arm. c. $\frac{3}{1}$. Older Danian. Kagstrup. a. Side view. b. Viewed from above. c. Lower marginal plate seen from without. d. Terminal marginal plate. Outer side.

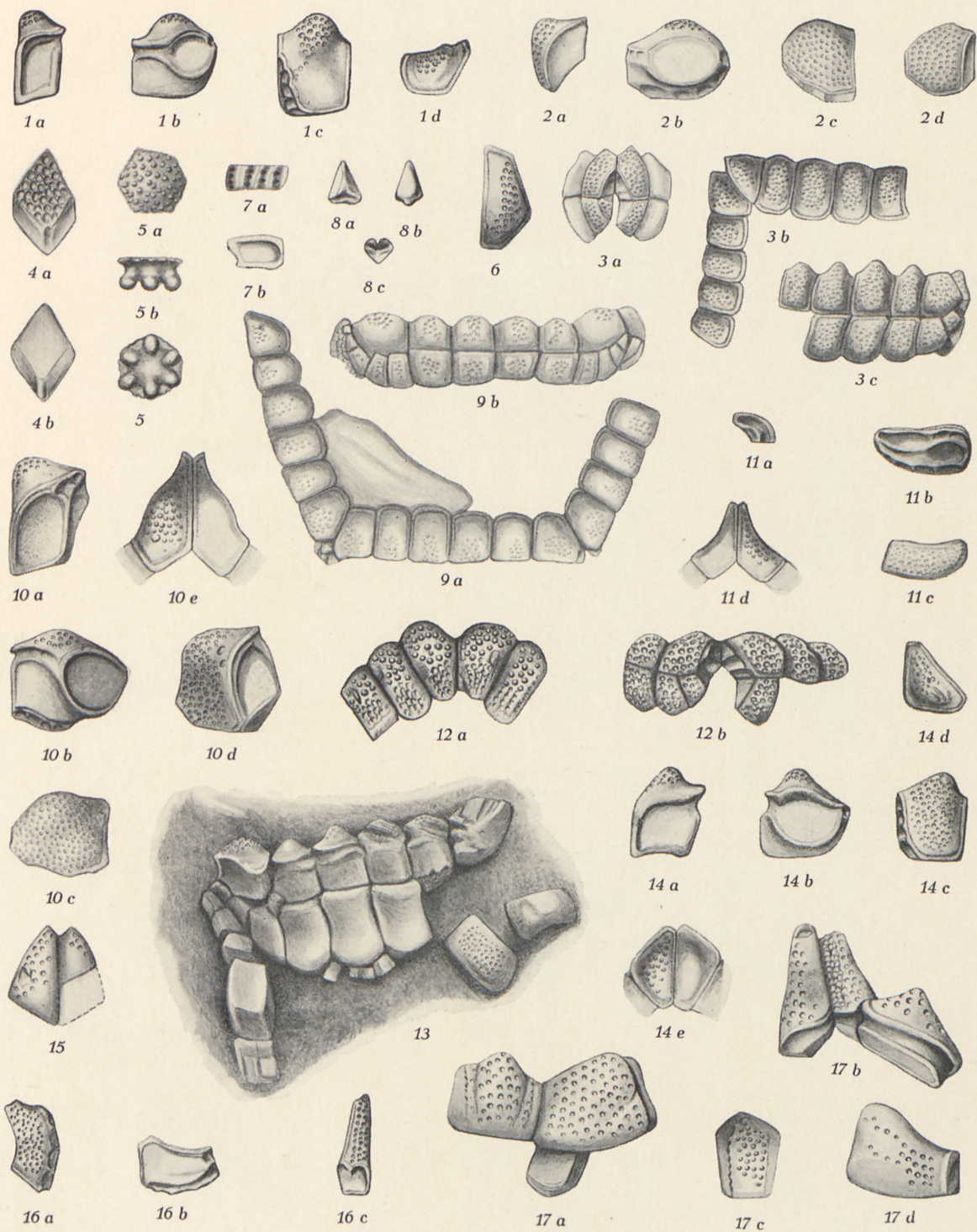
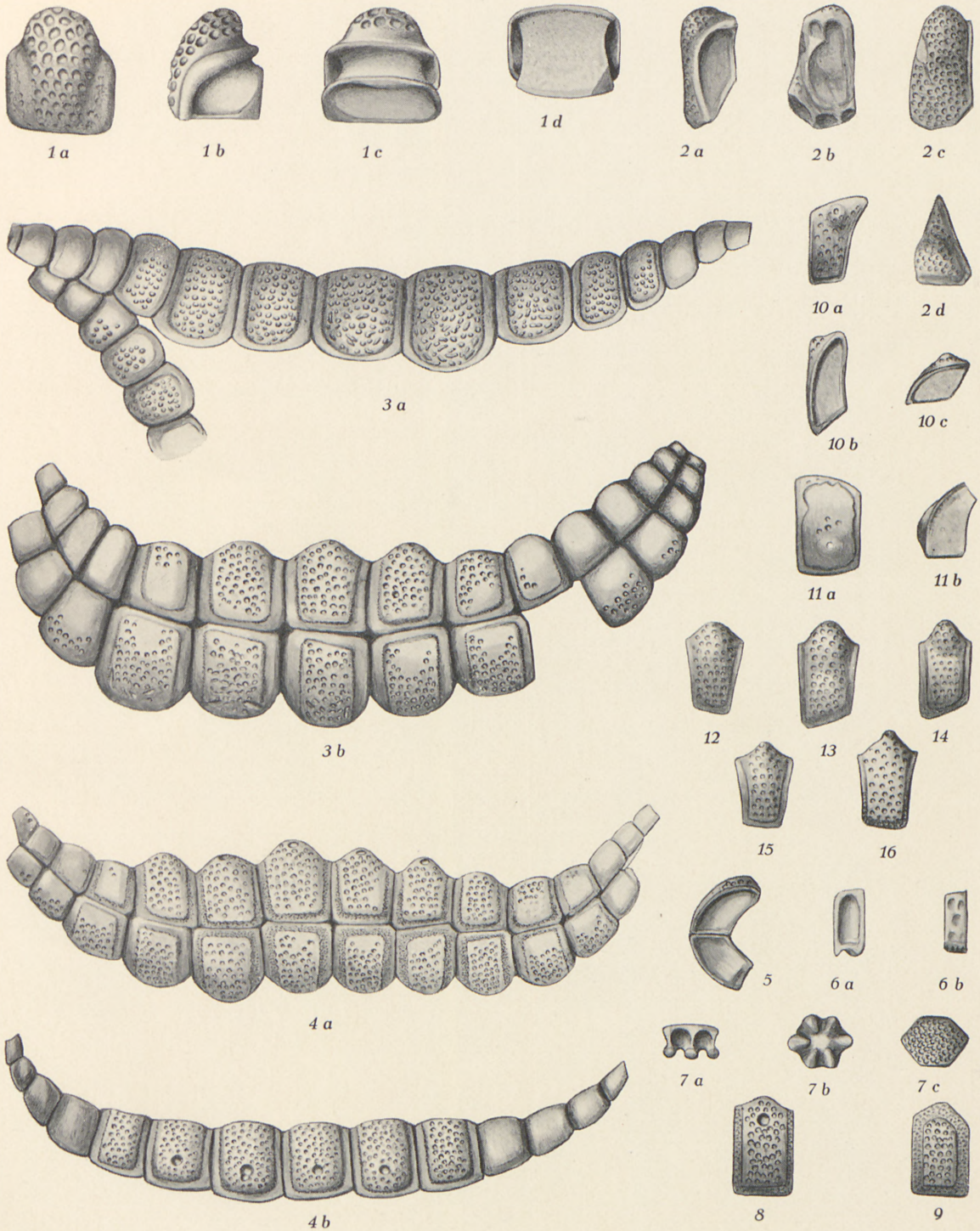


Plate II.

- Fig. 1. *Metopaster Spencerii* n. sp. Median supero-marginal plate. c. $\frac{4}{1}$. Older Danian. Stevns. a. Outer side. b. Median articular face. c. Inner side. d. Under side.
- 2. *Metopaster elevatus* n. sp. Terminal supero-marginal plate. c. $\frac{2}{1}$. Younger Danian. Herfølge. Bryozoan limestone. a. Median articular face. b. Inner side. c. Outer side. d. Viewed from above.
 - 3. *Recurvaster stevensensis* n. sp. Row of plates found with the plates in their original connection. c. $\frac{2}{1}$. White Chalk. Stevns. a. Viewed from above. b. Lateral view.
 - 4. *Recurvaster echinatus* n. sp. Row of plates. Reconstruction. c. $\frac{2}{1}$. White Chalk. Stevns. a. Lateral view. b. Viewed from above.
 - 5. Same. Profile of two connected marginalia.
 - 6. Same. Adambulacral plate. c. $\frac{4}{1}$. a. Articular face. b. Face showing towards the ambulacral furrow.
 - 7. Same. Plate from the papular zone. c. $\frac{4}{1}$. a. Lateral view. b. Viewed from below. c. Upper side.
 - 8. Same. Median supero-marginal plate. Outer side. c. $\frac{3}{1}$.
 - 9. Same. Median infero-marginal plate. Outer side. c. $\frac{3}{1}$.
 - 10. *Recurvaster mammillatus* (GABB). Median marginal plate. c. $\frac{3}{1}$. Younger Danian. Fakse. a. Outer side. b. Median articular face. c. Distal articular face.
 - 11. Same. Marginal plate without ornament. a. Outer side. b. Lateral view. c. $\frac{3}{1}$.
- Figs. 12—14. Same. Marginal plates showing variations. Outer sides. c. $\frac{3}{1}$.
- 15 and 16. Typical *Metopaster* marginals for comparison. c. $\frac{3}{1}$.



ST. HENTZE del.

Plate III.

- Fig. 1. *Ravniaster simplex* n. sp. Margin of plates. c. $\frac{5}{1}$. White Chalk. Stevns.
- 2. *Ravniaster simplex* n. sp. Reconstruction. c. $\frac{5}{1}$.
 - 3. *Ravniaster virgineus* n. sp. Extremity of the arm. c. $\frac{4}{1}$. White Chalk. Stevns. a. Viewed from above. b. Viewed from below.
 - 4. *Ravniaster lævis* n. sp. Connected plates. c. $\frac{4}{1}$. White Chalk. Stevns. a. Viewed from above. b. Viewed from below.
 - 5. *Ravniaster maculatus* n. sp. Extremity of the arm. c. $\frac{5}{1}$. Younger Danian. Fakse. Viewed from above.
 - 6. Same. Terminal supero-marginal plate. c. $\frac{5}{1}$. Younger Danian. Fakse. a. Viewed from above. b. Viewed from below. c. Articular face.
 - 7. Same. Median upper marginal plate. c. $\frac{5}{1}$. Younger Danian. Fakse. a. Viewed from below. c and d. The two articular faces.
 - 8. Same. 4 connected plates. Younger Danian. Fakse.
 - 9. *Ravniaster planus* n. sp. Extremity of the arm. Plates in their original connection. c. $\frac{5}{1}$. Older Danian. Korporalskroen. a. Viewed from above. b. Viewed from below.
 - 10. Same. Terminal supero- and infero-marginal plates found in their original position. c. $\frac{4}{1}$. Older Danian. Korporalskroen.
 - 11. Same. Terminal infero-marginal plate with remains of ambulacralia in their original position. c. $\frac{4}{1}$. Older Danian. Korporalskroen.
 - 12. Same. Terminal supero-marginal plate. c. $\frac{4}{1}$. Older Danian. Korporalskroen. a. Viewed from above. b. Articular face.
 - 13. Same. Reconstruction. c. $\frac{2}{1}$. Older Danian. Korporalskroen. a. Viewed from below. b. Viewed from above.
 - 14. *Teichaster anchylus* n. sp. Median supero-marginal plate. c. $\frac{2}{1}$. Older Danian. Kagstrup. a. Profile. b. Outer side.
 - 15. Same. Median supero-marginal plate. c. $\frac{2}{1}$. Older Danian. Kagstrup. a. Outer side. b. Profile.
 - 16. *Teichaster favosus* SPENCER. Median supero-marginal plate. c. $\frac{2}{1}$. White Chalk. Møn. a. Outer side. b. Profile.
 - 17. *Teichaster anchylus* n. sp. Supero-marginal plate towards the arm. c. $\frac{3}{1}$. Older Danian. Kagstrup. a. Profile. b. Outer side. c. Dorsal side.
 - 18. *Teichaster retiformis* SPENCER. Infero-marginal plate. c. $\frac{2}{1}$. Older Danian. Damhusaa (Copenhagen). Profile.
 - 19. Same. Supero-marginal plate. c. $\frac{2}{1}$. Older Danian. Damhusaa. a. Profile. b. Inner side. c. Outer side.
 - 20. *Pycinaster crassus* SPENCER. Median supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Stevns. a. Outer side. b. Profile.
 - 21. Same. Median supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Stevns. a. Outer side. b. Profile.

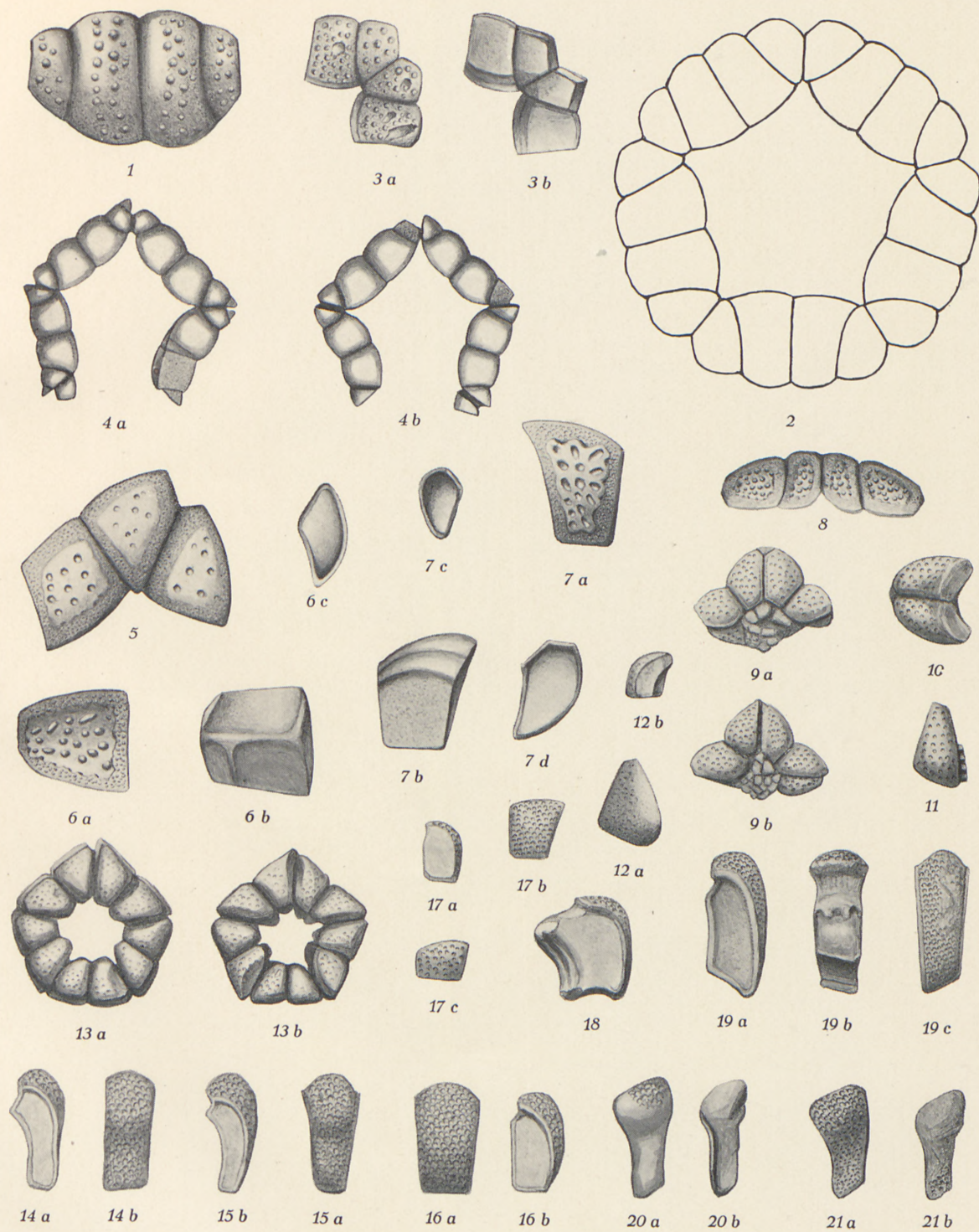


Plate IV.

- Fig. 1. *Pycinaster danicus* n. sp. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Fakse. Outer side.
- 2. Same. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Fakse. a. Outer side. b. Profile. c. Dorsal side.
- 3. Same. Median infero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Saltholm. a. Outer side. b. Profile.
- 4. Same. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Saltholm. a. Outer side. b. Profile.
- 5. Same. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Saltholm. a. Outer side. b. Profile.
- 6. *Pycinaster Rosenkrantzii* n. sp. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Tegholmen (Copenhagen). a. Outer side. b. Profile.
- 7. Same. Distal supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Tegholmen.
- 8. Same. Median supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Tegholmen. a. Outer side. b. Profile.
- 9. Same. Distal supero-marginal plate. c. $\frac{3}{1}$. Younger Danian. Tegholmen. a. Outer side. b. Profile.
- 10. *Ophryaster oligoplax* SLADEN. Median supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Møn. a. Upper side. b. Profile.
- 11. Same. Median supero-marginal plate towards the arm. c. $\frac{3}{1}$. White Chalk. Møn. a. Upper side. b and c. The two articular faces. d. Margin.
- Figs. 12—15. Same. Infero-marginal plates. c. $\frac{3}{1}$. White Chalk. Møn.
- Fig. 16. Same. Supero-marginal plate at the base of the arm. c. $\frac{3}{1}$. White Chalk. Møn. a. Upper side. b. Profile.
- 17. Same. Median supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Møn.
- 18. Same. Two united supero- and infero-marginal plates. c. $\frac{3}{1}$. White Chalk. Møn.
- 19. Same. Reconstruction of the arm. c. $\frac{2}{1}$. White Chalk. Møn. a. Upper side. b. Under side. c and d. The two sides of the arm.
- 20. Same. Arm plate. c. $\frac{3}{1}$. White Chalk. Møn. a. Profile. b. Upper side.
- 21. Same. Arm plate. Lower row. c. $\frac{3}{1}$. White Chalk. Møn.
- Figs. 22 and 23. Same. Two arm plates. c. $\frac{3}{1}$. White Chalk. Møn. a. Under side. b. Profile.
- Fig. 24. *Stauranderaster Boisii* FORBES. Arm. c. $\frac{3}{1}$. White Chalk. England. a. Cross-section. Profile. b. Lateral view. c. Viewed from above.
- 25. Same. Covering plate. Upper side. c. $\frac{3}{1}$. White Chalk. England.
- 26. *Stauranderaster mixtus* n. sp. Dorsal plate. c. $\frac{3}{1}$. White Chalk. Stevns. a. Viewed from above. b. Profile.
- 27. Same. Dorsal plate. c. $\frac{3}{1}$. White Chalk. Stevns. a. Viewed from above. b. Profile.
- 28. Same. Supero-marginal plate. c. $\frac{3}{1}$. White Chalk. Stevns. a. Profile. b. Outer side.
- 29. *Valettaster ocellatus* (SPENCER). Covering plate. c. $\frac{2}{1}$. Younger Danian. Rejstrup. a. Under side. b. Upper side.
- 30. *Asterias* sp. Dorsal plate. c. $\frac{5}{1}$. White Chalk. Møn. a. Under side. b. Upper side.
- 31. Same. Terminal plate. c. $\frac{5}{1}$. White Chalk. Møn. a. Dorsal side. b. Under side. c. Proximal margin. d. Distal end.
- 32. Same. Plate from the papular zone. c. $\frac{5}{1}$. White Chalk. Møn. a. Upper side. b. Under side. c. Profile.
- 33. *Recurvaster communis* n. sp. Median supero-marginal plate. c. $\frac{4}{1}$. Younger Danian. Herfølge. a. Upper side. b. Two united plates. Profile.
- 34. *Ravniaster carinatus* n. sp. Terminal supero-marginal plate, viewed from above. c. $\frac{4}{1}$. Younger Danian. Herfølge.
- 35. *Stauranderaster miliaris* n. sp. Supero-marginal plate showing ornament. c. $\frac{5}{1}$. Younger Danian. Herfølge.
- 36. *Stauranderaster speculum* n. sp. Dorsal plate showing ornament. c. $\frac{5}{1}$. Younger Danian. Saltholm.
- 37. *Valettaster granulatus* n. sp. Covering plate showing ornament. c. $\frac{5}{1}$. Younger Danian. Saltholm.
- 38. *Lophidiaster punctatus* n. sp. Marginal plate. c. $\frac{5}{1}$. Younger Danian. Saltholm. a. Profile. b. Outer side showing ornament.

