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# Cretaceous Asteroidea and Ophiuroidea

with Special Reference to the Species Found  
in Denmark

by

*H. Wienberg Rasmussen*

With 18 plates

Dansk sammendrag:  
Kridttidens søstjerner og slangestjerner  
med særlig hensyntagen til de  
i Danmark fundne arter

I Kommission hos  
C. A. Reitzels Forlag  
Axel Sandal  
København 1950

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H. WIENBERG RASMUSSEN.

*Mineralogical and Geological Museum  
of the University, Copenhagen.*

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## Abstract.

---

Knowledge of the Cretaceous asteroids and ophiuroids is extended on the basis of an abundant new fossil material. It is shown that several previously described species are identical. Those asteroids referred to the genera *Ravniaster* and *Mitraster* are nearly all young individuals of *Metopaster*. Description of ophiuroids on the basis of the relative frequency of single skeletal parts has shown itself to be an unfortunate method. The Danish, and a few foreign Cretaceous asteroids and ophiuroids are revised on the basis of the new observations. Six new species, five of which are found in Denmark, are described.

The following ontogenetic series have been found:

*Ravniaster simplex* → *Mitraster hunteri* var. *laevis* (in part) → *Metopaster poulsenii* → *Metopaster stevensensis*.

*Ravniaster virgineus* → *Metopaster tumidus*.

*Ravniaster laevis* → *Metopaster laevis* (= *Mitraster hunteri* var. *laevis* in part).

*Mitraster compactus* → *Metopaster parkinsoni*.

»*Mitraster rugatus*« → *Metopaster cingulatus* → *Metopaster uncatus*.

*Mitraster rugatus* → *Metopaster hunteri* (= *Mitraster hunteri*).

The genera *Ravniaster* and *Mitraster* are identical with *Metopaster*, and *Lophidiaster* with *Astropecten*. *Recurvaster stevensensis* and *R. echinatus* are identical with *R. radiatus* (= *Metopaster tumidus* var. *radiatus*). *Pycinaster lamberti* is identical with *P. crassus*, *Chomataster brünnichi* with *C. acules*, *Ophiura fitchii* with *Ophiomusium subcylindricum*, *Ophiura parvisentis* with *O. serrata*, and, possibly, *Ophiomusium stephensoni* with *O. danica*.

The following species are new to science: *Recurvaster blackmorei*, *Chomataster spenceri*, *Chomataster wrighti*, *Ophiura? hagenowi*, *Ophiura? substriata* and *Asteronyx? ornatus*.



## Asteroidea.

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Asteroids are free-living, star-shaped, generally five-armed echinoderms, whose arms grade evenly into the disc. On the under surface of the arm is found an open groove, the ambulacral groove, into which the tube feet protrude.

### Anatomy and Ontogeny of the Asteroids.

---

Asteroids possess a skeleton composed of calcareous ossicles. Such an ossicle is laid down as a very small needle which gradually grows and branches, producing a plate which is seen under the microscope to consist of a fine network. Each element of the skeleton constitutes an individual unit from the beginning. Only exceptionally can a skeletal element be produced by the fusion of several others.

The actual skeleton can be made up of several thousand ossicles. Above the ambulacral groove are found the ambulacral ossicles. These ossicles are arranged in two series and the series touch one another over the ambulacral groove. They meet the adambulacral ossicles below, and these form a complete series along each side of the ambulacral groove. There are just as many ambulacral as adambulacral ossicles, and in the majority of asteroids they alternate. The peristome is formed of specially developed innermost ambulacral and adambulacral ossicles, together with interradial ossicles. In a five-armed starfish the peristome is composed of ten adambulacral ossicles ( $ad_1$ ), twenty ambulacral ossicles (the fused  $a_1 + a_2$ ) and five inter-radial ossicles.

An unpaired terminal ossicle is found at the actual apex of the arm. The margin of the body is formed of a series of superomarginal and a series of inferomarginal ossicles. In some forms (*Spinulosa*, *Forcipulata*) these ossicles are reduced, while in others (*Paxillosa*, *Valvata*) they are well developed, and form a distinct margin. In the latter, the supero- and inferomarginals normally touch one another, and are generally opposite, more rarely alternate. There are just as many supero- as inferomarginals. The recent genera *Pentagonaster* and



*Tosia* together with the Cretaceous genus *Metopaster* are, however, exceptional. In these the ultimate superomarginal is large and in contact with several inferomarginals.

By the length of a marginal is usually understood its extension in the direction of the margin. The height is the extension at right angles to the contact surface between supero- and inferomarginals, and the breadth is the direction at right angles to the other two dimensions. This terminology is in agreement with the use of corresponding terms for the margin and the arm as a whole, and is stressed here because it can be tempting to employ the terms otherwise when only single ossicles are concerned, as a few palaeontologists have actually done. The direction of the arm is correspondingly the length direction of the ambulacral ossicles.

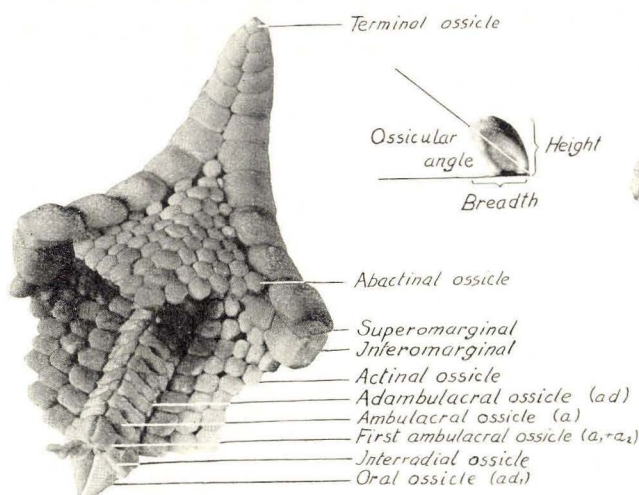


Figure 1.

*Recurvaster radiatus*. Reconstructed arm and median superomarginal of Individual 14.  $\times 1$ .



Figure 2.

*Recurvaster radiatus*. Ossicles from one individual. White Chalk, Stevns Cliff.  $\times 1$ .

On the actinal surface of the disc, apart from the ossicles already mentioned, are found small superficial ossicles, actinal ossicles, which cover the remainder of the actinal surface.

The abactinal surface is similarly covered by small superficial ossicles, the abactinal ossicles. There are eleven primary abactinal ossicles which are established before the remainder, and these may differ by being larger. In the centre lies the centrale, and a primary ossicle occurs in each radius and inter-radius. Secondary ossicles are often developed in the adult, both within and without the primary ossicles. These primary and secondary ossicles often form distinct radial series.

The madreporite occurs either as a specially developed inter-radial primary actinal ossicle, or as an independent ossicle distal to this.

In some species the abactinal ossicles form a close mosaic, while in others there are small areas of skin, papulae, among the ossicles. Supplementary ossicles, which unite the abactinal ossicles into a network, occur. The abactinal ossicles can be flat, polygonal plates, or they can have the form of tall columns with hair-like spines on the upper surface giving them a brush-like appearance. These are called paxillae.

External appendages in the form of pedicellariae and spines (often in the form of setae) are attached to the asteroid skeleton. Pedicellariae are only seen in fossil forms when they are attached in pits in the surface of an ossicle.

Most asteroids have a complete metamorphosis, and possess a ciliated, pelagic larval stage without definite skeleton. The first ossicles are laid down during metamorphosis, and a small starfish possessing the first two pairs of ambulacral ossicles, some or all of the primary actinal ossicles together with the terminal ossicles, is produced. Ambulacral, adambulacral and marginal ossicles are thereafter laid down at the tip of the arm proximal to the terminal ossicle, so that the youngest ossicles are always next the terminal. At the same time as new ossicles are formed, the previously formed ones increase in size and their appearance can be somewhat changed. The height of the ossicle often increases in proportion of the breadth, which is best expressed as an increase of the ossicular angle (text fig. 1.). The ossicles of the margin and ambulacral system are often numbered in accordance with their age sequence. In the adult individual of those species of asteroids which only possess a small number of marginals in the arm, this number seems to be constant or nearly constant. This is so in the genera *Metopaster* and possibly *Recurvaster* from Cretaceous deposits.

That change in appearance which occurs in the course of the growth of an asteroid from a small individual with only a few ossicles to the fully grown starfish is often very marked, and it has happened in several cases that zoologists have established several different species belonging to different genera on the basis of individuals which have later been shown to be only growth stages of one species (I. LIEBERKIND, 1935).

The size of an individual is given by the distance from the centre of the disc to the apex of an arm ( $R$ ), and to the margin between two arms ( $r$ ); i. e. by the lengths of the radius and inter-radius.



## Historical.

Occurrences of asteroids in Cretaceous deposits are not uncommon, but the material is difficult to work with as most often only dissociated ossicles, which only give a very uncertain impression of the animal's appearance, are found. The literature concerning these organisms is consequently rather slight.

That work which has had the greatest importance for our knowledge of the Cretaceous asteroids is SLADEN & SPENCER's great monograph, which was published during the years 1891—1908.

In 1913 SPENCER published an investigation of the evolution of the Cretaceous asteroids. In this are included brief descriptions of new forms, among which are a number from the Senonian and Danian of Denmark and Sweden. The material is arranged in series within which parallel evolution appears to have taken place. An increase in marginal height, and a change in ornamentation of the marginals from setae through rugosity to a smooth surface is found. This scheme of the evolution seems, however, only to reflect the coarsest features of its course, and there are several divergences.

A series of works on Cretaceous asteroids inspired by SLADEN & SPENCER's monograph, and SPENCER's investigation of asteroid evolution, appeared in the following years. Especial attention must here be drawn to VALETTE's works of 1902, 1915 and 1925, the last of which also includes Tertiary forms. A monograph of the Mesozoic Asteroids from the Paris Basin by MERCIER appeared in 1935. C. W. & E. V. WRIGHT, in England, have continued the study of Cretaceous asteroids; in 1940 they published their investigation of a series of new finds. A number of faunal lists, which have relied upon the English monographs, have appeared in Denmark (RAVN 1918, ROSENKRANTZ 1920, JESSEN & ØDUM 1923, ØDUM 1926 and K. BRÜNNICH NIELSEN 1917, 1919, 1926 and 1937). Finally in 1943 came the posthumous publication of K. BRÜNNICH NIELSEN's monograph of the Asteroids in the Senonian and Danian of Denmark. In 1945 the author published his investigation of some Danian asteroids.

Only a few investigations of the fossil representatives of the present animal group have been published in extra-European countries, and there is only reason here to mention two works. In 1876 GABB, described an asteroid from the Vincentown limesand in New Jersey, and this particular form seems also to be represented in the Danish Danian. LORIOLO published an investigation of Senonian asteroids from Egypt in 1909. In this he mentions a species which BR. NIELSEN compares with the genus "*Ravniaster*", but which FORTEAU (1914) has used as the basis of a separate genus, *Spenceria*.



## Material.

The compact asteroid skeleton is particularly well suited for preservation in rocks, just as is the case with the remains of other echinoderms. Since the classification is based upon skeletal features, it would be reasonable to attach considerable value to these fossils. There are, however, several factors which make work with them difficult. The marked change in appearance which can occur during the growth of an individual has been described in the previous section; this feature seems not to have been taken sufficiently into consideration in the treatment of fossil material. Another condition which makes the study more difficult is that the skeletal parts are not firmly connected together. Asteroid skeletons with the ossicles in their natural positions have thus only been found at a few favourable localities, and only very few occurrences of this character are known from the Danish Cretaceous deposits. In the Danish White Chalk (Senonian), on the other hand, there are a number of instances where the skeletal parts of a single individual have been found together, but where the ossicles have been more or less displaced. By comparison with related forms, and patient "jig-saw puzzling" it is possible to reconstruct the original appearance of the animal from such material (text figs. 1—2).

K. BRÜNNICH NIELSEN mentions in his monograph eleven occurrences from the White Chalk, and two from the Danian where several ossicles from a single individual were found together. By examination of the collections of the Mineralogical Museum, and the Geological Survey of Denmark, the presence of the remains of fifteen more individuals has been determined. In his collection of new material the author has been particularly interested in obtaining such associated remains. He has therefore concentrated his collecting on a single locality where such fossil occurrences seem to be most common, this is the northerly part of Stevns Cliff, north of Kulsti Rende, where the associated remains of about forty additional individuals have now been found. Associated remains of ten individuals have also been found on Mön Cliff. These specimens have been found because the individuals have been exposed in the profile either by weathering, or by cliff fall. A number of ossicles have also been lost for the same reasons, but all the same, the material has given considerable new information concerning the Danish asteroid fauna. Single asteroid ossicles are of much more frequent occurrence, and in many cases they are very characteristic. It is, however, generally only possible certainly to determine them if one is acquainted with the appearance and variation of the species from specimens from the same zone.

Numerous occurrences of single asteroid ossicles are known from the Danian. Knowledge of the Danian asteroid fauna is nevertheless scanty, because we have only the associated remains of six individuals.

It is worth stressing that the specimens include individuals of all ages, and that the actual size of the individual is without taxonomic importance. In some cases one finds a fossil species only represented by large, fully-grown individuals. VOIGT writes (1929 p. 121), "Die für die Erklärung der Feursteinbänder von Deecke und Klähn vertretene Hypothese eines jedesmaligen Absterbens der Fauna kann schon aus dem Grunde nicht zutreffen, da z. B. halberwachsene Echinocoryten und Gryphaeen auf Rügen kaum vorkommen. Ein Massensterben müsste seinen Ausdruck in der Fauna durch Exemplare aller Altersstadien finden". It is, however, by no means all animals that die of old age. W. K. SPENCER also writes (1913, p. 114), "The ossicles from Maestricht include numerous terminal superomarginalia, and these show clearly variations in height corresponding to those of the median series.... These variations may to some extent correspond to the age at which individual Asteroids perished...".

One find from the White Chalk of Stevns Cliff, north of Kulsti Rende deserves particular mention. Apart from the finds of individuals and single ossicles which have been made here, one mass of ossicles has been found representing several species, and individuals. An investigation of these ossicles gave the following data:

<i>Metopaster poulsenii</i> (young stage).....	89	ossicles
<i>Metopaster laevis</i> (at least three individuals) .....	178	—
<i>Metopaster undulatus</i> .....	40	—
<i>Recurvaster radiatus</i> (distal ossicles of small individuals) .....	71	—
<i>Recurvaster</i> and <i>Metopaster</i> , various ossicles .....	235	—
<i>Chomataster wrighti</i> .....	232	—
<i>Astropecten? pygmaeus</i> .....	7	—
Indeterminable, mostly damaged, ossicles.....	110	—
Total.....	962	ossicles

A similar occurrence is mentioned by WRIGHT (1940, p. 233). They describe their find as "... a large number of ossicles of ten species of asteroids, forming, almost certainly, a pellet of indigestible parts ejected by a starfish-eating fish or other animal." It is obvious that the particular starfish-eating animal at Stevns has not chosen its food at random, but has exclusively taken small individuals. None of the large ossicles from adults of *Metopaster* or *Recurvaster*, which are otherwise common at the locality, was present in this pellet.

A similar, but smaller assemblage of ossicles has been found in the Danian of Jutland. (p. 75).

## Palaeontology.

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As the classification of the Asteroidea is based mainly on skeletal characters, and as these can easily be observed in fossil specimens, it is possible to arrange fossil asteroids in genera and species according to the principles which are applied to recent forms. The insufficiency of the material constitutes, however, an important difficulty. In the case of several species only a single individual, or a few ossicles are all that is known. Representatives of only a few recent genera are known from the Cretaceous. It is, however, possible that by the investigation of new material, and by comparison with recent species one will be able to refer some of the fossil species to genera which are known from the present day.

That ten species should be represented among the eleven individuals which BR. NIELSEN mentions from the Danish White Chalk, eight being from Stevns Cliff, is both striking, and suspicious. If one examines the marine bottom fauna of a restricted area at the present day one always finds that there are a few species which dominate as far as numbers are concerned; these species being represented by many individuals. If one looks through the results of the Challenger Expedition (SLADEN 1889) one will see that there the asteroid fauna only reaches ten species at a single station, while at the majority of stations from one to six species were found.

The 78 Senonian individuals now known from Denmark comprise 12 species, the two dominating species being represented by 28 and 17 individuals. The new finds indicate that several of the "species" formerly described from Denmark are merely individuals of varying size, and ornament within a single species. Thus the revision of the species gives the fauna a more natural character.



## Order Valvata PERRIER.

### Family Goniasteridae FORBES.

Genus **Metopaster** SLADEN 1893.

Synonym: *Mitraster* SLADEN 1893.

*Ravniaster* BR. NIELSEN 1943.

**Diagnosis.**—Asteroids whose body is pentagonal, limited by straight or slightly concave sides. Margin formed by a small number of large supero- and inferomarginals which are provided with a depressed border covered by a number of rows of delicate, closely placed setae. Within the border the ossicle is smooth or provided with scattered setae. In adults the ultimate superomarginal is the largest of all the ossicles; it contacts several inferomarginals of distally decreasing size. The abactinal surface is covered by large more or less rounded ossicles whose surface is smooth, or provided with granules or delicate setae. The adambulacral ossicles are provided with from four to eight marginal spines. Tall bivalved pedicellariae are often present on the marginals.

**Genotype.**—*Metopaster parkinsoni* (FORBES). Senonian.

**Historical.**—The genus *Metopaster* was established by SLADEN in 1893 for Cretaceous asteroids close to the recent genera *Pentagonaster* and *Tosia*. He writes, concerning the relation of the genus to *Pentagonaster* (including *Tosia*), page 31, "*Metopaster* differs from *Pentagonaster* by the large ultimate paired supero-marginal plates, by the comparatively small number of supero-marginal plates, which are also fewer in number than the infero-marginal series, and by the character of the ornamentation of the marginal plates of both series".

An examination of the genotypes, of *Pentagonaster* as well as *Tosia*, shows, however, that these genera agree very closely with *Metopaster*, particularly in those characters which SLADEN stated should separate them. That SLADEN found differences must be because the genus *Pentagonaster* formerly had a wider definition than now, including genera such as *Ceramaster* and *Plinthaster*.

**Affinity with *Pentagonaster* and *Tosia*.**—These two genera were established by GRAY in 1840, and include a few species from Australia and New Zealand. The genotypes are *P. pulchellus* GRAY, and *T. australis* GRAY. These two genera are very close to one another, and should perhaps be regarded as a single genus (FISHER 1911, p. 166; LIVINGSTONE 1932, p. 375).

The outline in *Pentagonaster* and *Tosia* is pentagonal with straight or slightly concave sides, less commonly with strongly concave sides and projecting arms. Likewise in *Metopaster* the sides are straight or

slightly concave, but in a few cases (*M. spencerii*) the sides are strongly concave, and the arms projecting.

The margin in *Pentagonaster* and *Tosia* may be composed of as many as eight superomarginals in each side of an arm. In most species there are three or four superomarginals. The number is normally constant for the species. To each of the median superomarginals there is an inferomarginal of about the same size, but somewhat less swollen. There are several inferomarginals of distally diminishing size corresponding to the ultimate superomarginal. In *Metopaster* there are found from two to four superomarginals in each half arm. In this case also, the ultimate superomarginal is larger than the others, and corresponds to several inferomarginals. In *P. pulchellus* and several species of *Metopaster* the ultimate superomarginal of adults can attain an extremely large size. The most proximal of those inferomarginals which correspond to the ultimate superomarginal is often of the same size as the median inferomarginals, but in *P. pulchellus* and *M. carinatus* it is of about the same size as the corresponding superomarginal, and distal to it there are only one or two quite small inferomarginals. Secondary ossicles can sometimes occur between some of the marginals in these two species. In a few cases in these three genera there can be an extra superomarginal in one side of an arm, while at the same time the ultimate superomarginal is smaller than usual, as though the extra marginal has arisen by the division of a normal ultimate superomarginal.

The ornament of the marginals in *Pentagonaster* and *Tosia* is composed of a single row of closely placed setae which encircle the otherwise smooth ossicle. In *Metopaster* there is a border of several rows of closely placed setae, and the central area is covered by scattered setae attached in small pits. There can also be a slight granulation of the surface. In a single species (*M. uncatus*) there is only a granulation, and one species (*M. laevis*) has quite smooth ossicles.

The abactinal surface in *Pentagonaster*, *Tosia*, and *Metopaster* is covered with large, more or less rounded ossicles with a slightly stellate base. Their surface is in *Pentagonaster* and *Tosia* smooth or with only an extremely fine granulation, and is encircled by a single row of delicate setae. In most species of *Metopaster* the whole exposed surface of the abactinal plates is covered by a granulation, and there are small setae attached in pits. A single species (*M. laevis*) has quite smooth abactinal ossicles.

The actinal surface is covered by oblique polygonal ossicles which in *P. pulchellus* have a border possessing a single row of closely placed setae, while in *Tosia* they are wholly or partly covered by closely placed setae, the amount varying within the species. In *Metopaster* the whole surface is covered by closely placed setae.



The adambulacral ossicles bear a row of spines on the margin, and a parallel row on the actinal surface, together with smaller spines or setae on the abradial portion of the actinal surface. In *Pentagonaster* and *Tosia* there are only two spines on the margin, while there are from four to eight in *Metopaster*.

Pedicellariae, of a tall bivalved type, are commonly found attached in shallow furrows on the actinal ossicles of *Pentagonaster*, and on the marginals and a few other ossicles of *Metopaster*, whereas they seem to be wanting in the typical representatives of the genus *Tosia*.

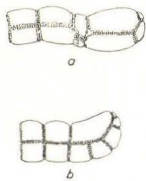


Figure 3.

Fig. 3. Lateral view of arm.  $\times 1$ .  
a. *Pentagonaster pulchellus*. b. *Tosia australis*.

Fig. 4. Impressions of pedicellariae.  $\times 5$ .  
a-b. *Pentagonaster pulchellus* (after Mortensen)  
c-d. *Metopaster tumidus*. e-g. *M. poulsenii*.  
h. *M. undulatus*. i. *M. kagstrupensis*.  
j. *M. spencerii* k. *M. elevatus*.

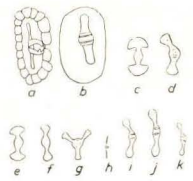


Figure 4.

**Affinity with *Ceramaster*.**—The recent genus *Ceramaster* differs from *Metopaster* in not possessing large ultimate superomarginals corresponding to several inferomarginals. Abactinal, actinal, and adambulacral ossicles agree with *Metopaster* both in appearance and ornament, and the same is true for the pedicellariae. The ornamentation of the marginals also corresponds in some cases to that in *Metopaster*.

**Conclusion.**—*Metopaster* seems thus to be quite close to the genera named, and it is doubtless their ancestral form. It seems to be distinguished from *Pentagonaster* and *Tosia* by the greater number of spines on the adambulacral ossicles, and by having several rows of closely placed setae on the depressed border of the marginals and on the abactinal ossicles. It seems to be distinguished from *Ceramaster* by the large ultimate superomarginal. But it is, however, possible that new discoveries will make it necessary to unite some of these genera.

**Young individuals of *Metopaster*.**—The two most obvious characters in *Metopaster* are the ornamentation, and the arm structure with the special development of the ultimate superomarginal. The latter characteristic is, however, only present in adult individuals. Young individuals of species of *Pentagonaster* and *Tosia* are not mentioned in the zoological literature. From our knowledge of asteroid ontogeny we know, however, that the very young *Metopaster*, just after metamorphosis, has only had a single ossicle, the terminal ossicle, in each arm. During growth the marginals are formed proximal to the terminal os-

sicle, and numbered in order of appearance. Small asteroids with only very few arm ossicles, and an ornamentation as in *Metopaster* have, however, been described as a genus, *Ravniaster*.

The formation of inferomarginals at the apex of the arm in *Metopaster* continues for a while after the full complement of superomarginals is formed, so that several small inferomarginals meet the ultimate superomarginal. This is the case in all those asteroids belonging to the genera *Mitraster*, *Metopaster*, *Tosia* and *Pentagonaster*. It is general that in the literature the number of inferomarginals corresponding to the ultimate superomarginal is stated. Examination of the fossil material confirms, however, that the number of inferomarginals bears a close relation to the size of the individual, and therefore undoubtedly also to its growth-stage. As long as the ultimate superomarginal has not reached the same size as the preceding superomarginals the animal will have a rounded outline like *Mitraster*. After growth has ceased the individual will have the ultimate superomarginal as the largest ossicle, and we have the typical adult *Metopaster* or *Pentagonaster*.

Fossil Material.—The new collection of asteroids which has been made from the Danish White Chalk shows with certainty that such an ontogeny as described above really has taken place. Those forms from the Danish White Chalk described as *Ravniaster* and *Metopaster* are connected by a complete series of transition forms: from small *Ravniaster*-like individuals through *Mitraster*-like forms to the adult *Metopaster*. The tumidity of the superomarginals increases during growth, as also does the height of the margin in relation to its breadth.

This ontogeny is best illustrated by the Senonian species *Metopaster poulsenii* and *Metopaster laevis*, but material has also been found which appears to represent the *Ravniaster*-stage of *Metopaster tumidus* and *M. kagstrupensis*. Individuals at the *Ravniaster*-stage have been found in the Cretaceous material from England and Denmark, and furthermore single ossicles in Sweden and France.

The genus *Mitraster*.—The ontogeny sketched above, and the investigation of the growth of *Metopaster poulsenii*, described in detail later, make it desirable more closely to consider the genera *Mitraster* and *Ravniaster*, and the species referred to them.

The genus *Mitraster* was established by SLADEN 1893 and is described thus (p. 57):

"Body depressed and cycloid, or cyclo-pentagonoid in contour. Marginal plates with co-ordinated granulose elevations and punctations, and a surrounding narrow depressed border with very minute punctations for the articulation of setae. Supero-marginal plates few in number and all subequal in size, forming a broad uniform border to the disk. Abactinal area covered with polygonal plates, some of which may have



stellate or substellate bases, and upon the tabulae are borne small, more or less co-ordinated granules. Infero-marginal plates more numerous than the supero-marginal series, and decreasing in size as they approach the extremity; the surface marked with punctations, which may be co-ordinated in a similar manner to that of those on the supero-marginal series, and may be associated with granulose elevations. Actinal intermediate plates small, polygonal, covered with uniform, crowded, shallow punctations, upon which granules were originally borne. Armature of the adambulacral plates arranged in longitudinal lines, which may be slightly oblique. Small entrenched pedicellariae may be present occasionally on the actinal intermediate plates".

It is clear from this description, and it is also stressed by SLADEN, that *Mitraster* agrees with *Metopaster* in nearly all its characters. This applies also to the ornamentation of the marginals with the depressed margin bearing small closely placed setae and with scattered setae on the central part, and also to the small number of marginals, and the characteristic feature that the ultimate superomarginal corresponds to several inferomarginals. The differences between the two genera are confined to: 1. In *Metopaster* the ultimate superomarginal is larger than the remaining marginals, while in *Mitraster* the size is about the same. 2. In *Metopaster* the body is limited by straight or slightly concave sides, while *Mitraster* is more rounded with slightly convex sides. 3. The marginals in *Mitraster* may bear a granulation as well as spine-pits with setae.

From our knowledge of ontogeny in *Metopaster* we know, however, that: 1. The ultimate superomarginal is largest only in fully grown individuals; in slightly younger individuals it is of about the same size as the other superomarginals. 2. The want of a large, and protruding ultimate superomarginal will give the not fully grown individual a more rounded appearance. 3. In *Metopaster poulsenii* it is seen that the marginals of young individuals of *Metopaster* may bear a granulation, as well as spine-pits.

Since the differences between these two genera thus agree exactly with the differences between a fully-grown and not quite fully-grown *Metopaster*, it is to be assumed that those asteroids described as species of *Mitraster* are really the young of species of *Metopaster*.

The following species have been classed in the genus *Mitraster*:

- Mitraster hunteri* (FORBES)
- Mitraster hunteri laevis* BR. NIELSEN
- Mitraster compactus* (FORBES)
- Mitraster rugatus* (FORBES)

An investigation of the specimens referred to these species has given the following result:

1. *Mitraster hunteri laevis* BR. NIELSEN. Well preserved individuals of this form have been found during the collecting of new material. As will be seen later it has shown itself to be a typical representative of the genus *Metopaster*, and not *Mitraster*.

2. *Mitraster compactus* (FORBES). In the diagnosis of this species SPENCER states (1905, p. 67) that the outline is slightly rounded pentagonal, but corrects this on the following page, where he writes, "The supero-marginal plates appear to have been straight and the inferior series but slightly cycloidal. This, together with the large comparative size of the ultimate paired plate, would bring the species very near to the genus *Metopaster*. FORBES remarked upon the fact that it appeared to be intermediate between *Goniaster* (*Metopaster*, SLADEN) *uncatus* and *Goniaster* (*Mitraster*, SLADEN) *rugatus*. I have therefore considerable doubt as to the validity of the separation of these two genera."

The body is straight-sided. There are four superomarginals in each side of the arm, the last being not quite as large as those preceding. The marginals have a depressed border within which they are smooth, or provided with a few spine-pits. This species is quite close to the genus *Metopaster*; its appearance and the number of marginals make it likely that it represents young individuals of *Metopaster parkinsoni* (FORBES).

3. *Mitraster hunteri* (FORBES). According to SLADEN (1893, p. 59) the body has a rounded pentagonal outline. An examination of the material shows that the sides have been straight or very slightly convex. There have been three superomarginals in each side of the arm, the ultimate superomarginal generally being of the same size as the others. The superomarginals are highest near the outer side of the ossicle, but there is here no such marked abactinal swelling as in *Metopaster uncatus*. The ornament of the marginals is composed of a depressed border and scattered spine-pits, together with a generally rather strong granulation on the abactinal part of the superomarginals.

*Mitraster hunteri* does not give the impression of being a young stage of an other species, and there are no species of *Metopaster* to which one reasonably can refer it. However, it does not seem to differ from *Metopaster*, and it would therefore not be reasonable to refer it to any genus other than *Metopaster*.

Some individuals with a distinctly narrower margin, and only two superomarginals on each side of the arm should, as SLADEN stated, be considered as a distinct species or variety (SLADEN 1893, p. 62, pl. 9, fig. 3.).

4. *Mitraster rugatus* (FORBES). The body has straight sides. There are three superomarginals in each side of the arm. The last of these is somewhat smaller than the others, and has a triangular outline, just as is the case in not fully-grown individuals. The abactinal and lateral sur-



faces are at right angles to one another, and are connected by a short curve. The ornament of the marginals is composed of a depressed border, and within this a strong granulation, and sometimes scattered spine-pits. SLADEN writes of this species (1893, p. 66), "Although at first sight the differences between *Mitraster Hunteri* and *Mitraster rugatus* appear well marked, I am not perfectly satisfied as to the species being altogether independent." After an investigation of the material, I find it likely that at least some of the individuals called *Mitraster rugatus* are young individuals of *Metopaster hunteri*. Other individuals whose superomarginals possess no spine-pits, and have a distinct abactinal swelling on the outer part of the ossicle are, in palaeontological collections, referred to *Mitraster rugatus*. These individuals are strongly reminiscent of *Metopaster uncatatus*, and *Metopaster cingulatus*. SLADEN (1893, p. 55) writes of *M. cingulatus*, "*Metopaster cingulatus* is readily distinguished from *Metopaster uncatatus* by its very short broad superomarginal plates, by their more limited and more conical tumidity, by their greater height as seen in the margin, as well as by their different ornamentation. The ultimate plates are triangular, and do not present the peculiar form characteristic of *Metopaster uncatatus*. In many respects *Metopaster cingulatus* appears to hold an intermediate position between *Mitraster rugatus* and *Metopaster uncatatus*." After an investigation of these forms there can be no doubt that a number of the individuals referred to *Mitraster rugatus*, together with *Metopaster cingulatus*, are young growth-stages of *Metopaster uncatatus*.

Conclusion. The result of the investigation of *Mitraster* is thus that *Mitraster rugatus* and *Mitraster compactus* may be supposed to be young individuals of species of *Metopaster*. The following series showing the ontogeny can be drawn up:

*Mitraster rugatus* → *Metopaster hunteri*  
 "Mitraster rugatus" → *Metopaster cingulatus* → *Metopaster uncatatus*  
*Mitraster compactus* → *Metopaster parkinsoni*

*M. hunteri laevis* is a typical *Metopaster*. *M. hunteri* is an independent species, which, however, does not differ from the genus *Metopaster* in such a way that it would be justified to maintain the genus *Mitraster*. It should therefore be called *Metopaster hunteri*, and in agreement with this, the name *Mitraster* is raised as a synonym for *Metopaster*.

The genus *Ravniaster*.—The genus *Ravniaster* was established by BR. NIELSEN in 1943 for small asteroids having very few marginals with an ornamentation as in *Metopaster*, and generally with equal numbers of supero- and inferomarginals. As already shown, it may be expected that asteroids with these characters really are young individuals of species of *Metopaster*. BR. NIELSEN described three

species of *Ravniaster* from the Senonian, and three from the Danian.

The Senonian species of *Ravniaster*. The abundant asteroid material from the White Chalk of Stevns Cliff, north of Kulsti Rende, shows that there is steady and continuous change in the size and appearance of the individuals. They range from very small forms which are like *Ravniaster virgineus*, through *Ravniaster simplex*, *Mitraster*-like individuals and *Metopaster poulsenii* to *Metopaster stevensensis*.

It does not seem possible to distinguish the smallest of the individuals from *Ravniaster virgineus*. But as that species has been established on the basis of a specimen from the White Chalk of Mön, where *Metopaster poulsenii* is not found, but where, on the other hand, the very similar *Metopaster tumidus* occurs, there is reason to believe that the individual described as *Ravniaster virgineus* is a young *Metopaster tumidus*. The individual described as *Ravniaster simplex* is without doubt a young example of that species which is here included under the name *Metopaster poulsenii* BR. NIELSEN.

There is also a perfectly uniform development from *Ravniaster laevis* to a *Metopaster* with smooth marginals, *Metopaster laevis*, of which BR. NIELSEN has described a marginal under the name *Mitraster hunteri* var. *laevis*.

The very youngest asteroid growth stages, where only one or two supero- and inferomarginals are present in each side of the arm, have not yet been found in the Danish White Chalk. They are, however, known from the Danian in Denmark (BR. NIELSEN, 1943, pl. 3, fig. 9.), and from the Senonian in England (pl. 3, fig. 9—10).

The Danian species of *Ravniaster*. BR. NIELSEN chose the Danian species *Ravniaster planus* as the genotype for *Ravniaster*. The material described of this species includes a very small individual, and marginals of a *Metopaster*-like type. The small individual ( $R = 2$  mm) is the smallest fossil individual known; it has only one supero- and one inferomarginal on each side of the arm, and there can be no doubt that it is a very young individual of a starfish probably a *Metopaster*. It is, however, not possible to make a species determination of such an individual, as this would require reference material representing all age-groups, and, furthermore, species characters are often only slightly developed in very young asteroids. This individual is thus of doubtful affinity, and therefore very unsuitable as a type. As BR. NIELSEN has not put forward any type for *Ravniaster planus* the author has chosen a pair of connected ossicles figured by BR. NIELSEN as the type. The ossicles described as *Ravniaster planus* are all ultimate superomarginals each of which meets two inferomarginals. They agree with *Metopaster*, both in the structure of the tip of the arm and in the ornamentation, which is made up of a depressed border and scattered spine-pits. Ac-



cording to BR. NIELSEN, *Ravniaster* should differ from *Metopaster* in two important characters, namely, 1. There are only one or two superomarginals in each side of the arm, and 2. The ultimate superomarginal corresponds to only one (or two) inferomarginal. Concerning the first of these characters, it is of importance that several species of *Metopaster*, with only two superomarginals in each side of the arm, are found, and we know nothing of the number of ossicles in *Ravniaster planus*. Concerning the other character, it is important that only in very young individuals are there normally equal numbers of supero- and inferomarginals, while in the genotype, *Ravniaster planus*, there are two, and perhaps sometimes three inferomarginals corresponding to the ultimate superomarginal.

Several other species, apart from *Ravniaster planus* have been described from the Danian, they are: *Ravniaster carinatus*, *R. maculatus* and *R. granulatus*. *R. carinatus* and *R. maculatus* have a structure very similar to that of *R. planus*. However, in most individuals of *R. carinatus* there is one large inferomarginal corresponding to the ultimate superomarginal. *R. granulatus* is a divergent form, and presumably belongs to the genus *Ceramaster*.

Conclusion. The result of the investigation of *Ravniaster* is that the genotype, *Ravniaster planus*, is a species with the same arm-structure and ornament of the marginals as *Metopaster*, but with an unknown number of marginals. *Ravniaster carinatus* and *R. maculatus* are species of similar appearance. These species are therefore referred to the genus *Metopaster*. All the individuals of *Ravniaster* described from the White Chalk, together with one from the Danian, referred to *Ravniaster planus*, are young individuals of species of *Metopaster*.

Occurrence.—*Metopaster* is represented by a large number of species in the Cretaceous, and a single Tertiary marginal has also been referred to the genus. It is so close to some recent genera that it is likely that further investigation will either show that it is represented at the present time, or that it is identical with recent genera.

#### ***Metopaster cf. thoracifer* (GEINITZ).**

Plate 3, fig 18. Text fig. 5.

1918 *Metopaster parkinsoni* (FORBES), RAVN, p. 18.

Material.—A badly preserved starfish individual, and an isolated marginal from the Turonian Arnager-limestone in Denmark were determined by SPENCER as *Metopaster parkinsoni*, and mentioned by RAVN in 1918.

The individual is very worn and damaged by having been rolled

on the beach. The author has later found an other individual at the same locality; this is similarly badly preserved, and it is partly in-rolled. It is, however, possible on both individuals to measure both the length, and curvature of the sides, and the length, breadth and height of the



Figure 5.

*Metopaster* cf. *thoracifer*.  $\times 1$ .

marginals, so that it is possible to reconstruct the original appearance of the animal. On the other hand, the ultimate superomarginals and a number of the other marginals in both individuals are so damaged that their surface can not be observed. The single marginal found in the Arnager limestone is, however, a well preserved ultimate superomarginal, and it can thus supplement our knowledge of the form.

Collection of the Mineralogical Museum.

**Description.**—The outline is pentagonal, with only slightly concave sides. In individual no. 1 R:r as c. 24:19 mm., and in individual no. 2 as c. 18:14 mm. There are only two superomarginals in each side of the arm. The first (or median) superomarginal has about the same length as breadth; it is not very tall. The surface is even and slightly tumid. The second, or ultimate superomarginal is markedly longer, but of the same height. The distal half of this ossicle has met the corresponding ossicle of the other side of the arm in the mid-line. The ossicle has furthermore been in contact with three or four inferomarginals, as well as the small unpaired terminal. Inferomarginal no. 1 is of the same size, or slightly larger than the corresponding superomarginal. Ossicle no. 2 is of the same size, and has been in contact with a long facet on the underside of the ultimate superomarginal. Ossicles no. 3, 4 and 5 are small and oblique, they have contacted small facets on the distal part of the ultimate superomarginal. The outer surface of the marginals is provided with a narrow depressed border which has borne delicate, closely-placed setae. The central area is provided with scattered, well-separated, round spine-pits. The margin of the superomarginals is strongly depressed. In the well preserved ultimate superomarginal, the junction between the abactinal, and lateral parts of the ossicle is rounded in the proximal part of the arm, but sharper towards the distal apex, where it forms a slight protuberance.

**Affinity with species of *Metopaster*.**—The present form differs from *M. parkinsoni* in having only two superomarginals instead of four in each side of the arm. It also differs from *M. parkinsoni* in that superomarginal no. 1 has about the same breadth as length, in the strongly depressed border, and in the tendency to form a protuberance on the ultimate superomarginal. Only two species of *Metopaster* with



only two superomarginals in each side of the arm are known, they are *M. thoracifer*, and an undescribed species which has been referred by SLADEN (1893, p. 62) to *Metopaster hunteri* on the basis of the characteristic form, and granulation of the ossicle, and by WRIGHT (1940, p. 237) to *M. quadratus* because of the shape and abactinal swelling of the superomarginals. The present form is strongly reminiscent of *M. thoracifer*, not only in the number and height of the ossicles, but also in the strongly depressed border of the superomarginals; the length, and tendency of the ultimate superomarginal to form a protuberance together with the size of inferomarginal no. 2. The reason for my not feeling fully justified in referring it to this species is that typically developed powerful protuberances, such as are found on the greater part of the ultimate superomarginals of this species, are wanting. It is, however, apparent from the descriptions, and from the collections in the Sedgwick Museum, that this character can be wanting. The species *Stellaster plauensis*, described by GEINITZ (1871) is interpreted by LEHNER (1937, p. 173) as such individuals of *M. thoracifer* without horns; this does not, however, seem to agree with the shape of the marginals.

Occurrence.—*Metopaster thoracifer* is previously known from Cenomanian to Lower Turonian. The present occurrence is from the Upper Turonian. Arnager, Denmark.

### ***Metopaster poulsenii* BR. NIELSEN.**

Plate 1 and 2. Plate 3, fig. 1-8. Text fig. 4 e-g.

1943 *Metopaster poulsenii* BR. NIELSEN, p. 27, pl. 1, fig. 2-9.

1943 *Metopaster stevensensis* BR. NIELSEN, p. 30, pl. 1, fig. 10.

pars 1943 *Mitraster hunteri* SPENCER var. *lævis* BR. NIELSEN, p. 38.

1943 *Ravniaster simplex* BR. NIELSEN, p. 46, pl. 3, fig. 1-2.

Diagnosis.—A *Metopaster* with three superomarginals in each side of the arm; these ossicles are strongly tumid. The ornamentation is that typical of the genus, but a weak granulation often occurs, particularly in younger individuals. The median supero- and inferomarginals are all of about the same height.

Type.—The holotype is the individual described by K. BRÜNNICH NIELSEN, 1943 pp. 27-28, pl. 1, fig. 2-8. It originates from the Upper Senonian White Chalk of Stevns Cliff, north of Kulsti. Collection of the Mineralogical Museum.

Description.—The body is pentagonal with straight, or almost straight sides. The margin is formed of large, powerful marginals. In the adult there are three superomarginals in each side of the arm. The



number of inferomarginals is greater, as several (up to six) inferomarginals of distally decreasing size correspond to the ultimate superomarginal. The superomarginals have a swelling of the central abactinal area. The marginals have a depressed border with small, closely-placed setae, and within the border scattered, somewhat larger setae attached in pits in the surface. The superomarginals—particularly in their abactinal part—can also bear a granulation; this is most often the case in young individuals. In the adult *Metopaster poulsenii* the length, breadth and height of the median superomarginals are about the same; the ossicle no. 2 is, however, often slightly shorter, and slightly oblique. The median inferomarginals have about the same dimensions. The inferomarginals are slightly oblique, and their size decreases evenly towards the tip of the arm. BR. NIELSEN states as a species characteristic of *Metopaster poulsenii* that the ultimate superomarginal is smaller than the other superomarginals. As has been mentioned above, however, this will be the case with every starfish at a certain stage of growth. These phenomena will be further illustrated during the examination of the separate individuals. The superomarginals have a large surface directed towards the body cavity, and abactinally to this a surface which has been in contact with the ossicles of the abactinal surface. This latter surface has no great height, being much lower than in the very similar ossicles of *Recurvaster radiatus*. The terminal ossicle is very small; it is almost pyramidal with a furrow on the actinal surface in continuation of the ambulacral groove. It has borne two oblique facets which have been in contact with the two ultimate superomarginals, and it has not possessed spines or setae.

The abactinal surface has been covered by low, prismatic, generally hexagonal ossicles. The free abactinal surface bears a strong granulation, and in some cases also spine-pits. The sides of the ossicle are concave, and the corners of the base are slightly drawn out. The primary abactinal ossicles are very large.

The actinal surface is covered by low, oblique, polygonal ossicles, whose free surface bears large well separated spine-pits.

The adambulacral ossicles have borne a row of five or six spines on the edge, and three rows on the surface.

The ambulacral ossicles are large and slightly curved. The impressions of pedicellariae are seen on the marginals of a number of individuals. They are composed of small circular depressions from which two or three short furrows originate, each ending in a new circular depression.

Affinity with other species.—*Metopaster poulsenii*, with its markedly tumid marginals is reminiscent of *M. tumidus* from the Senonian, and *M. kagstrupensis* from the Danian.

It seems to differ from *M. tumidus* in having only three superomarginals in each side of the arm; in that the margin in *M. tumidus* is relatively higher, and narrower, and in that the ossicular angle is larger.

WRIGHT (1940, p. 236, pl. 13, fig. 13, pl. 16, fig. 6) mention a reconstructed individual of a *Metopaster*, which they interpret as an early form of *M. tumidus*. The individual is reconstructed with three superomarginals on each side of the arm, and it is very similar to *M. poulsenii*, but at the present it is not possible to say anything concerning this similarity, or the correctness of the reconstruction.

*M. kagstrupensis* has the same number of marginals as *M. poulsenii* and the difference between the two species is extremely slight. It seems, however, to be possible to separate them, since in *M. kagstrupensis* the ossicular angle is larger, the marginals shorter and the inferomarginals distinctly higher than the superomarginals. Furthermore, the lateral surface of the ultimate superomarginals is as a rule slightly concave in *M. kagstrupensis*, and the arm tip therefore slightly projecting.

**Material.**—In order to illustrate the ontogeny of the species, and its variation, a number of the specimens which may be referred to this species are now mentioned in greater detail. The individuals are arranged according to their size (R).

All the specimens are in the collection of the Mineralogical Museum.

1. Remains of a very small individual in White Chalk, with a number of the ossicles in their natural relative positions. R:r as c. 8:6 mm. Ossicular angle c. 20°. A very small wedge-shaped third superomarginal is found apart from two supero- and inferomarginals on each side of the arm. There has perhaps also been a newly formed third inferomarginal present. The first two marginals correspond exactly in appearance with the individual described as *Ravniaster virgineus*. This comes, however, from a locality where *Metopaster poulsenii* is unknown, but where, on the other hand, the very similar *M. tumidus* occurs, and it is therefore reasonable to assume that the individual described as *R. virgineus* is a young *M. tumidus*. The marginals have the usual narrow depressed border. The superomarginals bear a granulation; the inferomarginals are smooth. The surface of the abactinal ossicles has a distinct granulation.

Pl. 1, fig. 1. Pl. 2, fig. 3a. Pl. 3, fig. 1a, 3a, 4a, 5a and 7. Upper Senonian. Stevns Cliff, north of Kulsti Rende.

2. Associated ossicles of an individual described by BR. NIELSEN as *Ravniaster simplex*. R:r as c. 9:7 mm. Ossicular angle c. 20°. This individual is somewhat larger than the previous, and the margin is broader. Only the first and second marginals are preserved, and



the individual thereby gets a robust and rounded appearance. That there has also been a third supero- and inferomarginal in each side of the arm is shown by the large distal facet on superomarginal no. 2. Ornamentation is as in the preceding individual. BR. NIELSEN states that there is no distinction between the border and the central area, but a closer examination shows, however, that a small depressed border can be seen, although it is only distinct at a few places on the small ossicles.

Pl. 1, fig. 2. Pl. 2, fig. 3b.

Upper Senonian, Stevns Cliff, Eskelund.

3. Remains of a slightly larger individual than the preceding. Four marginals forming the tip of the arm were found in their natural relative positions, while the remaining ossicles were dislocated. R:r as c. 10·5:8 mm. Ossicular angle c. 20°. The first two superomarginals are of practically the same shape as in the preceding individual, but in this case the small third superomarginal is also preserved. Just as in the preceding individuals, there have been just as many superomarginals as inferomarginals, and the individual has similarly been a typical "*Ravniaster*". The marginals have a distinct depressed border. The superomarginals bear a strong granulation on the abactinal part of the outer surface, but there are, furthermore, scattered spine-pits on both the supero- and inferomarginals.

Pl. 1, fig. 3. Pl. 2, fig. 3c. Pl. 3, fig. 8.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

4. A few associated marginals from an individual of the same size and appearance as the preceding. Upper Senonian. Stevns Cliff, Eskelund.
5. Remains of an individual. R:r as c. 15:12 mm. Ossicular angle c. 27°. This individual does not at first sight differ from the previous. It is slightly larger, and the spine-pits are more prominent. Only a slight granulation can be discerned on the abactinal part of the superomarginals, but otherwise the shape and appearance of the individual ossicles is very nearly the same. The third, or ultimate superomarginal is slightly smaller than the others. There is, however, one distinctive feature: the ultimate superomarginal meets not one, but two inferomarginals, and therefore has two facets on its actinal surface. It must therefore be considered as a *Metopaster*, or rather, as a "*Mitraster*", since individuals of *Metopaster*-type, but with small ultimate superomarginals, and often bearing a granulation on the superomarginals, are sometimes referred to this particular genus. A revision of the collection left by Dr. BR. NIELSEN shows that it was median supero-



marginals of the type found in this, and preceding individuals, which, together with smooth ultimate superomarginals, formed the basis for the variety *Mitraster hunteri* var. *laevis*, which will be referred to in the following.

Pl. 1, fig. 4. Pl. 2, fig. 3d.

Upper Senonian, Stevns Cliff, north of Kulsti Rende.

6. Two superomarginals found together in the White Chalk. R:r as c. 20:16 mm. Ossicular angle c.  $22^\circ$ . The ultimate superomarginal is of about the same size as the median marginals; it has contacted three inferomarginals. Spine-pits are dominant, but there is also a well developed granulation on the abactinal part of the outer surface.

Pl. 1, fig. 5.

Upper Senonian, Stevns Cliff, north of Kulsti Rende.

7. Remains of an individual described by BR. NIELSEN (1943, pl. 1, fig. 9.) as *Metopaster poulsenii*, R:r as 26:20 mm. Ossicular angle c.  $25^\circ$ . The ultimate superomarginal is similar in size to the median marginals; it has contacted four inferomarginals. The ornamentation consists of spine-pits; there is no apparent granulation. There are a few abactinal ossicles present; they have a strongly granulated surface, without spine-pits. The actinal ossicles possess large spine-pits.

Pl. 1, fig. 6. Pl. 2, fig. 3e.

Upper Senonian, Stevns Cliff, north of the lighthouse.

8. Remains of an individual slightly larger than the previous. R:r as c. 27:22 mm. Ossicular angle c.  $28^\circ$ . The ultimate superomarginal is similar in size to the median marginals; it has contacted four inferomarginals. Apart from spine-pits, there are granules present on the abactinal part of the superomarginals. The abactinal ossicles are strongly granulated, and some of them are also provided with distinct spine-pits. The actinal ossicles possess spine-pits.

Pl. 1, fig. 7. Pl. 2, fig. 3f. Pl. 3, fig. 1b, 2a, 3b, 4b, 5b.

Upper Senonian, Stevns Cliff, north of Kulsti Rende.

9. Remains of an individual of the same size as the previous. Ossicular angle c.  $32^\circ$ . Spine-pits are dominant, but there is also a granulation of the abactinal part of the superomarginals. The ultimate superomarginal has corresponded to four smaller inferomarginals. Upper Senonian, Stevns Cliff, north of Kulsti Rende.
10. Remains of an individual, R:r as c. 35:27 mm. Ossicular angle c.  $35^\circ$ . On this individual the ornamentation of the marginals consists exclusively of spine-pits, there being no granulation. The ultimate superomarginals of two arms show a divergence in shape.

In the tip of one arm the ultimate superomarginal is distinctly smaller on the one side than on the other. In another arm tip the ultimate superomarginal is divided into a larger, proximal, and a smaller, distal ossicle, which together correspond to the ultimate superomarginal on the opposite side of the arm. Such abnormalities, which SPENCER called a "breaking-down" of the ultimate superomarginal, are a not uncommon variation in species of the genera *Metopaster*, *Tosia* and *Pentagonaster*.

The individual has been reconstructed (Pl. 1, fig. 8) with equal numbers of ossicles on each side of the arm, and it is not quite regularly pentagonal. It is not unlikely that that arm side which has a very short ultimate superomarginal has had an extra superomarginal. The abactinal ossicles are provided with spine-pits, and a strong granulation; the actinal ossicles bear spine-pits.

Pl. 1, fig. 8. Pl. 2, fig. 3g. Pl. 3, fig. 1c, 3c, 5c.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

11. Holotype. Remains of an individual described by BR. NIELSEN (1943, pl. 1, fig. 2—8) as *Metopaster poulsenii*. R:r as c. 35:29 mm. Ossicular angle c. 37°. The ultimate superomarginal is very short, and the size of the animal (R) is thus small as compared with the size of the marginals, which are heigher than in the following individual. Just as in the previous individual, one arm shows a divergence, in that the ultimate superomarginals of the two sides of the arm are not equally large. The ultimate superomarginals have contacted four inferomarginals. The ornament consists of spine-pits. The abactinal ossicles have a strong granulation and a few spine-pits; the actinal ossicles have spine-pits in the surface.

Pl. 1, fig. 9. Pl. 2, fig. 3h.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

12. Connected remains of an individual, with the ossicles in their natural relative positions in the White Chalk. R:r as c. 40:33 mm. Ossicular angle c. 40°. The superomarginals are all of about the same size, but the ultimate superomarginal is, however, the largest. It has been in contact with five inferomarginals. The ornamentation consists of a distinct granulation on the abactinal part of the superomarginals, as well as the general presence of spine-pits. The abactinal ossicles bear both spine-pits and a strong granulation; the actinal ossicles bear only spine-pits.

Pl. 2, fig. 1, 3i. Pl. 3, fig. 1d, 2b, 3d, 4c, 5d, 6.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

13. Connected remains of an individual. R:r as c. 55:45 mm. Ossicular angle c. 50°. The ultimate superomarginal in this individual is the largest of the marginals. It has a marked abactinal swelling,



just like the other superomarginals, and has been in contact with six inferomarginals. The shape does not differ importantly from the corresponding ossicle in the previous individual, but corresponds at the same time exactly with that single ultimate superomarginal which BR. NIELSEN described as *Metopaster stevensensis*. The ornamentation is composed of spine-pits.

Pl. 2, fig. 2, 3j.

Upper Senonian, Stevns Cliff, north of Kulsti Rende.

Growth in *M. poulsenii*.—The above account of the most important, and best preserved individuals referred to *M. poulsenii* shows that when these individuals are arranged according to size they form a perfectly continuous series. Both the height of the margin, and the ossicular angle increase during growth. The superomarginals of the smallest individuals possess a dominant granular ornament, but during growth spine-pits gradually become dominant. All transitions, from a powerful granulation of the abactinal surface of the superomarginals, through forms where the granulation can only be seen on a few of the ossicles when the lighting is favourable, to individuals where no granulation can be detected, are found among individuals of intermediate size.

The smallest individuals found of this species, have two normal, and a small, wedge-shaped third superomarginal in each side of the arm. The size of marginal no. 3 increases during growth, so that it becomes the largest of all. Although there are no more than three superomarginals on each side of the arm, the formation of small inferomarginals proximal to the terminal ossicle continues. When the third superomarginal approaches the median marginals in size, it corresponds to two inferomarginals (pl. 1, fig. 4). During the course of growth the number is increased so that in the largest individual found (pl. 2, fig. 2.) there are six inferomarginals corresponding to an ultimate superomarginal.

Those stages which *M. poulsenii* thus passes through during growth have previously been described as independent species, namely, *Ravnaster simplex*, *Mitraster hunteri* var. *laevis* (pars), *Metopaster poulsenii* and *Metopaster stevensensis*. The youngest stages of this species, with only one or two upper and lower marginals in each side of the arm, have so far not been found.

Occurrence.—Upper Senonian, Upper Maastrichtian, Stevns Cliff, Denmark.



**Metopaster tumidus** SPENCER.

Plate 4, fig. 1-5. Text fig. 4c-d.

- 1913 *Metopaster tumidus* SPENCER, p. 113, pl. 10, fig. 8, 15.  
 Pl. 14, fig. 1, 2. Pl. 15, fig. 1, 2, 4, 6, 7.  
 non pl. 15. fig. 3, 5.
- 1925 *Metopaster tumidus*, UMBGROVE, p. 207, fig. 1-27.
- 1935 *Metopaster tumidus*, MERCIER, p. 30, pl. 1, fig. 17 a-f.
- ? 1940 *Metopaster tumidus*, WRIGHT, p. 233, pl. 13, fig. 13. Pl. 16,  
 fig. 6. Text fig. 6.
- 1943 *Metopaster tumidus*, BR. NIELSEN, p. 26, pl. 1, fig. 1 a-d.  
 Text fig. 17.
- 1943 *Ravniaster virgineus* BR. NIELSEN, p. 49, pl. 3, fig. 3.  
 Text fig. 29.

Diagnosis.—A *Metopaster* with four abactinally swollen superomarginals on each side of the arm.

Type.—As the holotype SPENCER chose the ultimate superomarginal which he figured (1913) pl. 15, fig. 1, from the Upper Senonian of Rügen in Germany. The lower proximal corner of this ossicle is wanting, and the ossicle has therefore a somewhat more robust and rounded appearance in SPENCER's figure than it had originally. Collection of the British Museum (N.H.).

Description.—The body has straight or nearly straight sides. BR. NIELSEN (1943, p. 27) distinguishes between a variety where the apical angle of the arm is about  $90^\circ$ , and an other where the angle is "somewhat less than  $90^\circ$ ". The available material does not justify such a distinction. The margin is formed of tall, powerful ossicles. In a reconstruction, SPENCER has used four ossicles in each side of an arm. How far this number has been known with certainty, or is only chosen by analogy with the closely related *M. parkinsoni* (FORBES), is not apparent, as the only individual which SPENCER has known is not further mentioned. Those individuals which have been found in Denmark show, however, that there have lived *Metopasters* in that part of the Danish White Chalk which is of the same age as the White Chalk of Rügen, which, both in regard to the number of ossicles, and other characters, agree with SPENCER's reconstruction of *M. tumidus*. The ossicular angle is large, and the margin relatively narrow. The median supero- and inferomarginals are of about the same height. The marginals are provided with a marked abactinal swelling, which includes only a part of the length of the ossicle. The ultimate superomarginal has contacted as many as six smaller inferomarginals. The tip of the arm (the terminal ossicle) is to be found at about the same level as the abactinal surface of the animal. The ornamentation consists of a nar-

row depressed margin with very delicate, closely placed spine-pits, together with scattered spine-pits within the border, those on the swelling being as a rule a little larger than the remainder.

BR. NIELSEN, 1943, p. 26, writes, "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".

An examination of the ossicles figured by SPENCER shows, however, that while pl. 15, fig. 3 and 5, have belonged to *Recurvaster radiatus*, all the other ossicles have belonged to *Metopaster*. From the account of ontogeny in *Metopaster* given above, there is reason to believe that the ossicles shown on pl. 15, fig. 4 and 6, are from a slightly younger individual of *Metopaster tumidus*, which, together with *M. undulatus* is the only species of *Metopaster* known from Rügen.

SPENCER's reconstruction, pl. 14, fig. 1 and 2, and pl. 10, fig. 15, give a good picture of the appearance of the species, and the tall, relatively narrow margin with large ossicular angle. It must be stated, however, that superomarginal and inferomarginal no. 2, in the left arm of the reconstruction shown in fig. 2, are ossicles of *Recurvaster radiatus*. This is shown by the obliquity of the superomarginal, its lesser swelling, and larger facets towards the body cavity; together with the low, broad, compact form of the inferomarginal. SPENCER's figure, pl. 10, fig. 8, shows an ultimate superomarginal with two swellings. This appearance is also seen in the ossicles of this species figured by UMBGROVE (1925), but here there are in several cases also developed small powerful protuberances.

JAN MERCIER (1935, p. 30) mentions *Metopaster tumidus* from the zone of *Micraster cor-testudinarium* (Coniacien) in France. *M. tumidus* is, however, nowhere else found in such old deposits, and it is not apparent from MERCIER's figures whether it really is this species which is presented.

WRIGHT (1940, p. 236) mention a reconstruction of a *Metopaster* which they consider to be an early form of *M. tumidus*. The ossicles seem to belong to a rather young *Metopaster* individual. Whether there really have been three ossicles in each side of the arm is not quite certain. As *M. tumidus* has four superomarginals in each side of the arm, and is presumably descended from *M. parkinsoni*, which has the same number of ossicles, it is not likely that an early form of *M. tumidus* should have had three superomarginals in each side of the arm.

Affinity with other species.—*Metopaster tumidus* is distinguished from *M. parkinsoni* by its marked abactinal swelling; from *M. poulsenii*



by the number of superomarginals in each side of the arm, by the tall, narrow margin, and large ossicular angle. It is furthermore distinguished from *M. kagstrupensis* by the number of superomarginals, and presumably also by the fact that supero- and inferomarginals are of about the same height.

Material.—BR. NIELSEN (1943, p. 26, pl. 1, fig. 1) mentions an ultimate superomarginal from Mön. During the revision of the material from the Mineralogical Museum associated remains of one individual from Mön, and two from Aalborg have been found. Furthermore, the remains of an adult and two young individuals from Mön have later been found, together with a large number of single marginals representing all growth-stages.

All the specimens mentioned are in the collection of the Mineralogical Museum.

1. Some marginals of *Metopaster*, found in the collection of the Mineralogical Museum, have been shown on closer examination to correspond so closely that there can be no doubt that they originate from a single individual. When they are arranged they form the tip of an arm, with adjacent parts of the sides. R:r as c. 63:47 mm. Ossicular angle c.  $50^{\circ}$ . The appearance of the ultimate superomarginal is identical in all details with the ossicle figured by BR. NIELSEN, and this seems to have belonged to the same individual. The inferomarginals bear scattered spine-pits. On the superomarginals are found very few scattered spine-pits, and a number of somewhat larger spine-pits, which cover the swollen portion. The apical angle of the arm has been c.  $90^{\circ}$ . The impressions of bivalve pedicellariae are seen on several ossicles.

Pl. 4, fig. 2.

Upper Senonian. Mön Cliff.

2. A collection of asteroid ossicles from Frederiksmünde near Aalborg was shown by closer examination to be made up of ossicles from two individuals, no. 2 and no. 3. Particularly those ossicles belonging to individual no. 2 showed quite clearly, by small irregularities of the articulation surface, how the ossicles had been connected. R:r as c. 58:41 mm. Ossicular angle c.  $50^{\circ}$ . There have clearly been four superomarginals in each side of the arm. The sides of the body have been slightly concave, and the apical angle of the arm is  $80^{\circ}$ — $90^{\circ}$ . The margin has been tall. The ultimate superomarginals are short, and of somewhat varying size. The tip of the arm (the terminal ossicle) has been almost on a level with the abactinal surface of the disc. The ornamentation consists of the scattered spine-pits characteristic of the species; these being larger, and more closely placed on the abactinal swelling. The os-



sicles are very similar to some of the ossicles which are included in SPENCER's reconstruction pl. 14, fig. 1. The impressions of bivalve pedicellariae are seen on several of the ossicles. Pl. 4, fig. 3. Upper Senonian. Frederiksmunde near Aalborg.

3. The ossicles lay, together with those of the previously mentioned individual, in a jar in the collection of the Mineralogical Museum. They are from a slightly smaller individual. R:r as c. 55:40 mm. Ossicular angle c.  $45^{\circ}$ . The margin is not quite as narrow, or the ossicular angle as large as in the previous individual. There is the same ornamentation, with scattered spine-pits which are larger, and more closely placed on the swollen areas of the superomarginals. There are impressions of pedicellariae on a number of the ossicles.

Pl. 4, fig. 4.

Upper Senonian. Frederiksmunde near Aalborg.

4. A large number of connected ossicles of a young *Metopaster*, found in the White Chalk of Mön. An investigation of the marginals shows with certainty that there have been four superomarginals in each side of the arm. R:r as c. 33:25 mm. Ossicular angle c.  $30^{\circ}$ . The sides of the body are slightly concave. The margin is evenly rounded, but, however, equally as tall, and with equally as large an ossicular angle as ossicles of the same size of *M. poulsenii*. Only one ultimate superomarginal is preserved; this has corresponded to two inferomarginals and there is a rather large terminal facet. This development can, however, very well be a characteristic of the individual. A single ultimate superomarginal found on Mön shows the same structure, the others have, however, been in contact with several inferomarginals and a very small terminal ossicle. Ornamentation consists of a depressed border and very few scattered spine-pits. The abactinal surface has been covered by rather tall, polygonal ossicles, possessing spine-pits and a granulation of the surface. The actinal surface has been covered by flat, oblique, polygonal ossicles bearing spine-pits. Ambulacral, adambulacral and oral ossicles are also present among the remains of this individual. The adambulacral ossicles have 3—4 spines on the margin, and on the actinal surface a short furrow, as well as the impressions of about four spines. It will be natural to regard the present individual as a young example of *M. tumidus*, since this species, and *M. undulatus*, are the only species of this genus which are known from the White Chalk of Mön; this is also confirmed by the single ossicles found.

Pl. 4, fig. 5.

Upper Senonian. Mön Cliff.

5. Two connected marginals from an individual of about the same size as the preceding, and with the same small number of spine-pits, found at Dronningestolen, Mön.
6. A number of ossicles of an adult, in flint, found at Dronningestolen, Mön. They correspond to the other specimen and give no information concerning the number of marginals. The abactinal ossicles possess spine-pits and bear a granulation. The adambulacral ossicles have four or five marginal spines and four actinal rows, each of three spines in shallow furrows in the surface.
7. Four connected ossicles of a small individual, from Mön. Described by BR. NIELSEN as *Ravniaster virgineus*. As previously mentioned, those asteroids from the Danish White Chalk described as *Ravniaster* seem to be young individuals of species of *Metopaster*. *Ravniaster virgineus* is exactly similar to the previously mentioned individual no. 1 of *Metopaster poulsenii*. As *M. poulsenii* is not known from Mön, it is likely that *Ravniaster virgineus* is a young individual of the very similar *M. tumidus*.

Pl. 4, fig. 1.

Upper Senonian. Mön Cliff.

8. There is material of *Metopaster tumidus* from Rügen in the collection of the Mineralogical Museum; it has been collected and determined by SPENCER. The ossicles concerned agree well in appearance both with SPENCER's holotype, and with the Danish material.
9. BR. NIELSEN (1943, p. 27, text fig. 17) mentions an ultimate superomarginal of an individual from Båstad in Sweden. This ossicle is, however, divergent in its slight height, and low ossicular angle, and is perhaps a *M. poulsenii*.

Occurrence.—Upper Senonian, Lower Maastrichtian, in Denmark. Mucronata zone in England, Germany, France, Belgium and Holland.

### ***Metopaster lævis* (BR. NIELSEN).**

Plate 3, fig. 11-14.

pars 1943 *Mitraster hunteri* FORBES var. *lævis* BR. NIELSEN, p. 38.

1943 *Ravniaster lævis* BR. NIELSEN, p. 47, pl. 3, fig. 4.

Diagnosis.—A *Metopaster* with three superomarginals in each side of the arm. The marginals have been completely smooth.

Type.—As there is no type-specimen of *Mitraster hunteri lævis*, the young individual described as *Ravniaster lævis*, from the Upper Seno-



nian of Stevns Cliff, is the holotype for the present species. Collection of the Mineralogical Museum.

Historical.—BR. NIELSEN (1943, p. 38) mentions some median superomarginals which, in their shape and ornamentation, are like ossicles of "*Mitraster*" *hunteri*. It has been shown (p. 30) that these ossicles have belonged to young individuals of *Metopaster poulsenii*. BR. NIELSEN, however, placed them together with a pair of smooth ultimate superomarginals of *Metopaster*-type from the same locality, and established on this basis a new variety of FORBES's species. This variety should thus have median marginals with spine-pits and granules, while the ultimate superomarginal should be completely smooth. It is unlikely that such a combination was correct, and new specimens show that a completely smooth species of *Metopaster* lived in the White Chalk Sea of Stevns. The smooth ultimate superomarginals mentioned by BR. NIELSEN are in the collection of the Mineralogical Museum, and they can with certainty be referred to the smooth species now discovered. The connected remains of two adults of this species have been found in the White Chalk of Stevns. Furthermore, the remains of several individuals, representing different growth stages, are included in the collection of ossicles interpreted on p. 14 as a pellet of indigestible matter. A very young individual of this species must have had the character of a smooth *Ravniaster*. BR. NIELSEN has described just such a one under the name *Ravniaster laevis*.

Description.—*Metopaster laevis* is, even in adult specimens, only a rather small species. The largest individual so far found has R:r as 26:20 mm., and there are no single ossicles available which indicate that it could attain a markedly greater size. The body has not, as BR. NIELSEN assumed on the basis of an ultimate superomarginal, and as is given as a generic character for *Mitraster*, been evenly rounded, but has been limited by straight or slightly concave sides. There have been three superomarginals in each side of the arm. The length and height of the marginals is less than the breadth (small ossicular angle). The inferomarginals have about the same height as the superomarginals. The marginals are provided with a very narrow depressed border which, particularly in adults, can only be seen with difficulty, or is even wanting. They are otherwise quite smooth, there being no spine-pits present.

The abactinal surface has been covered by rather tall, smooth, prismatic ossicles; the primary abactinal ossicles being distinctly larger than the remainder.

The actinal surface has been covered by low, oblique, polygonal ossicles, whose surface has been provided with spine-pits.

The adambulacral ossicles have had four or five spines on the edge



and parallel to this on the actinal surface there is a furrow and two rows of three spine-pits each.

Neither ambulacral or oral ossicles, nor impressions of pedicellariae have been observed.

Affinity with other species.—This species is clearly to be separated from all hitherto known species by its ornamentation, but it agrees otherwise in all characters with the genus *Metopaster*; especially in the outline, and the structure of the margin.

Material.—Apart from single marginals the associated remains of three individuals have been found in the Upper Senonian.

All the specimens are in the collection of the Mineralogical Museum.

1. The connected remains of a small individual described by BR. NIELSEN as *Ravniaster laevis* are the holotype for the present species. R:r as c. 5.0:3.5 mm. There are only two supero- and inferomarginals present in each side of the arm, but it is, however, likely that there has been a small, disc-shaped third marginal. A narrow depressed border is visible on the inferomarginals.

Pl. 3, fig. 11.

Upper Senonian. Stevns Cliff, Eskelund.

2. Among the ossicles mentioned on p. 14, from a pellet ejected by a starfish-eating animal, are the remains of at least three individuals of *Metopaster laevis*. A part of one individual has been reconstructed from some of these ossicles. R:r as c. 15:11 mm. Ossicular angle c.  $20^{\circ}$ . There have been three superomarginals in each side of an arm. The ultimate superomarginal has been in contact with two smaller inferomarginals, so that there have been four inferomarginals on each side of the arm.

Pl. 3, fig. 12.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

3. Remains of an individual. The shape and appearance of the marginals made it easy to unite them so that they form three sides of the animal. R:r as c. 19:14 mm. Ossicular angle c.  $25^{\circ}$ . The sides are slightly concave. The tips of the arms are slightly curved upwards. The margin is lowest (5.5 mm.) in the middle of the side, and highest (6.5 mm.) at the ultimate superomarginal. Three inferomarginals have corresponded to the ultimate superomarginal. The terminal ossicle has been quite small.

Pl. 3, fig. 13.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

4. Remains of a slightly larger individual. R:r as c. 26:20 mm. Ossicular angle c.  $30^{\circ}$ . The margin has a height of c. 8 mm. in the middle of the side, and 9 mm. in the distal part, which is only

slightly swollen. There are three superomarginals, the ultimate superomarginal corresponding to three inferomarginals. The terminal ossicle is small.

Pl. 3, fig. 14.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

Occurrence.—Upper Senonian, Upper Maastrichtian. Stevns Cliff, Denmark.

### ***Metopaster undulatus* SPENCER.**

Plate 3, fig. 15-16. Text fig. 4 h.

1913 *Metopaster undulatus* SPENCER, p. 118, pl. 10, fig. 19, 20, pl. 15, fig. 20-24.

? 1935 *Metopaster undulatus*, MERCIER, p. 29, pl. 1, fig. 15.

? 1940 *Metopaster undulatus*, WRIGHT, p. 238, pl. 14, fig. 5, 6.

1943 *Metopaster undulatus*, BR. NIELSEN, p. 31.

1943 *Metopaster granulatus* BR. NIELSEN, p. 32, pl. 1, fig. 12.

Diagnosis.—A *Metopaster* whose superomarginals have an undulating surface. The ultimate superomarginal has a short, broad and rounded appearance. The ornamentation consists of an often depressed border, which passes more or less evenly over into the central area, which is covered by scattered, rounded spine-pits of varying size. A granulation can also occur on the abactinal part of the superomarginals.

Type.—The ossicle from the Upper Senonian of Rügen, figured by SPENCER, 1913, pl. 15, fig. 20, is the holotype for this species. Collection of the British Museum (N. H.).

Description.—This species is known only from finds of very incomplete individuals and single marginals. It is therefore impossible to say anything concerning the exact outline of the animal, or the number of marginals. On the basis of the frequency of median marginals and ultimate superomarginals, SPENCER comes to the conclusion that there have only been two marginals on each side of the arm. He states, however, that an individual with three is to be found in BRYDONE's collection. This particular individual proved, however, to be a small, very badly preserved *Metopaster*, whose affinity with the present species is not quite certain. WRIGHT (1940, p. 238, pl. 14, fig. 5, 6) mention an individual from the middle Mucronata Zone in England. This individual is interpreted as an early form of *M. undulatus*. It has three superomarginals on each side of the arm, but since it is, as suggested, not a typical *M. undulatus*, it gives no sure clue as to the number of marginals there has been in the species. The profile of the superomarginals shows

two protruding portions, an abactinal and a lateral, and between these an embayment. The inferomarginals slope more evenly. The median marginals, particularly those of the superior series, are quite short. The ultimate superomarginal has a compact, rounded appearance, which gives the whole animal a rounded outline.

The ornamentation is peculiar in that the spine-pits are of very varying size, the largest being found on the lateral protruding portion. When a depressed border is present, it often passes evenly over into the central area. A granulation of the abactinal swelling is frequently found. SPENCER (1913, pp. 119 and 168) distinguishes between a younger, normal, form, and an older, rugose variety. As the relationship of the older specimen from Dorset is doubtful, and the rugose form has now been found in the uppermost White Chalk of Stevns, such a distinction is hardly justified. Spencer states that at Trimmingham the normal form is the most common, however, all the ossicles from this locality preserved in the Sedgwick Museum bear granules, even though there are in some cases only a few, or even only single granules present on each ossicle.

The impression of a pedicellaria is seen on a single marginal from Aalborg. It has the form of a depression from which two short, slender furrows stretch out in opposite directions.

MERCIER (1935, p. 29) records this species from the *Micraster cor-testudinarium* Zone in France. It is, however, impossible to decide from MERCIER's description and figure whether it really is this species which is concerned.

BR. NIELSEN (1943, p. 31) mentions this species from the White Chalk of Denmark. He furthermore establishes (p. 32, pl. 1, fig. 12) a new species, *Metopaster granulatus*, on the basis of typical ossicles of *M. undulatus*. The similarity between the two species is obvious, and is also stressed by BR. NIELSEN, who at the same time states that *M. granulatus* differs in that, "the anterior angle of the (ultimate superomarginal) plate is very large, larger than in *M. undulatus*. It measures about  $100^\circ$ , so that the margin of the animal is rather drawn in at the place where the extremity of the arm was." It is, however, hardly possible to talk of an anterior angle, as the ultimate superomarginal has a very rounded outline. That there is no possibility of separating the two species on this character is best seen by comparing the outline of the type specimen for *M. granulatus* (pl. 3, fig. 16, in the present work) with the corresponding outline in SPENCER's reconstruction of *M. undulatus*. Since BR. NIELSEN himself stresses the identity of the other characters, there is no reason here to repeat them.

Affinity with other species.—*Metopaster undulatus* is characteristic, both in its ornamentation, and its marginal profile, and is easily recognizable from other known species. SPENCER (1913, p. 106) thinks



that *M. undulatus* is descended from *M. decipiens*, a small form whose margin has extended at the cost of the central area. There is, however, an even transition between the margin and the central area in this species, and the profile of the ossicles also separates the two species. The variety *triminghamensis* established by WRIGHT (1940, p. 238) differs both in ornamentation and in the length and curvature of the ultimate superomarginals.

**Material.**—SPENCER states (p. 169) that *M. undulatus* is rare in the Senonian and Upper Danian of Denmark. No specimen of this species from the Danian has, however, been found during examination of the Danish collections. A number of marginals of this species are available from White Chalk localities around Aalborg. Those ossicles upon which BR. NIELSEN based his description of *M. granulatus* are from Rørdal near Aalborg. The ossicles used in this reconstruction possibly originate from a single individual. The ultimate superomarginal has corresponded to three inferomarginals. There is one further old find of presumably associated ossicles from the same locality: the associated ossicles of a very small individual from Blegkilde, near Aalborg. This individual does not differ from the remainder in other than size. It bears a very powerful granulation on the abactinal part of the superomarginals. The ultimate superomarginal has corresponded to two inferomarginals. Two supero- and two inferomarginals of a rather large individual have been found on Stevns Cliff, north of Kulsti. Finally, single ossicles of this species have been found in the White Chalk of Stevns Cliff, Mön Cliff, Eerslev and Aalborg.

The specimens mentioned are in the collection of the Mineralogical Museum.

**Occurrence.**—Upper Senonian, England, Germany and Denmark.

### ***Metopaster angulatus* BR. NIELSEN.**

Plate 3, fig. 17.

? 1940 *Metopaster undulatus* var. *triminghamensis* WRIGHT, p. 238, pl. 14, fig. 11.<sup>1</sup>

1943 *Metopaster angulatus* BR. NIELSEN, p. 30, pl. 1, fig. 11.

**Diagnosis.**—A *Metopaster* whose ultimate superomarginal is rather low, long and curved, so that the proximal and distal parts form an angle with each other.

**Type.**—The marginal described by BR. NIELSEN from the Upper Senonian White Chalk near Enegaarde, Præstø, is the holotype. Collection of the Mineralogical Museum.

**Description.**—*Metopaster angulatus* is established on the basis of a single ultimate superomarginal. This differs from all other known

Danish species by its long, slender and curved form. In spite of its small size, it gives the impression of having belonged to an adult, and it has corresponded to four inferomarginals. The exposed surface is evenly arched, and the ossicular angle small. The proximal part of the ossicle shows a tendency towards the undulating surface which characterizes *M. undulatus*. The ornamentation consists of a depressed border with rather few scattered spine-pits.

Affinity with other species.—WRIGHT (1940, p. 238, pl. 14, fig. 11) described a form, *Metopaster undulatus* var. *triminghamensis*, from the upper Mucronata bed near Trimingham, England. This species is similarly described from single ultimate superomarginals. It does not seem possible certainly to distinguish these two species on the basis of the available material.

Material.—Only a few ultimate superomarginals of *M. angulatus* are known from Enegaarde, Denmark.

Collection of the Mineralogical Museum.

Occurrence.—Upper Senonian, Maastrichtian. ? England, Denmark.

### ***Metopaster kagstrupensis* BR. NIELSEN.**

Plate 5, fig. 1-4. Text fig. 4 i.

pars 1913 *Metopaster mammillatus* (GABB), SPENCER, p. 115.

1943 *Metopaster kagstrupensis* BR. NIELSEN, p. 33, pl. 1,  
fig. 13, 14, 15.

1945 *Metopaster kagstrupensis*, W. RASMUSSEN, p. 418.

Diagnosis.—A *Metopaster* with three superomarginals in each side of the arm; they are strongly tumid. Ornamentation is that common for the genus. The ossicular angle is large. The median inferomarginals are taller than the superomarginals. The tip of the arm (the terminal ossicle) is generally situated at about the level of the animal's abactinal surface.

Type.—The individual from the Lower Danian of Stevns Cliff figured by BR. NIELSEN (1943, pl. 1, fig. 13.) is chosen as the type. Collection of the Mineralogical Museum.

Description.—The sides of the body are straight or nearly straight; the marginals large, and powerful. There are three superomarginals in each side of the arm. The inferomarginals are—at least in the available individuals—taller than the superomarginals. This is, however, naturally not the case with the small distal inferomarginals which meet the ultimate superomarginal. Just as in *M. tumidus* the ossicular angle is rather large. The marginals are tumid, and the superomarginals have a swelling of the central, abactinal area.



The ornament of the marginals is that typical of the genus, with scattered spine-pits within a depressed border. The ultimate superomarginal has, as seen from the abactinal side, the triangular outline usual in species of the genus *Metopaster*. It has met several smaller inferomarginals which, in contrast to the superomarginals, are of distally decreasing size. The actual tip of the arm (the terminal ossicle) has been situated rather high up on the ultimate superomarginal. BR. NIELSEN (1913, p. 34) states that there have been four inferomarginals corresponding to the ultimate superomarginal. This is also true for the large ossicles figured by BR. NIELSEN. Even larger ultimate superomarginals of this species, showing as many as six facets corresponding to inferomarginals, are, however, found. One may presume that in younger individuals of the species the number of facets has been smaller, and that the very small individuals have been "*Ravniaster*"-like, with just as many supero- as inferomarginals. BR. NIELSEN (1943, p. 34, pl. 1, fig. 15) mentions two ultimate superomarginals of different size, one having corresponded to three, and the other to two inferomarginals. He takes this difference as an example of the difference in size and number of the marginals which one sometimes can meet within a single *Metopaster* individual. From that knowledge of the ontogeny which has been gained from the investigation of *Metopaster poulsenii*, there can be no doubt that these differences are directly related to the growth-stage of the individual. One divergent ossicle, an example of that irregularity which SPENCER has called "the breaking-down of ultimate superomarginalia", has been found. This ossicle has contacted three inferomarginals, and has two facets showing that it has met two superomarginals of the opposite side of the arm. Small ultimate superomarginals belonging to a "*Ravniaster*"-like stage of *Metopaster* have been found at localities where *M. kagstrupensis* is common. That part of the superomarginal directed towards the ossicles of the abactinal surface is quite narrow as in other *Metopaster* species, showing that the abactinal surface has been covered by rather low prismatic ossicles.

The remaining parts of the skeleton of this species, and impressions of pedicellariae are not known with certainty.

Affinity with other species.—BR. NIELSEN (1943, p. 34) stresses the great similarity between *M. poulsenii*, and *M. kagstrupensis*. He states that they differ from one another in the shape of the ultimate superomarginal. Reference is presumably hereby made to the small size which, according to BR. NIELSEN, characterizes the ultimate superomarginal of *M. poulsenii*. Since it has been shown above that this small size is only an expression of the age of the individual, and there can thus be no difference between the species in this respect, the obvious thing to



do is to unite them into a single species. *M. kagstrupensis* seems, however, to be distinguished from *M. poulsenii* in that the inferomarginals are taller than the superomarginals, the ossicular angle is larger, the marginals shorter, and the ultimate superomarginal less rounded, the arm tip in *M. kagstrupensis* having as a rule been slightly projecting. It differs from *M. tumidus* partly in the relation between the heights of the supero- and inferomarginals, and partly in the number of marginals. It differs from *M. elevatus* in that the margin is lower, the ultimate superomarginal is longer, and the tip of the arm is placed higher in relation to the ultimate superomarginal. The greater breadth of the margin, and the fact that the ultimate superomarginal is more compact and without a distal swelling distinguishes the present species from *M. spencerii*.

**Material.**—Two individuals of this species have been found, apart from a large number of single marginals. The first individual is chosen as the type. R:r as c. 35:28 mm. This individual shows the number of marginals, and also the relation between the heights of the supero- and inferomarginals, this being as 8:10 mm. It was found in the Lower Danian of Stevns Cliff. The other individual was found in a flint erratic in Denmark, but is presumed also to come from the Danian. This specimen also shows the great height of the inferomarginals; the heights of the supero- and inferomarginals in this case are 9 and 12 mm. The ultimate superomarginal has contacted five inferomarginals. A few abactinal ossicles are seen; they have a strongly granulated surface. The actinal surface is covered by oblique, polygonal ossicles, whose surface bears spine-pits. The adambulacral ossicles are short and broad; they are provided with about six spine-pits on the edge, and several rows of less distinct spine-pits on the actinal surface. The impressions of pedicellariae are seen on a few of the marginal and actinal ossicles. Pl. 5, fig. 1—3 shows three marginals from individuals of different size. The first is from an individual of "*Ravniaster*"-type, as it has corresponded to only one inferomarginal. The second has been in contact with two inferomarginals, and the last is from an individual whose ultimate superomarginal has been in contact with four inferomarginals, apart from the terminal ossicle.

The specimens figured are in the collection of the Mineralogical Museum.

**Occurrence.**—Lower Danian. Denmark.

**Metopaster spencerii** BR. NIELSEN.

Plate 5, fig. 5-8. Text fig. 4 j.

pars 1913 *Metopaster mammillatus* (GABB), SPENCER, p. 115, pl. 15, fig. 11.1943 *Metopaster spencerii* BR. NIELSEN, p. 35, pl. 1, fig. 16, 17,  
pl. 2, fig. 1.

**Diagnosis.**—A *Metopaster* whose sides are concave, and whose marginals have a breadth which is less than both the length, and the height. The narrow ultimate superomarginal attains its greatest height in a powerful swelling near the distal end. The ornamentation consists of scattered spine-pits.

**Type.**—The ossicle from the Lower Danian of Stevns Cliff figured by BR. NIELSEN, pl. 1, fig. 16, and used by him in his description of this species, is chosen as the type. Collection of the Mineralogical Museum.

**Description.**—This species was established and described on the basis of single ossicles, and it is still only known in this form. It is therefore impossible to give the outline or the number of marginals. The angle between the outer side of the ultimate superomarginal, and the mesial facet is  $15^{\circ}$ — $25^{\circ}$ . The angle between the two sides of the arm has thus been  $30^{\circ}$ — $50^{\circ}$  at the ultimate superomarginal. This shows that *M. spencerii* must have had more concave sides, and narrower, more projecting arms than any other known species of *Metopaster*. At the same localities where the ultimate superomarginals of this species occur, are also found narrow median superomarginals of a completely corresponding type. BR. NIELSEN regards these as belonging to the species, and there can be no doubt as to his correctness. From the shape of the ossicles it is seen that the margin has been narrow, and the ossicular angle large. The breadth of the median superomarginals is less than both the length, and the height; the outer side of these ossicles continues in a powerful, but clearly limited abactinal swelling. A peculiar character of the median superomarginals is their concavity where they meet the other superomarginals, and the abactinal ossicles. The impression is given of a furrow stretching over the end-facets and the abactinal part of the inner facet. The powerful swelling of the distal end of the ultimate superomarginal varies very much in appearance; as is also to be seen from the figures. This swelling reaches always to the mid-line of the arm, and therefore governs the shape of the mesial facet. BR. NIELSEN (1943, p. 35) states that four inferomarginals have corresponded to the ultimate superomarginal. In the largest specimen so far found six inferomarginals, apart from the small terminal ossicle, have corresponded to the superomarginal. There have been three in the smallest specimen found. The superomarginals in pl. 5, fig. 5—8

have corresponded to 3, 4, 5 and 6 inferomarginals respectively. The ornamentation consists of scattered spine-pits, which are slightly larger on the swelling than over the rest of the surface. A depressed border is only visible on some of the ossicles.

The other skeletal parts of this species are unknown.

The impressions of pedicellariae are seen on some marginals; there is a depression from which two grooves extend in opposite directions, ending in smaller depressions.

Affinity with other species.—The present species is clearly distinguished from all other known species by the narrow margin, the outline, and the swelling on the distal part of the ultimate superomarginal. There are generally one or more marked swellings in *M. thoracifer* from the Cenomanian and Lower Turonian. These are, however, laterally placed on the much broader marginal, and therefore do not influence the mesial facet. The same applies to *Metopaster parkinsoni calcar* SPENCER which occurs in the Swedish Senonian.

Material.—As mentioned, only single ossicles of this species have been found. The median as well as the ultimate superomarginals are easily recognizable. It is on the other hand more difficult with certainty to refer inferomarginals to this species.

The ossicles figured are in the collection of the Mineralogical Museum.

Occurrence.—Lower Danian. Denmark.

### ***Metopaster elevatus* BR. NIELSEN.**

Plate 5, fig. 9-10. Text fig. 4 k.

pars 1913 *Metopaster mcnamillatus* (GAEB), SPENCER, p. 115, pl. 10, fig. 9.

1943 *Metopaster elevatus* BR. NIELSEN, p. 36, pl. 2, fig. 2.

Diagnosis.—A *Metopaster* whose ultimate superomarginal is very short and tall, with a strong abactinal swelling. The tip of the arm (the terminal ossicle) is only slightly elevated above the lower edge of the superomarginals. The ornamentation is composed of a depressed border, and within this scattered spine-pits, which are largest on the abactinal swelling.

Type.—The holotype is the ultimate superomarginal from the Upper Danian of Herfølge, figured by BR. NIELSEN, pl. 2, fig. 2. Collection of the Mineralogical Museum.

Description.—Only a few occurrences of single ultimate superomarginals are known with certainty. The angle between the outer side, and the mesial facet is c.  $50^\circ$ , corresponding to an angle of c.  $100^\circ$  for the arm apex. This shows that the sides of the body have been straight or nearly straight. Furthermore, the shape of the proximal facet shows



that the margin has been rather tall, and evenly rounded. The ossicle is itself short and tall. A powerful swelling includes the whole abactinal surface. The largest ultimate superomarginal so far found has corresponded to four inferomarginals; the smallest shows three downwardly directed facets, and has therefore met three inferomarginals, apart from the small terminal ossicle. The tip of the arm has been only slightly upturned. The amount of upturn is greatest in the large ossicle mentioned above; here the apex has been situated on a level with the middle of the superomarginals. In the remaining specimens the apex is only very slightly elevated, or not at all. As a result of this shape the mesial facet of the ultimate superomarginal is oval in outline with its ends at the top of the ossicle above, and at the arm-tip below. The ornamentation is composed of a depressed border, and within this scattered spine-pits, which are largest on the abactinal swelling. The impression of a pedicellaria of *Metopaster*-type is seen on a single ossicle.

Affinity with other species.—*Metopaster elevatus* is mainly reminiscent of *M. kagstrupensis*, but differs from this and other species by its tall, short ultimate superomarginals, and the only slightly upraised tip of the arm. It differs also in the ornamentation, which is distinctly coarser on the abactinal swelling of the ultimate superomarginal than on the remainder of the ossicle.

Material.—Only fifteen ultimate superomarginals of this species are known.

Collection of the Mineralogical Museum.

Occurrence.—Middle Danian in Denmark.

### ***Metopaster planus* (BR. NIELSEN).**

Plate 5, fig. 11.

1943 *Ravniaster planus* BR. NIELSEN, p. 51, pl. 3, fig. 10-13.

Text fig. 21, 22. ? pl. 3, fig. 9.

pars 1945 *Ravniaster planus*, W. RASMUSSEN, p. 421, pl. 9, fig. 7.  
non pl. 9, fig. 8.

Diagnosis.—A *Metopaster* whose marginals bear a depressed border, and within this scattered spine-pits which are particularly numerous along the often rather sharp boundary between the abactinal and lateral parts of the outer surface of the ultimate superomarginal. The ultimate superomarginal has met an almost equally large inferomarginal, and distal to this, one or two small inferomarginals.

Type.—The fragment of an individual from the Lower Danian of Korporalskroen, figured by BR. NIELSEN 1943, pl. 3, fig. 10, is chosen as type. Collection of the Mineralogical Museum.

Historical.—*M. planus* is established on the basis of a number of

marginals found in the Danish Danian. These ossicles are all ultimate superomarginals, or corresponding inferomarginals. A number of median marginals are also found in the Danian deposits, but it has not been possible to make a certain reconstruction by using them. When BR. NIELSEN found a very young asteroid ( $R = 2$  mm) in the Danian, with one supero- and one inferomarginal in each side of the arm, he concluded that there had existed a species which (when fully grown) only had a single supero- and inferomarginal in each side of the arm.

Description.—Judging by the size of the marginals, *M. planus* seems to be a small species. The number of marginals in each side of the arm is unknown. The ultimate superomarginal is most often nearly triangular, with about the same length as breadth, while the height is distinctly less. It has met the corresponding ossicle from the other side of the arm over most of its length, having been in contact with the small abactinal ossicles only in a small proximal part. The ossicle is only slightly tumid. In the proximal part of the arm the abactinal and lateral surfaces pass evenly into one another; in the distal part they meet in a more or less sharp edge. The proximal end-surface is almost as tall as the ossicle as a whole, rather narrow and arched with the concavity directed towards the body cavity. The ultimate superomarginal has been in contact with one inferomarginal of nearly equal size. Distal to this is found one, or, in a very few instances, two or none inferomarginals. The large inferomarginal has a triangular outline; its proximal articulation surface is narrow, and curved similarly to that of the superomarginal. The inferior series of marginals bear the impressions of the adambulacral ossicles. That part directed towards the body cavity has the character of a furrow along the length of the ossicle. The distal articulation surface is very small, and triangular; it has met the very small distal inferomarginal. The exposed surface is more evenly arched than in the superomarginal.

The ornamentation of the marginals is composed of a narrow depressed border, and scattered spine-pits, which on the ultimate superomarginal are most common on the lateral part of the surface, and particularly along the junction between the lateral and abactinal parts. Pedicellarian impressions have not been observed.

Affinity with other species.—This, and especially the following species are reminiscent of the recent *Pentagonaster pulchellus* in the large inferomarginal corresponding to the ultimate superomarginal, but they differ from this markedly, both in shape, and ornamentation.

The author stated in 1944 that it was not possible to distinguish between the present species, and "*Ravniaster*" *carinatus* on the basis of the type of the former, and the description of the latter. A later investigation of the holotype of *R. carinatus* has, however, shown that this agrees



very badly with the description. This question will therefore have to be referred to again (see below).

**Material.**—Single ossicles of this species have been found at the majority of Danian localities in Denmark. The fragment chosen as type, and an inferomarginal with a few attached adambulacral ossicles are all that is known of connected remains. Those ossicles which are included in the reconstruction figured by BR. NIELSEN, 1943, pl. 3, fig. 13 agree well with the type individual. Supero- and inferomarginals are, however, exchanged in some places. The correctness of the reconstruction without median marginals is extremely doubtful. The ossicle figured by BR. NIELSEN, pl. 3, fig. 12, is not a superomarginal, but an inferomarginal. Whether the very small individual figured by BR. NIELSEN has belonged to this species cannot be determined. The inferomarginal figured by the author, 1945, pl. 9, fig. 8, has presumably belonged to an other species (see p. 55).

The ossicles figured are in the collection of the Mineralogical Museum.  
Occurrence.—Danian. Denmark.

### ***Metopaster carinatus* (BR. NIELSEN).**

Plate 5, fig. 12-13.

1943 *Ravniaster carinatus* BR. NIELSEN, p. 52, pl. 4, fig. 34.

pars 1945 *Ravniaster planus*, W. RASMUSSEN, p. 421.

**Diagnosis.**—A *Metopaster* whose ultimate superomarginal is long, and more or less curved. Only the distal half meets the corresponding ossicle from the other side of the arm in the mid-line. The surface is evenly curved. There is a narrow depressed border, and within this spine-pits which are evenly distributed over the whole surface. The ossicle has contacted an equally large inferomarginal.

**Type.**—The marginal from the Upper Danian of Herfølge figured by BR. NIELSEN, 1943, pl. 4, fig. 34, is the holotype. Collection of the Mineralogical Museum.

**Historical.**—This species was described by BR. NIELSEN in 1943. Only one ossicle is figured. The author showed in 1945 that this species could not be distinguished from *M. planus* on the basis of the description. The holotype has been found later, however, and it shows itself to be very different from the description. It represents a type of ossicle which has only been found in abundance at a single locality, Herfølge. In spite of the difficulty of working with species only known from single ossicles, it seems to be possible to keep the species separate. Their dif-



ferent frequencies at the different Danian localities make it likely that *M. carinatus* is an independent species.

Description.—*M. carinatus* is a small species with marginals of the same size as *M. planus*. The number of marginals in each side of the arm is unknown. The ultimate superomarginal is long, and slightly curved in agreement with the sides of the body having been concave. Only in the distal half has the ossicle met the corresponding ossicle from the opposite side of the arm. The free surface is evenly curved without any suggestion of a ridge. The ornamentation consists of a narrow depressed border, and spine-pits which are uniformly distributed over the whole surface. The proximal articulation facet, which has been in contact with the median superomarginals, is rather small, low and broad. This surface is peculiar in about half of the ossicles; being divided into two or three smaller facets. This peculiar appearance will be understood by comparison with the recent *Pentagonaster pulchellus*, where secondary ossicles are often interposed between the marginals—especially proximally to the ultimate superomarginal, and the corresponding inferomarginal. These ossicles are therefore sometimes in contact with several ossicles at their proximal end, and thus obtain an appearance which agrees exactly with that which we find in *M. carinatus*. In the great majority of cases the ultimate superomarginal has been in contact with a single, equally large inferomarginal. In only a few cases is there found a very small distal inferomarginal. *M. carinatus* is thus also reminiscent of *P. pulchellus* in this feature. The inferomarginal is consequently triangular in outline, and ends in a terminal point. It has been in contact with the adambulacral plates over the greater part of its length. The free surface is evenly curved, provided with a narrow depressed border, and numerous, uniformly distributed spine-pits.

Affinity with other species.—*Metopaster carinatus* differs from *M. planus* in the even curvature of the ultimate superomarginal, without any suggestion of a ridge; in the distribution of the spine-pits, and the long, slightly curved form of the ossicles. As mentioned above, it is reminiscent of *P. pulchellus* in often having only a single inferomarginal corresponding to the ultimate superomarginal, and in that the small surface directed towards the median superomarginals is often subdivided into several facets.

Material.—Only single marginals from the Upper Danian are known. They are common in material from Herfølge, but are, however, also found at other localities.

Collection of the Mineralogical Museum.

Occurrence.—Upper Danian, Denmark.

**Metopaster maculatus** (BR. NIELSEN).

Plate 5, fig. 14-15.

1943 *Ravniaster maculatus* BR. NIELSEN, p. 50, pl. 3, fig. 5-8. Text fig. 30.

**Diagnosis.**—A *Metopaster*, whose ornamentation is made up of a depressed border-zone, and a very limited central area bearing scattered spine-pits. One or two inferomarginals correspond to the ultimate superomarginal.

**Type.**—The ossicle from the Upper Danian of Fakse, figured by BR. NIELSEN, 1943, pl. 3, fig. 6, is chosen as type. Collection of the Mineralogical Museum.

**Description.**—This species is only known from single marginals. The outline of the animal, and the number of marginals is not known. BR. NIELSEN assumed that there had been two superomarginals in each side of the arm. The ultimate superomarginal generally corresponds to a large, proximal, and a rather small distal ossicle. The marginals are rather low, oblique and evenly tumid. The ultimate superomarginal meets the corresponding ossicle from the other side of the arm in the mid-line; it has therefore a triangular outline when seen from the dorsal side. The ornamentation is reminiscent of that general in the genus *Metopaster*, but it is peculiar in that the slightly raised central area is very limited, and can even be completely wanting.

**Affinity with other species.**—The ornament of *Metopaster maculatus* is reminiscent of *Metopaster exsculptus* SPENCER, and especially of *M. decipiens* SPENCER, but it differs by having a smaller number of inferomarginals corresponding to the ultimate superomarginal.

**Material.**—A large number of marginals of this species have been found in the Middle Danian, particularly in the limestone at Fakse.

Collection of the Mineralogical Museum.

**Occurrence.**—Upper Danian. Denmark.

**Metopaster sp.**

Plate 5, fig. 16.

Typical forms of *Metopaster*, with several inferomarginals corresponding to the ultimate superomarginals, have not previously been known from the uppermost Danian. Typical ultimate superomarginals from a rather small, unknown species of *Metopaster* are, however, now available from several localities with uppermost Danian. The ossicles are rather low, evenly tumid and possess no conspicuous characters that could be used for a specific diagnosis. It would be difficult to dis-

tinguish this from the young of other typical species of *Metopaster* in material from localities where such occur.

Occurrence.—Upper Danian. Denmark.

#### Genus *Ceramaster* VERRILL 1899.

Diagnosis.—Asteroids whose body is pentagonal with only slightly projecting arms. The abactinal ossicles are covered by closely placed setae. The marginals bear setae, which are sometimes restricted to a border while the central, slightly elevated area is smooth, or provided with a few scattered setae.

Genotype.—*Ceramaster granularis* (RETZIUS) 1783. Recent.

Affinity with other genera.—The genus *Ceramaster* is close to *Pentagonaster*, but has marginals whose size decreases towards the tip of the arm, and equal numbers of supero- and inferomarginals (or a single extra inferomarginal). The marginals of *C. placenta* (MÜLLER & TROSCHEL) have an ornamentation composed of a border bearing fine, closely placed setae, and a central slightly elevated area bearing a few scattered setae attached in small pits. In this it is strongly reminiscent of Cretaceous individuals of *Metopaster*. Concerning this species FISHER (1911, p. 205) writes, "*placenta* is in many respects an aberrant member of this group", and later, "*C. placenta* seems to tend towards *Tosia*". Two other species, *bourgeti* (PERRIER), and *ammophilus* (FISHER), have very similar marginals (but fewer of them) and are referred to a separate genus, *Sphaeriodiscus* FISHER.

Fossil species of *Ceramaster*.—Several species which have been referred to *Metopaster* differ from the normal appearance of this genus by not having a large ultimate superomarginal corresponding to several inferomarginals. Some of these species are, in appearance, close to *C. placenta*, and partly also to the two species of *Sphaeriodiscus*; these are mentioned here under the genus *Ceramaster*.

Occurrence.—The genus *Ceramaster* has hitherto only been known recent, but it seems also to be represented in the Danian. There is also an (undescribed) species from the Danish Oligocene which must be referred to this genus.

#### *Ceramaster dividius* (W. RASMUSSEN).

Plate 5, fig. 17.

1945 *Metopaster dividius* W. RASMUSSEN, p. 419, pl. 9, fig. 3, 4, 5, pars fig. 6.

Diagnosis.—A *Ceramaster* with a pentagonal outline, and nearly straight sides. The margin is formed of just as many superomarginals



as inferomarginals. The marginals are provided with a depressed border bearing fine, closely placed setae, and within this, scattered setae attached in spine-pits. In the outermost part of the arm the superomarginals meet in the mid-line. This produces an ossicle which, seen from the abactinal side, has a characteristic pentagonal outline.

Type.—The penultimate superomarginal from the Upper Danian near Svanemøllen, in Copenhagen, figured by the author, 1945, fig. 3a and 3b, is the type. Collection of the Mineralogical Museum.

Description.—This species is only known from single marginals, and it is therefore impossible to decide how many marginals there have been in an individual. The sides of the body have only been slightly concave. The marginals have about the same length, breadth and height. The superomarginals have an abactinal swelling. The marginals in the distal part of the arm have met each other in the midline over the length of at least two marginals. An ossicle with a characteristic pentagonal outline is produced where the marginals from the two sides of the arm meet.

Affinity with other species.— This species differs from other species of *Ceramaster* in the narrow, and uniformly setaceous depressed border, and the scattered setae on the central area.

Material.—Single marginals are known from most Danish Upper Danian localities.

Collection of the Mineralogical Museum.

Occurrence.—Upper Danian, Denmark.

### ***Ceramaster granulatus* (W. RASMUSSEN).**

Plate 5, fig. 18.

1945 *Ravniaster granulatus* W. RASMUSSEN, p. 422, pl. 9, fig. 9.

Diagnosis.—A *Ceramaster* with equal numbers of superomarginals and inferomarginals. In the outermost part of the arm the marginals of the two sides meet in the mid-line, producing an ossicle whose outline, seen from the dorsal side, is characteristically pentagonal. The free surface of the ossicles is evenly tumid, without an abactinal swelling; it is provided with a depressed border within which spine-pits and a marked granulation are found.

Type.—The characteristic pentagonal superomarginal in the left side of the reconstruction figured by the author, 1945, pl. 9, fig. 9 is chosen as type. It is from the Upper Danian of Fakse. Collection of the Mineralogical Museum.

Description.—Only superomarginals are known with certainty from this species. They are rather low, and the free surface is evenly, but

strongly tumid. The structure of the arm is as in *Ceramaster dividuus*, there being equal numbers of supero- and inferomarginals, and the ossicles of the outermost part of the arm have met each other in the mid-line producing a characteristic pentagonal ossicle. There may have been small marginals distal to the pentagonal ossicle. The ornamentation consists, just as in most species of *Metopaster*, of a depressed border, and within this scattered spine-pits, and generally also a powerful granulation.

Affinity with other species.—The arm-structure in this species is reminiscent of *Ceramaster dividuus*, but it differs in the shape and ornamentation of the marginals, and especially in the even tumidity of the surface.

Material.—A large number of isolated marginals from Fakse, and also a few from other localities.

Collection of the Mineralogical Museum.

Occurrence.—Upper Danian. Denmark.

***Ceramaster* cf. *granulatus* (W. RASMUSSEN).**

Plate 5, fig. 19.

pars 1945 *Ravniaster planus* BR. NIELSEN, W. RASMUSSEN, p. 421, pl. 9, fig. 8.

A large number of marginals from the limestone at Fakse are available; of these the superomarginals are just like *C. granulatus* in shape, while the inferomarginals agree with that figured by the author in 1945 as *R. planus*. These ossicles, which probably originate from one and the same species, have possibly belonged to *C. granulatus*, and they differ from the type of this species only in not possessing a granulation. The inferomarginal differs from *M. planus* in its short, broad form, and rather large distal facet.

Occurrence.—Upper Danian. Denmark.

**Genus *Recurvaster* BR. NIELSEN 1943.**

Diagnosis.—Asteroids whose bodies pass evenly into the upturned arms. Just as in *Metopaster* the ornament consists of a narrow depressed border covered by fine, closely placed spine-pits, and within this scattered, somewhat larger, circular spine-pits in which small spines or setae have been attached. There are equal numbers of supero- and inferomarginals. They decrease evenly in size towards the tip of the arm, and in the outermost part of the arm the superomarginals have met each other in the mid-line.

Genotype.—*Recurvaster radiatus* (SPENCER). Upper Senonian.



**Description.**—This genus was established by BR. NIELSEN for asteroids whose marginals, like the ossicles of *Metopaster*, have a depressed border, and scattered spine-pits on the central part of the free surface, but which do not have the generally straight-sided, pentagonal outline, and large ultimate superomarginal which is characteristic of the genus *Metopaster*. The body passes evenly into the pointed, upcurved arms, whose marginals decrease in size towards the tip of the arm. While the first (median) marginals are almost like the corresponding ossicles of *Metopaster*, the ossicles of the arm are without or nearly without spine-pits. BR. NIELSEN states that these ossicles are also without a depressed border. This is, however, not the case, but the border on the distal ossicles is very narrow and inconspicuous. The marginals of the arm are markedly oblique. The superior series are curved, and the inferior long and narrow. The abactinal surface is covered by tall, prismatic, hexagonal ossicles.

**Affinity with other genera.**—Among recent genera *Recurvaster* is reminiscent of *Ceramaster*, and especially *Plinthaster*. The Cretaceous species of *Metopaster* are like *Recurvaster* in that the first marginals have about the same shape, and ornamentation. This similarity is very conspicuous when one is concerned with single ossicles, but if one sees the distal marginals, or the whole animal, they are clearly two very different types. In 1913 SPENCER described the *Recurvaster*-type as radiate varieties of species of *Metopaster*. He thought that the ultimate superomarginal in *Metopaster* is formed by the fusion of several ossicle rudiments (1913, p. 108), and that the radiate varieties were produced when this fusion did not take place. The new, well-preserved specimens which have been found in the meantime show, however, that the difference includes far more than just the superomarginals of the arm. The inferomarginals, and the terminal ossicle are also of a type quite different from *Metopaster*. "*Metopaster tumidus* var. *radiatus*" is, as will be shown later, identical with the species of *Recurvaster* described by BR. NIELSEN from the Senonian. Concerning *Metopaster quadratus* SPENCER, the fact is that the two individuals which are known show irregularity in the number and shape of the superomarginals, but, however, without therefore being like *Recurvaster*. Similar irregularities are also known in a few other species. WRIGHT, in 1940, described two species, *Metopaster stainforthi* and *M. icenicus*, both of which diverge from the typical *Metopaster* in not having an enlarged ultimate superomarginal. While the last mentioned form is very much like *Metopaster* or *Ceramaster*, *M. stainforthi* bears a considerable likeness to *Recurvaster*.

**Occurrence.**—*Recurvaster* is only known from the Senonian and Danian.



**Recurvaster radiatus** (SPENCER).

Plate 7. Plate 8, fig. 1-2. Plate 9, fig. 1-3. Text fig. 1-2.

1913 *Metopaster tumidus* var. *radiatus* SPENCER p. 113, pl. 14, fig. 3,  
pl. 15, fig. 3, 5.

1935 *Metopaster tumidus* var. *radiatus*, MERCIER, p. 30.

? 1940 *Metopaster tumidus* ? var. *radiatus*, WRIGHT, p. 236, text fig. 6 a-b.

1943 *Recurvaster stevensensis* BR. NIELSEN, p. 39, pl. 2, fig. 3,  
text fig. 26-28.

1943 *Recurvaster echinatus* BR. NIELSEN, p. 41, pl. 2, fig. 4-9.

**Diagnosis.**—A *Recurvaster* whose median supero- and inferomarginals are of about the same length as height, and are provided with scattered spine-pits, and a depressed border bearing very fine, closely placed spine-pits, but without a granulation. The abactinal surface has been covered by polygonal ossicles bearing spine-pits.

**Type.**—The arm fragment from Trimmingham in England included in the reconstruction figured by SPENCER in 1913, pl. 14, fig. 3, is the type. Collection of the Sedgwick Museum, Cambridge.

**Historical.**—SPENCER (p. 113) describes this species thus, “. . . . forms of *Metopaster tumidus* in which the terminal supero-marginalia are broken down into small ossicles. The extremity of the arm is thus straightened and the arm appears longer. A “radiate” appearance is thus given to the specimen. Further, whereas the great majority of the supero-marginalia of *M. tumidus* “proper” are apparently regularly uniform in height on the same specimen, the ossicles of these regressed forms gradually taper to the extremity and thus bring about an asymmetry in the articulating facets for neighbouring plates, an important distinctive character.” BR. NIELSEN established the species *Recurvaster stevensensis* on the basis of a very similar individual from the White Chalk of Stevns Cliff. His concurrence with SPENCER’s opinion, and his acceptance of the individual figured by SPENCER as a variety of *Metopaster tumidus* are due to his misinterpretation of SPENCER’s fig. 3 on pl. 14. BR. NIELSEN writes concerning this (p. 23): “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”. An investigation of the type specimen shows, however, that this consists of disarticulated *Recurvaster* marginals, together with an arm fragment comprising four superomarginals and four inferomarginals on each side. These sixteen arm ossicles are in their natural positions and belong to a single individual. The arm fragment has been pressed down so as to be on a

level with the other ossicles, but it is clearly to be seen, also from SPENCER'S figure, that, in order to join with the remaining ossicles, it must have curved just as in the Danish *Recurvaster*-individuals. Only this arm is present in the reconstruction: the others, being plaster-casts, have a rounded appearance, which is even more apparent in the figure. It seems here, as though the arm is terminated by a quadrant-shaped ossicle, while in actual fact the termination of the arm is not even present. The arm fragment, as well as the single ossicles, corresponds for that matter very well with the *Recurvaster stevensensis* described by BR. NIELSEN. The similarity between *R. radiatus* and *Metopaster tumidus* is thus limited to the shape and ornamentation of the median superomarginals, and even these are distinguishable from one another as stated on p. 60.

*Recurvaster stevensensis* and *R. echinatus*.—On the basis of the two *Recurvaster* individuals which he knew, BR. NIELSEN established two species, since he meant that the specimens differed so much that it was unthinkable that they should be united under the same specific name. According to the descriptions the two species are separated by the facts that while in *R. stevensensis* the spine-pits on the marginals are often connected by short furrows, those of *R. echinatus* are well separated, and one, in which a small spine has been attached, is larger than the others. Another difference should be that the terminal ossicle in *R. stevensensis* has borne three spines, while in *R. echinatus* there have been more. It has not been possible to observe any difference in the appearance of the adambulacral ossicles. More than twenty individuals have been obtained since BR. NIELSEN'S publication appeared; these show that there has been marked variation in those characteristics which were to separate the species. In the following table are shown examples of how those characteristics which should separate the two species vary independently among individuals from Stevns Cliff. These characteristics are also treated in the subsequent examination of the material.

Individual No.	Character of spine-pits.	Larger spine-pits on median superomarginals.	Number of spines on terminal ossicle.
13. ( <i>R. stevensensis</i> )	connected	0	3
8. ( <i>R. echinatus</i> )	separate	1	2
9]	»	0	2
12	»	2	unknown
11	»	0	1
14	few connected	1-3	1

Description.—*Recurvaster radiatus* is a pentagonal, stellate starfish with extended, upturned arms. Because of this curvature the ratio R:r



does not give a good expression of the outline; the ratio is, however, stated for each individual. The margin is formed of powerful supero- and inferomarginals, whose size decreases evenly towards the tip of the arm. BR. NIELSEN estimated the number of supero- and inferomarginals in each side of the arm (calculated, as usual, from the middle of the side to the tip of the arm) as eight. It has been shown that, both in the individuals mentioned by BR. NIELSEN, as well as in the later collected adults where the number of plates could be determined, this number has been ten. Five distal superomarginals of both sides have met in the mid-line. A more exact impression of the individual ossicles is given by pl. 8, fig. 1. It is seen that the first superomarginal is almost completely symmetrical, with a regular and powerful abactinal swelling over the whole length of the ossicle. There is a rather broad depressed margin, within which are scattered spine-pits. No. 2 is slightly lower, and oblique. No. 3 is only slightly tumid. No. 4 is only very slightly tumid, and has fewer spine-pits. No. 5 and those closely following, are wedge-shaped in correspondance with the upturning of the arm; they have only a few spine-pits, or none. The distal part of no. 5 has met the corresponding ossicle of the other side of the arm. Ossicles no. 6—10 have about the same appearance, but are of diminishing size. The last ossicle is, however, quite short, and discoid in those individuals which are not fully grown. The ultimate superomarginal has met the terminal ossicle in an oblique facet. The profile of the median superomarginals shows that the facets directed towards the body-cavity and towards the abactinal ossicles form an angle of nearly  $180^\circ$  with each other. In the first ossicles these two facets are of about the same size. Ossicle no. 5 forms the transition to the arm, where the superomarginals meet their counterparts over most of their height in the mid-line, leaving no room for abactinal ossicles. The three first inferomarginals have a very broad depressed border, and within this evenly scattered spine-pits. The margin becomes more narrow on the succeeding ossicles, and the spine-pits are more concentrated towards the actinally, disappearing completely on the last ossicles. The first inferomarginal is nearly symmetrical; it is short and broad. The parts directed towards the body-cavity, and the actinal ossicles form almost a right angle with each other. The following ossicle is slightly oblique. Ossicle no. 3 is longer and slightly wedge-shaped, in correspondance with the curvature of the arm which begins with the next ossicle. No. 4, and the following ossicles are relatively long and narrow. The adambulacral ossicles have met no. 4, which bears facets directed both towards these and the actinal ossicles. There have been no actinal ossicles in the following part of the arm, the adambulacral ossicles having been in contact with the inferomarginals over the whole of their height. The height and ossicular



angle increase during growth, but are for that matter different at different parts of the margin in a single individual. In young individuals the margin is lowest in the interradius; it is highest here in older individuals.

The terminal ossicle is relatively large and cone-shaped; it has met the ultimate superomarginals in two oblique facets. On the under surface there is a furrow in continuation of the ambulacral groove. There have been from one to four short, powerful cone-shaped spines on the ossicle.

The abactinal ossicles are rather tall and six-sided, with spine-pits on the surface, and with drawn-out corners on the under-side.

The madreporite has been observed on a single individual; it has a triangular outline. The adjacent abactinal ossicles are oblique, and extend under the madreporite.

The actinal ossicles are lower, oblique, polygonal ossicles with spine-pits on the outer surface.

The adambulacral ossicles have had a row of spines on the edge, and three rows on the surface. This ornamentation continues on the very large, triangular ossicles which have bounded the mouth.

The ambulacral ossicles are large and slightly curved. They decrease in size towards the tip of the arm without changing shape; while the adambulacral ossicles become taller, and more slender towards the arm, reaching their greatest height at the base of the arm, after which their size steadily diminishes.

The interradi al ossicle is large, and shield-shaped.

The impressions of pedicellariae have been observed on the marginals of two individuals. They have the form of a circular depression from which two furrows extend in opposite directions.

Affinity with other species.—*Recurvaster radiatus* is distinguishable from the species found in the Danian by the tumidity and slight height of the superomarginals; from *R. blackmorei* by the shape and ornamentation of the superomarginals, and the ornament of the abactinal ossicles. The median superomarginals can be distinguished from the very similar ossicles of *Metopaster* by the more even tumidity, and the greater height of the facet directed towards the abactinal ossicles.

Material.—Apart from single ossicles, the associated remains of twenty-eight individuals have been found in Denmark. Those finds which are particularly useful in elucidating the appearance, and variation of the species will be mentioned in greater detail.

The Danish specimens are in the collection of the Mineralogical Museum.

1. The remains of a very small individual. There have been at least five supero- and inferomarginals in each side of the arm. R:r as

c. 12:7 mm. The marginals are slightly tumid, have a depressed border and very few scattered spine-pits.

Pl. 7, fig. 1.

Upper Senonian. "Norden", Aalborg.

2. Remains of a small individual in White Chalk. There have been at least six supero- and inferomarginals in each side of the arm. R:r as c. 17:12 mm. The marginals are slightly tumid. The ossicular angle in superomarginal no. 1 is c.  $15^{\circ}$ . Marginals no. 2 and 3 are very slightly higher than no. 1. The distal part of superomarginal no. 3, and the succeeding superomarginals, have met their corresponding ossicles in the mid-line of the arm without allowing room for abactinal ossicles. Similarly, the corresponding inferomarginals have met the adambulacral ossicles without giving room for actinolateral ossicles. The ornamentation consists of a depressed border, and scattered, well-separated spine-pits. W. K. SPENCER has labelled the specimen "*M. tumidus*. (young specimen?)".

Pl. 7, fig. 2.

Upper Senonian. Mön Cliff.

3. Remains of an individual of about the same size and appearance as the preceding. A number of the marginals and superficial ossicles bear impressions of pedicellariae.

Upper Senonian. Mön Cliff.

4. Remains of a small individual. There have been at least seven supero- and inferomarginals in each side of the arm. R:r as c. 20:13 mm. The height of the margin increases greatly from the middle of the side to the base of the arm by the third marginal, where it reaches its greatest height. The most distal part of superomarginals no. 3, and the succeeding superomarginals, have met each other in the mid-line of the arm without allowing room for abactinal ossicles. The inferomarginals from no. 2 have met the adambulacral ossicles. The marginals have a depressed border. The first three superomarginals, and the first four inferomarginals also have scattered, well separated spine-pits. The primary abactinal ossicles are large. The adambulacral ossicles bear the impressions of a row of spines on the edge, and possibly three rows on the actinal surface.

Pl. 7, fig. 3.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

5. Remains of an individual. There have been at least seven supero- and inferomarginals in each side of the arm. R:r as c. 27:17 mm. In superomarginal no. 1 the ossicular angle is c.  $20^{\circ}$ . The margin reaches its greatest height by marginal no. 3. The superomarginals from no. 4 have met each other in the mid-line. The inferomargi-



nals from no. 3 have met the adambulacral ossicles. The marginals have a depressed border, and scattered, well separated spine-pits. Marginals no. 3 and 4 have only very few spine-pits, and these succeeding are smooth.

Pl. 7, fig. 4.

Upper Senonian, hardened White Chalk. Stevns Cliff, north of Kulsti Rende.

6. Remains of an individual similar to the preceding in size and ornament. Marginals no. 1—4 are of about the same height.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

7. Remains of an individual. There have been nine supero- and inferomarginals in each side of the arm. R:r as c. 50:32 mm. The height of the margin decreases slightly, but steadily from the middle of the side towards the tip of the arm. The first superomarginals are strongly tumid; the following are less tumid. From superomarginal no. 5 these ossicles have met in the mid-line of the arm. The inferomarginals from no. 4 have met the adambulacral ossicles. Superomarginal no. 8 ends with a slightly oblique, curved facet, which suggests that ossicle no. 9 has been very small and wedge-shaped, and that ossicle no. 10 has not been formed. The spine-pits are well separated; they are largest on the first marginals. On the distal marginals of the arm there are only few spine-pits.

Pl. 7, fig. 5, pl. 9, fig. 1.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

8. Remains of an individual described by BR. NIELSEN as *R. echinatus*. It is of about the same size and appearance as the preceding individual, but on each of the median superomarginals a particularly large spine-pit is found, apart from the usual spine-pits. The terminal ossicle seems to have possessed two spines. The adambulacral ossicles do not differ in appearance from those of the other individuals.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

9. Remains of an individual. There are ten supero- and inferomarginals in each side of the arm. R:r as c. 60:35 mm. The ossicular angle of superomarginal no. 1 is c. 40°. The median superomarginals are evenly, and strongly tumid. Spine-pits are well separated. The superomarginals from no. 5 have met in the mid-line of the arm, and the inferomarginals from no. 4 have met the adambulacral ossicles. Superomarginal no. 10 is very small and wedge-shaped. The terminal ossicle has possessed two spines.

Pl. 9, fig. 3.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.



10. Remains of an arm with the ossicles in their natural positions. Superomarginals no. 10 are small and wedge-shaped. There has been one spine on the terminal ossicle.

Pl. 7, fig. 6.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

11. An arm in White Chalk, with the ossicles almost in their natural relative positions. The size and appearance is almost as in the two preceding individuals. There has been one spine on the terminal ossicle.

Pl. 7, fig. 7.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

12. Remains of an individual in White Chalk. The ossicles of a part of an arm are in their natural relative positions. The size is about as in the preceding individual. Ornamentation consists of well separated spine-pits, two of which are, at least on one median superomarginal, markedly larger than the remainder.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

13. Remains of an individual described by BR. NIELSEN as *Recurvaster stevensensis*. BR. NIELSEN is in doubt whether his reconstruction with eight ossicles in each side of the arm is correct. An investigation shows that it is not. From his figure 3b on plate 2, it is seen that the superomarginals used in the reconstruction of the left-hand arm are no. 1, 3, 5, 6, 7, 8 and 9, and in the right-hand arm no. 2, 4, 5, 6, 7, 8, 9 and 10. The presence of the unused types of ossicles has been ascertained among the ossicles left over from the reconstruction. The particular individual has therefore had ten superomarginals, and ten inferomarginals in each side of the arm. Superomarginal no. 10 is small and wedge-shaped. The individual has been slightly larger than the three preceding. The ornamentation is peculiar in that some of the spine-pits are fused into short furrows. It may be remarked that the depressed border is to be seen on all the ossicles, even on the small wedge-shaped no. 10, and it is not, as BR. NIELSEN stated, wanting on the distal marginals. There have been three spines on the terminal ossicle.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

14. The associated remains of a very large individual. A number of the arm-ossicles were in their natural relative positions in the White Chalk. This is the largest individual found. There are ten supero- and inferomarginals in each side of the arm. Marginal no. 10 is well developed, and there is no small, wedge-shaped ossicle to be found distal to it; this is presumably because the individual is fully grown, and ossicle-formation has ceased. R:r as c. 70:45 mm. The ossicular angle of marginal no. 1 is c. 40°. The arms are

very strongly upturned. The superomarginals from no. 5 have met in the mid-line of the arm. Inferomarginals no. 3 and 4 have touched the adambulacral ossicles abactinally to the actinolateral ossicles. From no. 5 the inferomarginals have been completely in contact with the adambulacral ossicles without giving room for actinolateral ossicles. The ornamentation is peculiar in that a number of the spine-pits fuse forming short furrows. On the median superomarginals there are 1—3 spine-pits which are larger than the rest. The terminal ossicle has possessed one spine.

Pl. 8, fig. 1, pl. 9, fig. 2. Text Figure 1.

Upper Senonian. Stevns Cliff, north of Kulsti Rende.

15. Remains of an individual of about the same size as the preceding. Pedicellarian impressions are seen on a number of the marginals.

Upper Senonian. Skeldervig, Stevns Cliff.

16. Single ossicles of this species have been found at all the more prominent Senonian localities in Denmark, such as the cliffs of Stevns and Mön, Aalborg and Eerslev. Furthermore, a terminal ossicle with three small, rounded spines has been found in the Senonian at a depth of 79—80 m in a boring at Fakse.
17. A number of ossicles of this species are available from Rügen. Among these are the ossicles figured by SPENCER, pl. 14, fig. 2 (supero- and inferomarginals no. 2 of the left-hand arm in the figure) and pl. 15, fig. 3 and 5. Other ossicles of this species from Rügen are to be found in the collections of the Mineralogical Museum.
18. The type for the species is from the English Upper Senonian, near Trimingham. A number of single ossicles also come from this locality. The remains of an individual whose ornamentation consists of well-separated spine-pits, and on the median ossicles one or two spine-pits of larger size than the rest, has also been found here. This individual, which is in the Sedgwick Museum in Cambridge, is shown in fig. 2, of plate 8.

Occurrence.—Upper Senonian. Germany, England and Denmark.

### ***Recurvaster blackmorei* n. sp.**

Plate 6, fig. 1-7.

Diagnosis.—A *Recurvaster*, in which those surfaces of the median superomarginals which are directed towards the body-cavity, and the abactinal ossicles form an obtuse angle with each other, and whose superomarginals are provided with a few granules on the abactinal border. The surface of the abactinal ossicles bears a strong granulation.



Type.—The presently described individual from the Lower Senonian of England is the holotype. British Museum (N.H.).

Description.—The outline is stellate pentagonal, with curved sides and upturned arms. R:r as c. 55:40 mm. There have been ten superomarginals, and presumably the same number of inferomarginals in each side of the arm. The marginals decrease evenly in size from the middle of the side towards the tip of the arm. Superomarginals no. 1 and 2 have about the same length as breadth (squarish). They are evenly and strongly tumid. Their profile differs from the profile of the corresponding ossicles in *Recurvaster radiatus* in the obtuse angle formed by the surfaces directed towards the body-cavity and towards the abactinal ossicles. Ossicle no. 3, and those following, are less tumid, slightly oblique and curved, and the part directed towards the body-cavity becomes lower towards the tip of the arm (pl. 6, fig. 2.). Superomarginals 5–10 have met the corresponding ossicles from the opposite side of the arm in the mid-line, just as in *Recurvaster radiatus*. The marginals are thus strongly reminiscent of the corresponding ossicles of this species. The underside of the ultimate superomarginal is not preserved. This ossicle is of similar length to the preceding one, and seems to have had the same appearance as the corresponding ossicle in an adult *Recurvaster radiatus*. The ornamentation consists of the depressed border of the marginals, and the scattered spine-pits which are general on the slightly raised area of the median marginals in the genera *Metopaster* and *Recurvaster*. The marginals of the arms have no—or at most a few—spine-pits. There are small rugosities on the abactinal border of all the superomarginals. The abactinal ossicles are covered by strong, closely-placed granules, which form a uniform, not stellate ornamentation. There are spine-pits on the actinal ossicles.

Affinity with other species.—*Recurvaster blackmorei* is reminiscent of *Metopaster quadratus* in that the median superomarginals are nearly quadrate, and furthermore in that neither of the two previously figured individuals of *M. quadratus* have large ultimate superomarginals. The two species differ, however, in important matters: the outline, the character of the arm, the ornament of the marginal and abactinal ossicles, and the lack of abactinal swelling on the outermost part of the superomarginals. The species is distinguished from *Recurvaster radiatus* by the profile of the median ossicles, and furthermore by the granulation of the superomarginals and abactinal ossicles. It may apparently be considered as a separate species of the genus *Recurvaster*.

Material.—An individual in Dr. H. P. BLACKMORE'S collection in the British Museum (N.H.) is all that is known of the species; it comes from East Harnham, near Salisbury, and on the label it is referred to "*Metopaster cf. quadratus* SPENCER".



Occurrence.—Lower Senonian. Zone with *Actinocamax quadratus*. East Harnham, Salisbury, England.

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

Plate 8, fig. 3-13. Plate 9, fig. 4.

1876 *Goniaster mammillata* W. M. GABB, p. 178, fig. 2, 2b. Non fig. 2a.

1893 *Goniaster mammillata*, W. B. CLARK, p. 32, pl. 5, fig. 1a-h.

1907 *Pycinaster mammillatus*, SPENCER, p. 110.

pars 1913 *Metopaster mammillatus*, SPENCER, p. 114, pl. 10, fig. 16, pl. 15, fig. 8, 9, 10. Non pl. 10, fig. 9, pl. 15, fig. 11.

1943 *Recurvaster mammillatus*, BR. NIELSEN, p. 43, pl. 2, fig. 10-14, text fig. 23, 24.

Diagnosis.—A *Recurvaster* whose median superomarginals are tall and strongly tumid, the height being greater than the length, and the breadth.

Type.—The inferomarginal from the Vincentown limesand of New Jersey, U. S. A., figured by GABB in 1876, is the holotype. Apart from this ossicle, GABB figures a median superomarginal, 2b, and an other ossicle, 2a. The last differs in its ornamentation and probably belongs to an other species.

Description.—CLARK describes the find thus: "GABB mentions the discovery of about thirty detached marginal plates of this species. They differ widely in shape by reason of their position upon the margin, but among those examined the majority are higher than wide, and swollen on the outer surface. Certain of the plates show marked protuberances upon the general level of the plate. The surface of the plates is punctate, the small depressions being arranged in rows that cross one another at right angles".

The appearance of the ossicle figured, together with the description, in which it is stated that the marginals vary according to their position on the animal, seems to establish the present species as a *Recurvaster*.

Affinity with other species.—*Recurvaster mammillatus* differs from other known species of this genus by having tall, strongly tumid median superomarginals.

Material.—*Recurvaster mammillatus* is from the Vincentown limesand, New Jersey. This deposit is referred by some to the uppermost Cretaceous and by others to the Eocene; the fossils are in a number of respects similar to those of the Danian.

A part of a *Recurvaster* individual has been found in the limestone of Saltholm. SPENCER described this in 1913 as a typical "*Metopaster*

*mammillatus*". There are four superomarginals and four inferomarginals from the middle of the side (ossicles no. 1 and 2). SPENCER characterizes the species thus: "Body high. Supero-marginalia pronouncedly asymmetric, generally with a prominent tumidity which stretches well over the level of the abactinal surface of the disc and occupies the whole of the upper surface of the ossicle. Ornament coarse, that of the supero-marginalia often confined to the tumid portion of the plate".

The similarity between this and the American specimen is marked, and it is probably justified to refer them to the same, or to very closely related species. However, the spine-pits in the Danish ossicles are more irregularly distributed than is stated in the description of the American ossicles.

Apart from the individual mentioned by SPENCER, single ossicles of *Recurvaster* have been found in all zones of the Danian, not only as BR. NIELSEN stated, in the Upper Danian. They are particularly common in the Upper Danian. Both median and distal ossicles of *Recurvaster*-type have been found. The median superomarginals show a distinct variation in shape and ornament, from tall, slender, slightly swollen ossicles, with very few spine-pits, to shorter, more tumid ossicles with numerous spine-pits. These types seem to be connected by transitional forms, and it has not been possible to distinguish more than one species in the available material.

The distal arm ossicles which have been found, show that the structure of this species has been very similar to that of the Senonian species. The superomarginal series of the arm have met in the mid-line, without giving room for abactinal ossicles. The median inferomarginals of both the American, and the Danish specimen are very low and broad, almost cuboid.

A number of terminal ossicles very similar in appearance to those of the Senonian *Recurvaster radiatus*, have also been found in the Upper Danian of Saltholm, where ossicles belonging to the present species are particularly common. They have been provided with 1—3 powerful spines.

The Danish specimens are in the collection of the Mineralogical Museum.

Occurrence.—Vincentown limesand (Danian?), New Jersey, U.S.A. Lower and Upper Danian in Denmark.

#### ***Recurvaster communis* BR. NIELSEN.**

1943 *Recurvaster communis* BR. NIELSEN, p. 45, pl. 4, fig. 33.

Slightly oblique marginals of *Recurvaster*-type with the ornamentation general in *Recurvaster* and *Metopaster*. The ossicles are low, and broad.

BR. NIELSEN figures two ossicles from the Upper Danian of Herfølge. The ossicles are glued together as though they have been supero- and inferomarginal. They are, however, both inferomarginals. These particular ossicles do not differ visibly from the numerous inferomarginals of about the same size which are found in the Danian, and of which at least a number represent young individuals of those species of *Metopaster* and *Recurvaster* known from the Danian. The extent to which the present ossicles represent a separate species, as BR. NIELSEN meant, can hardly be decided unless a fortunate specimen of associated ossicles from a single individual should be found, throwing light on the problem.

#### Genus **Teichaster** SPENCER 1913.

**Diagnosis.**—Asteroids whose tall margin is limited by regular marginals which meet each other with parallel, or nearly parallel surfaces. The ornament of the outer surface consists of large, uniform, rather closely-placed spine-pits.

**Genotype.**—*Teichaster favosus* SPENCER, Senonian.

**Affinity with other genera.**—*Teichaster* is similar to the genus *Crateraster*, from which, according to SPENCER, it is descended. It has not, however, the characteristically lipped spine-pits of *Crateraster*, and it is also—at least in adults—without any granulation, whereas this ornament is common on the abactinal surface of marginals of *Crateraster*.

**Occurrence.**—One species from the Upper Senonian, and two from the Danian have been described.

#### **Teichaster favosus** SPENCER.

Plate 10, fig. 1-2.

1913 *Teichaster favosus* SPENCER, p. 122, pl. 12, fig. 14, 15, 16, 18, pl. 16, fig. 14, 15, 16.

1940 *Teichaster favosus*, WRIGHT, p. 240, pl. 14, fig. 12, 13.

1943 *Teichaster favosus*, BR. NIELSEN, p. 53, pl. 3, fig. 16, text fig. 7-8.

**Diagnosis.**—A *Teichaster* with rather short arms, and a rather broad, evenly rounded interr radial part. The surface of the marginals is covered by large, uniformly distributed spine-pits, which do not touch one another. In the outermost part of the arm the two series of superomarginals have met in the mid-line.

**Type.**—The individual from the Upper Senonian of Studland, Dorset, figured by SPENCER (1913) pl. 12, fig. 14, is the holotype. Collection of the British Museum (N.H.).



Description.—*Teichaster favosus* has rather short arms, which are connected by evenly curved sides. There is no sharp junction between the arm and the interradius. The superomarginals in the outermost part of the arm have met abactinally, without giving room for abactinal ossicles. This is seen in the holotype and also in the individual figured (from the actinal side, and laterally) by WRIGHT (1940). It is again seen in the less typical, presumably young, individual from the Danish White Chalk.

The ornamentation is always composed of uniform spine-pits, which are larger than the normal spine-pits of genera other than *Crateraster*. They are closely placed, without, however, touching. The Danish specimen suggests that there has been a granulation present in young individuals of *T. favosus*.

The type for this species is a small, badly preserved individual. The remains of distinctly larger individuals are figured by SPENCER (pl. 12, fig. 16, and pl. 16, fig. 14), and by WRIGHT (1940, pl. 14, fig. 12–13). WRIGHT states, p. 240, that both a larger and a smaller form are found at Trimmingham. The remains of both large and small individuals are also known from the Danish White Chalk. It is, however, not impossible that these can have belonged to the same species. The small, younger, individuals show a distinct similarity with *Crateraster quinqueloba* from which this species is thought to be descended, but they have, however, not the typical crater-shaped, or lipped spine-pits on the marginals. The pair of ossicles figured by SPENCER (1913, pl. 12, fig. 16, and fig. 15?) consists of an inferomarginal above, and a superomarginal below—this can clearly be seen by comparison with WRIGHT's specimen of this species. The ossicles shown by Spencer in fig. 14–16, also on pl. 16, are all inferomarginals. The impressions of the adambulacral ossicles with which it has been in contact are clearly seen on the inner side of the marginal shown in fig. 16.

The difference in shape, and appearance of the supero- and inferomarginals is often slight. However, the inferomarginals are relatively taller, and more slender; less curved, and with a more obtuse angle between the surfaces directed towards the body-cavity and the actinal ossicles.

Affinity with other species.—*Teichaster favosus* differs from the genus *Crateraster* by its ornamentation, and from other species of *Teichaster* in the shape of its marginals, especially the superomarginals.

Material.—*Teichaster favosus* is not common in the Danish White Chalk. The associated remains of an individual which were mentioned by BR. NIELSEN (1943, p. 54, text fig. 8), and which may presumably be interpreted as a young individual of this species, have been found in the White Chalk of Stevns Cliff. The abactinal and lateral surfaces of

the ossicle have formed a right angle with one another. The inferomarginals have been more evenly curved. The ornamentation consists of closely placed spine-pits, but on the abactinal part of the superomarginals there are also a few granules; this difference from the normal adult *Teichaster* is reminiscent of *Crateraster*. The abactinal surface has been covered by polygonal ossicles which are smooth, or bear a fine granulation. The actinal surface is covered by flat polygonal ossicles bearing spine-pits. The adambulacral ossicles have had a row of spines on the edge, and on the actinal surface there has been a powerful longitudinal keel provided with spines. Single marginals of larger, more typical individuals, have been found in the White Chalk.

No remains have been found in the Danian deposits, which can with certainty be referred to this species.

The specimens figured are in the collection of the Mineralogical Museum.

Occurrence.—Upper Senonian in England, Germany and Denmark.

### ***Teichaster anchylus* BR. NIELSEN.**

Plate 10, fig. 3-4.

1943 *Teichaster anchylus* BR. NIELSEN, p. 54, pl. 3, fig. 14, 15, 17, text fig. 9.

Diagnosis.—A *Teichaster* whose margin is high and whose ossicular angle is large. Both the supero- and inferomarginals are tall, slender, rather short and not robust.

Type.—The inferomarginal from the Lower Danian of Kagstrup, figured by BR. NIELSEN, 1943, pl. 3, fig. 14, is chosen as the type. Collection of the Mineralogical Museum.

Description.—Only single marginals are known of this species. There is only slight variation. The median part of the margin is formed of rather short, tall, slender ossicles of large angle; the end faces are parallel or nearly parallel. The superomarginals can, however, be slightly wedge-shaped: slightly longer above than below. The median superomarginals often bear a slight abactinal swelling. The facets towards the abactinal ossicles are concave, forming a sharply marked furrow along the abactinal border. The inferomarginal has a tall slightly concave lateral surface which curves round towards the actinal surface. The parts of the median superomarginals, and inferomarginals which are directed towards the body-cavity are very closely conformable with the outer surfaces of these ossicles. The ornamentation is composed of large, uniform, rather closely placed spine-pits which are slightly deeper on the abactinal and actinal surfaces.



Affinity with other species.—The tall, slender, not robust ossicles distinguish this species from other species of *Teichaster*.

Material.—A large number of marginals of this species have been found at Lower Danian localities.

The specimens figured are in the collection of the Mineralogical Museum.

Occurrence.—Lower Danian of Denmark.

### ***Teichaster retiformis* (SPENCER).**

Plate 10, fig. 5. Text fig. 6 h.

1913 *Teichaster favosus* var. *retiformis* SPENCER, p. 122, pl. 12, fig. 17, 19.

1943 *Teichaster retiformis*, BR. NIELSEN, p. 55, pl. 3, fig. 18-19, text fig. 10.

Diagnosis.—A *Teichaster*, whose superomarginals are tall, slightly tumid, and can be slightly wedge-shaped (longer above than below). The free abactinal-lateral surface slopes evenly. The median inferomarginals in the adult are very large, broad, and with a very compact appearance. The ornamentation is composed of large, uniform, closely placed spine-pits, which cover the whole surface.

Type.—The inferomarginal from the Upper Danian of Annetorp in Sweden, figured by SPENCER, 1913, pl. 12, fig. 17, is chosen as the type. Collection of the British Museum (N.H.).

Description.—This species is established on the basis of isolated ossicles of which the robust inferomarginals are particularly characteristic, and recognizable, and therefore chosen here as the type. This species can attain an appreciable size. The largest inferomarginal which has been found has a height and breadth of about 12 mm. (Text fig. 6h). While the superomarginals form an inclined upper edge to the animal, the inferomarginals are more angular, or even protruding, being bounded by lateral, and actinal outer surfaces which are almost at right angles. The lateral part of the surface can, especially in large specimens, be rather concave and recurved. The compact, relatively low inferomarginals, and the tall, slightly tumid superomarginals clearly separate this species from *T. favosus*. That similarity which is apparent from SPENCER's pl. 12, fig. 16 and 17 is due to the fact that in fig. 16 the supero- and inferomarginals are exchanged (see p. 69). On the other hand both the shape of the ossicle, and the appearance of the articulation facet in SPENCER's specimen pl. 12, fig. 17, and the appearance of the ossicle in a find of connected ossicles from the Danian near Legind in Denmark, confirm that SPENCER's figure of the present species is correctly orientated. When the ossicles of species of *Teichaster* are correctly orientated



is seen that the evolution of the genus is more complicated than was earlier assumed, and demonstrated by SPENCER's pl. 12, fig. 15—17.

The associated remains of a rather small individual of this species have been found in the Danian near Legind. These remains only constitute a small part of the individual, but give, however, certain information concerning the appearance of the species, just as they confirm the mutual connection between the supero- and inferomarginals. The median superomarginals are tall, slender and slightly tumid. The median inferomarginals are of about the same height, but more robust. The lateral surface is steeply inclined, and plane or even slightly concave; it passes rather sharply over into the actinal, slightly tumid part of the surface. A rather sharp ridge divides the surface directed towards the body-cavity from that directed towards the actinal ossicles. The shape of the articulation facets of the superomarginals of the arms shows that these have met in the mid-line. Their outer surface is evenly curved, not tumid. The inferomarginals of the arm are steep sided and slender, but more evenly curved than the median inferomarginals. They have met the ossicles of the ambulacral system in a plane surface without any ridge. The ornamentation is composed of rather large, uniform, closely-placed spine-pits. The abactinal surface has been covered by polygonal ossicles bearing rather large, round spine-pits similar in appearance to those of the marginals. The actinal surface has been covered by oblique, polygonal ossicles with the same ornamentation. The adambulacral ossicles have a concave surface towards the ambulacral groove. The actinal surface bears two extremely weak longitudinal furrows. Only very weak traces of small spines are seen on the edge of the ossicles. A single short and robust ambulacral ossicle from the distal part of the arm is present.

**Affinity with other species.**—The very large and robust median inferomarginals distinguish this species from other species of *Teichaster*.

**Material.**—A single individual, and a number of marginals of this species have been found.

The individual figured is in the collection of the Geological Survey, Denmark.

**Occurrence.**—Upper Danian. Sweden and Denmark.

#### Genus **Pycinaster** SPENCER 1907.

Synonym: *Pycnaster* SLADEN 1891.

**Diagnosis.**—Asteroids with a relatively small disc and slender, but robust arms. The margin is broad, and formed of very tall, powerful

ossicles, which are often slightly irregular, and more or less wedge-shaped in appearance. The surface directed towards the body-cavity is rough. The inferomarginals are often displaced in relation to the superomarginals; the line of junction between supero- and inferomarginals being a zig-zag. Polygonal ossicles cover the abactinal surface.

Genotype.—*Pycinaster angustatus* (SLAHEN) is the genotype. Senonian.

Historical.—The genus *Pycinaster* was established as an independent genus by SLADEN (1891) under the name *Pycinaster*; this was, however, preoccupied, and was replaced by the name *Pycinaster* by SPENCER in 1907.

Occurrence.—The genus is represented by three Jurassic and seven Cretaceous species.

### ***Pycinaster crassus* SPENCER.**

Plate 10. Fig. 6-7.

1907 *Pycinaster crassus* SPENCER, p. 96, pl. 29, fig. 1-5.

1913 *Pycinaster crassus* SPENCER, p. 125, pl. 11, fig. 16-17, pl. 16, fig. 1-6.

1915 *Pycinaster lamberti* VALETTE, p. 35, fig. 11.

?1915 *Pycinaster crassus*, VALETTE, p. 38, fig. 13.

?1935 *Pycinaster crassus*, MERCIER, p. 12, pl. 1, fig. 4.

?1943 *Pycinaster crassus*, BR. NIELSEN, p. 56, pl. 3, fig. 20-21.

Diagnosis.—A *Pycinaster* with powerful marginals, the breadth of which is more than half the height. The marginals are smooth. The distal marginals have a pair of marked projections on the lateral surface.

Type.—The part of an arm from the Upper Chalk of Kent, figured by SPENCER (1907), pl. 29, fig. 2, is the holotype. British Museum (N.H.).

Description.—The remains of a few individuals of this species are known, they show that the arms have been rather narrow, but powerful. The marginals are large, broad and massive. On the abactinal surface of the arm the marginals have only been separated by a single row of abactinal ossicles (SPENCER 1907, pl. 29, fig. 2). The median marginals are tall and wedge-shaped, with a slight abactinal swelling. The arm-ossicles are lower, with a slightly curved surface. The marginals are smooth, but in the arm they are generally provided with two or three large spine-pits. The superomarginals are more slender, and rounded below, while the inferomarginals are similar, but more slender and rounded above, so that the marginals of the two series have not met each other in a simple facet; they have been wedged in between one



another, so that the junction between the two series has been a zig-zag. In the outer part of the arm a single row of large hexagonal ossicles has covered the abactinal surface, these have met the superomarginals which taper here above and below.

*P. lamberti*.—VALETTE (1915) described a new species, *P. lamberti*, and stated (p. 37) that this species differed from the type-specimen of *P. crassus* in the following characters: "1. les marginales brachiales de cet individu sont bien plus petites que celles du *Pycinaster Lamberti*. 2. Elles ont de rares rugosités sur leur face supérieure qui ne sont pas à comparer avec celles de mon espèce. 3. De plus, entre les deux séries de marginales, on voit une rangée de petites plaques en ovales irréguliers dont je n'aperçois pas les moindres traces sur le bras du *Pycinaster Lamberti*, cependant bien plus développé. 4. L'épaisseur des marginales de ce dernier est incomparablement plus grande que dans le type du *Pyc. crassus* représenté par SPENCER".

The difference in appearance of the two rows of ossicles in VALETTE's specimen, and particularly the appearance of the two lowermost (median) ossicles in his fig. 11.1 show, however, that the individual is on its side, so that the ossicles on the left of VALETTE's figure are superomarginals, and these on the right inferomarginals. The following objections to VALETTE's interpretation can be made: 1. The absolute size of an individual can have no value as a species characteristic when one is not certain of the animal's growth-stage. 2. According to VALETTE's figure, the rugosity of the French specimen agrees very well with that of the English and other specimens which I have had occasion to examine. 3. As the French specimen only includes one side of an arm the large, abactinal ossicles are not seen. 4. The breadth of the marginals as stated by VALETTE, is really their height. After being correctly orientated *P. lamberti* seems to agree very exactly, even in details, with SPENCER's type-specimen of *Pycinaster crassus*.

Affinity with other species.—*Pycinaster crassus* is, particularly in its smooth, very broad and robust median marginals distinguishable from other species of this genus.

Material.—Only a few ossicles of *Pycinaster* have been found in the Danish White Chalk. Among these are a few large, smooth, robust ossicles which must be referred to *P. crassus*. The remains of two individuals with an ornamentation of weak spine-pits have been found. BR. NIELSEN (1943, pl. 3, fig. 20—21) figures two ossicles from one of these individuals. It must be said concerning these, as well as the single ossicles figured by VALETTE (1915), and MERCIER (1935) that the ornamentation makes it doubtful whether they have belonged to the present species.

The ossicles figured are in the collection of the Mineralogical Museum.  
Occurrence.—Senonian. France, England, Denmark.



***Pycinaster danicus* BR. NIELSEN.**

Plate 10, fig. 8.

1943 *Pycinaster danicus* BR. NIELSEN, p. 57, pl. 4, fig. 1-5.

**Diagnosis.**—A *Pycinaster* whose marginals are covered on the outer surface by delicate, closely placed spine-pits. The median marginals are slender, tall and wedge-shaped (longest above); they can bear a few larger spine-pits on the abactinal part. The marginals of the arm are slightly tumid, constricted above and below. The supero- and inferomarginals have been partly wedged in between one another. One or two large raised spine-pits can be found on the surface of the arm marginals.

**Type.**—The ossicle from the Upper Danian of Fakse, figured by BR. NIELSEN (1943) pl. 4, fig. 1—2, is chosen as the type for this species. Collection of the Mineralogical Museum.

**Description.**—This species was described by BR. NIELSEN from single ossicles belonging to the genus *Pycinaster*. Together, they give a natural picture of a *Pycinaster*, and there is reason to believe that this combination is correct. There is a piece of limestone containing a large number of asteroid ossicles in the collection of the Geological Survey of Denmark; it comes from Helligkilde in Jutland. The majority of these ossicles are from a *Pycinaster danicus*, but there are also a few ossicles of other species and genera. It is therefore possible that this accumulation of ossicles, like that mentioned previously (p. 14), must be interpreted as a pellet of indigestible parts. This find confirms BR. NIELSEN's description of *Pycinaster danicus*; it includes a number of marginals from the arm and two from the interradius. The arm marginals are strongly reminiscent of those of *Pycinaster crassus*. The surface is slightly tumid, and covered by delicate, closely placed spine-pits, and one or two larger protuberances, or spine-pits. The inferomarginals are evenly rounded actinally, while they are constricted towards the superomarginals. The superomarginals and inferomarginals meet each other in a zig-zag line, and are partly wedged in between one another. The superomarginals of the arm are like the inferomarginals, but are constricted both above and below.

The median marginals are tall, oblique, wedge-shaped ossicles, longer above than below, and more slender than in *Pycinaster crassus*. The surface is provided with delicate spine-pits, or is nearly smooth. Several large spine-pits can be found on the narrow dorsal surface.

The surface of the marginals which is directed towards the body-cavity is uneven.

Impressions of pedicellariae are seen on some of the marginals.

**Affinity with other species.**—*Pycinaster danicus* differs from *P.*

*crassus* in having narrower marginals, and delicate spine-pits covering the surface. It differs from other species of *Pycinaster* in the large raised spine-pits on the marginals of the arm.

**Material.**—The associated marginals of a single individual, and a few marginals from the Upper Danian are all that is known of this species.

The individual figured is in the collection of the Geological Survey, Denmark.

**Occurrence.**—Upper Danian in Denmark.

### ***Pycinaster cornutus* W. RASMUSSEN.**

Plate 10, fig. 9.

1945 *Pycinaster cornutus* W. RASMUSSEN, p. 423, pl. 9, fig. 12-14.

**Diagnosis.**—A *Pycinaster* whose tall marginals are broader above, and have borne a single extraordinarily large spine which has been attached in a spine-pit which has covered all, or nearly all of the abactinal part of the ossicle.

**Type.**—The ossicle from the uppermost Danian near Svanemöllen, Copenhagen, figured by the author, 1945, pl. 9, fig. 12, is chosen as the type for this species. Collection of the Mineralogical Museum.

**Description.**—Only single ossicles of the above described type, and their corresponding spines are known. It is therefore difficult to form a conception of the original appearance of the whole animal. The ossicles are as a rule oblique or wedge-shaped, and are reminiscent of the ossicles from the base of the arm in *Chomataster*. However, the median ossicles in *Pycinaster* also have a similar oblique appearance. The part of the ossicle directed towards the body-cavity is somewhat uneven, and is thereby reminiscent of the genus *Pycinaster*.

**Affinity with other species.**—*Pycinaster cornutus* differs distinctly from all other known asteroids by its large abactinal spine.

**Material.**—Single superomarginals of this species have been found at a number of Upper Danian localities.

Collection of the Mineralogical Museum.

**Occurrence.**—Upper Danian. Denmark.

### ***Pycinaster aff. cornutus* W. RASMUSSEN.**

Plate 10, fig. 10.

A few ossicles of a *Pycinaster* which is very much like *P. cornutus* from the Upper Danian have been found in the White Chalk of Mön

Cliff. They differ, however, in that the outer surface is quite smooth, and without spine-pits except for the large facet which covers the greater part of the abactinal surface, and has borne a very powerful spine. The uneven surface towards the body-cavity agrees exactly with that generally found on ossicles of *Pycinaster*.

Occurrence.—Upper Senonian. Mön Cliff.

***Pycinaster? rosenkrantzii* (BR. NIELSEN).**

Plate 10, fig. 11. Text fig. 6 f.

1943 *Pycinaster rosenkrantzii* BR. NIELSEN, p. 58, pl. 4, fig. 6-9.

Diagnosis.—An asteroid whose interradial marginals have been tall, evenly tumid, more or less wedge-shaped and abactinally swollen. The marginals of the arm have been distinctly lower, evenly tumid, and not wedge-shaped. The outer surface of the marginals has been covered by closely placed spine-pits. There is often also a larger facet for the attachment of a spine at the junction between the lateral and abactinal parts of the outer surface. The surface directed towards the body cavity is evenly curved and without irregularities.

Type.—The ossicle from the Upper Danian of Teglhølm, Copenhagen, figured by BR. NIELSEN, 1943, pl. 4, fig. 6 is chosen as the type for this species. Collection of the Mineralogical Museum.

Description.—Only single marginals with the above described appearance are known. There is a distinct difference between the marginals of the arm and those of the interradius on the disc, as is the case in species of the genera *Pycinaster* and *Chomataster*. *P. ? rosenkrantzii* is like the genus *Pycinaster* in the somewhat wedge-shaped outline of the median superomarginals, which are longer above than below. On the other hand, none of the marginals have that uneven surface directed towards the body-cavity which is characteristic of this genus. The arm marginals are very much like the marginals of *Chomataster*, and the ossicle chosen as the type is somewhat reminiscent of the ossicle at the base of the arm in the *Chomataster* individuals reconstructed by WRIGHT (1940, p. 243). It is therefore possible that the present species should be referred to the genus *Chomataster*.

Affinity with other species.—*P. ? rosenkrantzii* differs markedly from other species of *Pycinaster* in the shape of the marginals. The arm marginals are reminiscent of the corresponding ossicles of *Chomataster acules*, while the median superomarginals are more strongly tumid than in this species. The median superomarginals can sometimes be reminiscent of *Teichaster anchylus*, but are most often more tumid.



**Material.**—Only a few marginals have been found which can with certainty be referred to this species.

The ossicle figured is in the collection of the Mineralogical Museum.

**Occurrence.**—Upper Danian, Denmark.

### Genus *Chomataster* SPENCER 1913.

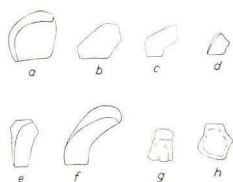
**Diagnosis.**—Asteroids with long slender arms which are relatively sharply demarcated from the disc. The marginals are tall, and the ornament of the outer surface consists of closely placed spine-pits. Paxillae have supposedly covered the abactinal side.

**Genotype.**—SPENCER chose *Chomataster acules* as the genotype. Senonian.

**Description.**—This genus was established by SPENCER (1913, p. 128) on the basis of single ossicles which could not be described in greater detail. WRIGHT (1940, p. 243) has later described two individuals which he refers to the same genus. They have long slender arms. The superomarginals meet each other abactinally over the whole length of the arm, without giving room for abactinal ossicles. There is a rather broad interradian portion between the arms.

**Affinity with other genera.**—SPENCER considered the genus *Chomataster* to be closely related to the also recent genus *Calliderma*. It seems to differ from this in the relatively sharp demarcation of the narrow arms from the body. The outline of the animal in WRIGHT's reconstruction shows similarity with the genera *Nymphaster*, *Ophryaster* and *Huræaster*. The first two are distinguished from one another by the structure of the abactinal side: the abactinal ossicles in the radius of *Nymphaster* do not meet completely, but allow the passage of papulae, whereas the abactinal ossicles of *Ophryaster* are stated completely to cover the abactinal side without permitting the passage of papulae. The abactinal side is not known in the genotype for *Chomataster*. The genus *Calliderma*, from which *Chomataster* is presumed to be descended, has typical paxillae. The abactinal side of *Chomataster wrighti*, to be described below, has similarly been covered by typical paxillae, and the same is true of *Chomataster marginatus* (SLADEN). The genus *Huræaster* is stated by VALETTE to be characterized by having an unpaired terminal ossicle. Such an ossicle is, however, found in all asteroids, although it has not yet been found in some of the incompletely known fossil species. None of these other genera have the sharp distinction between the disc and the arm which characterizes WRIGHT's reconstruction of *Chomataster*.

**Occurrence.**—Five species of this genus are known from the Senonian and Danian.



Text Figure 6.

**Chomataster acules** SPENCER.

Plate 10, fig. 12. Text fig. 6 e.

1913 *Chomataster acules* SPENCER, p. 128, pl. 12, fig. 28, 31, pl. 16, fig. 8-13.1943 *Chomataster acules*, BR. NIELSEN, p. 59, text fig. 12.1945 *Chomataster brünnichi* W. RASMUSSEN, p. 422, pl. 9, fig. 10-11.

**Diagnosis.**—A *Chomataster* whose steep-sided superomarginals have a large facet for a powerful spine at the junction between the lateral and abactinal parts of the surface.

**Type.**—The ossicle from the Upper Senonian on Rügen in Germany, figured by SPENCER, 1913, pl. 16, fig. 8, is the holotype. Collection of the British Museum (N.H.).

**Description.**—SPENCER stated that the superomarginals of this species are quite smooth, apart from the one very large spine-pit. The author therefore established a new species, *C. brünnichi*, including marginals from the Danian, whose surface is covered by closely placed spine-pits. Later investigations have, however, shown that ossicles of exactly the same appearance are also found in the Senonian White Chalk near Aalborg, and on Stevns, Mön and Rügen. Ossicles of *Chomataster* are, however, not very common in either the Senonian or Danian of Denmark. The rather shallow spine-pits can in some cases be indistinct and difficult to see, according to the state of preservation, but they seem never to be wanting. An investigation of the ossicles from Rügen described by SPENCER (1913) gave the following result: the inferomarginal pl. 12, fig. 28, has distinct spine-pits, the superomarginal has weak, but distinct spine-pits. Weak spine-pits can be seen on most of the ossicles in the reconstruction pl. 12, fig. 31. The ossicle pl. 16, fig. 8 (holotype) is very slightly uneven, but spine-pits cannot be discerned. The ossicles pl. 16, fig. 10, 11 and 12 have very weak, but, however, distinct spine-pits. The ossicle pl. 16, fig. 13 is apparently smooth. It may therefore be assumed that the surface of all these marginals has primarily been covered by closely placed, weak spine-pits, and *C. brünnichi* must therefore be taken as identical with *C. acules*.

No specimen of connected ossicle of this species is known, and it is therefore impossible to form a certain impression of the appearance of

the species, but it seems, however, to have had long, slender arms, and has presumably had a similar outline to WRIGHT's reconstruction of this genus.

Affinity with other species.—*Chomataster acules* differs from other species of *Chomataster* in the height, and steep-sidedness of the median superomarginals, and by the powerful abactinolateral spine.

Material.—Single marginals of this species are known from the majority of Danish Senonian and Danian localities.

The ossicle figured is in the collection of the Mineralogical Museum.

Occurrence.—Upper Senonian in England and Germany. Upper Senonian and Danian in Denmark.

### ***Chomataster præcursor* SPENCER.**

Text fig. 6 a.

pars 1913 *Chomataster præcursor* SPENCER, p. 128, pl. 12, fig. 27.  
non pl. 12, fig. 26, 30.

non 1943 *Chomataster præcursor*, BR. NIELSEN, p. 59.

Diagnosis.—A *Chomataster* whose short and compact marginals have an evenly tumid surface which is covered by closely placed spine-pits.

Type.—The pair of marginals from the Senonian of Köpinge in Sweden, described by SPENCER, 1913, pl. 12, fig. 27 is the holotype. Collection of the Geological Institute, Lund.

Affinity with other species.—This species is established on the basis of single ossicles from Köpinge; they unfortunately do not permit a more exact description of the animal. Asteroids from England and Denmark, with marginals which have a quite different profile, and whose connection with this species is very doubtful, have been referred to it. These ossicles are described below as *Chomataster spenceri*.

Occurrence.—*Chomataster præcursor* is only known with certainty from Köpinge in Sweden. Upper Senonian, Campanien.



**Chomataster spenceri** n. sp.

Plate 10, fig. 13-14. Text fig. 6 c.

?pars 1913 *Chomataster præcursor* SPENCER, p. 128, pl. 12, fig. 26.  
non pl. 12, fig. 27.

1943 *Chomataster præcursor*, BR. NIELSEN, p. 59.

**Diagnosis.**—A *Chomataster* whose superomarginals have a low, but steep lateral surface which passes sharply over into a broad sloping abactinolateral surface. The outer surface is only slightly tumid; it is covered by delicate, closely placed spine-pits. The surface directed towards the body-cavity conforms to the outer surface of the ossicle.

**Type.**—The superomarginal from the proximal part of an arm shown on pl. 10, fig. 13 is the holotype. It is from the Upper Senonian of Mön Cliff. Collection of the Mineralogical Museum.

**Description.**—The superomarginals have a steep lateral, and a long, sloping abactinolateral outer surface. The surface directed towards the body-cavity is conformable with these. The supero- and inferomarginals meet in a rather narrow facet, and the median superomarginals also meet the abactinal ossicles in rather narrow facets. The superomarginals of the arm have met each other in the mid-line with a low plane surface. The ornamentation is composed of closely placed circular spine-pits.

The appearance of the plates described is so characteristic that they will always be easily recognizable. Most of the ossicles from the English Cretaceous which SPENCER determined as *Chomataster præcursor* seem to belong to this species, and the same is true of the ossicles from the White Chalk of Denmark mentioned by BR. NIELSEN, 1943, p. 59.

The ossicles are very similar to the ossicles of the individual figured by WRIGHT, 1940, pl. 15, fig. 3, and pl. 16, fig. 5, which is interpreted as a transitional form between *Calliderma smithiae* and *Chomataster "præcursor"* (*C. spencerii* of the present work). It is likely that the *Chomataster* here described has had a very similar structure.

**Affinity with other species.**—This species is distinguished from the above mentioned form described by WRIGHT, in that the superomarginals have no abactinal portion forming an angle with the sloping abactinolateral part of the surface.

**Material.**—A few associated remains of a small individual of this species, together with single ossicles, have been found in the White Chalk of Denmark. None of these finds gives the possibility of making a certain reconstruction of the animal.

The specimens figured are in the collection of the Mineralogical Museum.

**Occurrence.**—Upper Senonian. England, Denmark.

**Chomataster wrighti** n. sp.

Plate 11, fig. 1-2. Text fig. 6 d.

**Diagnosis.**—A *Chomataster* with long, slender arms, whose superomarginals meet each other in the mid-line of the arm over its whole length. The disc is bounded by an interrarial margin which is rather sharply demarcated from the arm. The interrarial superomarginals are hardly tumid, but the other superomarginals are strongly tumid. The ornamentation is composed of spine-pits. A granulation, and large, crater-like depressions can also occur on the superomarginals.

**Type.**—The individual shown on pl. 11, fig. 1, is the holotype. It comes from the Upper Senonian White Chalk of Stevns Cliff. Collection of the Mineralogical Museum.

**Description.**—The outline agrees with that which characterizes WRIGHT's reconstruction of two individuals of this species, and it is on the basis of this very characteristic shape that the present species is referred to the genus *Chomataster*. The species is named after C. W. WRIGHT.

In the interradius there are two superomarginals (no. 1), whose almost square outer surface is not curved, and is only slightly tumid (Text fig. 6d). They have met the abactinal surface above with a somewhat concave facet. The following superomarginal (no. 2) has met the abactinal ossicles in the same way, but it is more strongly tumid, oblique and wedge-shaped, and has formed the transition to the arm. In some individuals it is larger than the other superomarginals, and is reminiscent of the corresponding ossicles in WRIGHT's reconstructions. The superomarginals of the arm are all tall and strongly tumid, although the size and degree of tumidity decrease towards the tip of the arm. The arm has been almost quadratic in cross-section. The supero- and inferomarginals are directly above one another, and they meet in a rather narrow facet. The inferomarginals are evenly curved; they are narrow on the arm, and have met the adambulacral ossicles over the whole length of the arm. The inferomarginals are larger and broader along the interrarial margin of the body.

The ornamentation is composed of closely placed, circular spine-pits, which can be slightly larger on the abactinal swelling of the superomarginal than on the remainder of the surface. A strong granulation is furthermore found among the spine-pits of some individuals, and large, crater-like spine-pits can be found on the swollen portion of the superomarginals. The abactinal side has been covered by paxillae. The actinal side has been covered by flat, oblique, polygonal ossicles with spine-pits. The adambulacral ossicles have a rather characteristic appearance as the proximal and distal ends are sloping, and there is a



pointed process on the proximal end, which has protruded into the ambulacral groove. The ornamentation of the outer surface is difficult to see, but there seems to be a row of six spines on the edge. A furrow and a keel run on the ventral surface parallel with the edge. On the keel, and on the rest of the surface there have been a few spines or setae in two rows. The ambulacral ossicles have no remarkable characteristics. Impressions of pedicellariae have been observed on a few of the marginals.

**Affinity with other species.**—The peculiar outline of *Chomataster wrighti* is reminiscent of WRIGHT's reconstruction of two individuals which are referred to this genus. On the other hand, the ornamentation is different from that in the other species referred to this genus, and the superomarginals of the arm are more tumid than in these species.

**Material.**—Single ossicles of this species have been found in the White Chalk of Mön, Stevns, near Aalborg, and at several other Danish localities, as well as on Rügen in Germany. The remains of six individuals have also been found on Stevns Cliff. These individuals have been found partly as associated ossicles, and partly as small arm fragments with marginals, ambulacral and adambulacral ossicles in their natural positions. On the basis of this material it has been a simple matter to reconstruct the animal in spite of the great difference between the ossicles of the disc and the arms.

All the specimens are in the collection of the Mineralogical Museum.

**Occurrence.**—Upper Senonian. Germany, Denmark.

### ***Chomataster marginatus* (SLADEN).**

Text fig. 6 b, 6 g.

1891 *Nymphaster marginatus* SLADEN, p. 18, pl. 8, fig. 4.

1907 *Nymphaster marginatus*, SPENCER, p. 116, text fig. 11.

1913 *Ophryaster marginatus*, SPENCER, p. 130.

**Diagnosis.**—A *Chomataster* with long, slender arms, and an evenly rounded interradius. The superomarginals have met each other in the mid-line over the whole length of the arm. The ornamentation of the marginals consists of widely separated spine-pits. The abactinal side is covered by typical paxillae. Pedicellariae are uncommon.

**Type.**—The individual from the Lower Senonian of Kent, England, figured by SLADEN, 1891, pl. 8, fig. 4, is the holotype. Collection of the British Museum (N.H.).

**Description.**—SLADEN (1891) writes in the description of this



species, p. 19, "The remains of a few isolated plates are preserved on the abactinal area of the fossil figured. They are all small and out of position, and are not available for description".

An examination of the holotype has, however, shown that there have been typical paxillae on the abactinal side. The species can therefore neither be referred to *Nymphaster* nor to *Ophryaster*. The outline of the animal, and the profile of the superomarginals with a short, steep lateral side, a long sloping abactinolateral portion and a narrow horizontal abactinal portion are very strongly reminiscent of the reconstruction of a *Chomataster* individual shown by WRIGHT (1940) pl. 16, fig. 5. However, the rather sharp distinction between disc, and arms is wanting in *C. marginatus*. The ornamentation of the marginals consists of well separated, uniform spine-pits.

Affinity with other species.—This species differs from the other species of *Chomataster* in the ornamentation of the marginals with scattered, well separated spine-pits.

Occurrence.—Lower Senonian. Bromley, Kent, England.

#### Genus *Ophryaster* SPENCER 1913.

Diagnosis.—Asteroids whose long slender arms pass evenly over into the broadly rounded interradiial part. The marginals are evenly curved, and slightly tumid. They have an obliquely placed facet directed towards the abactinal ossicles; this forms nearly a right angle with the facet directed towards the body cavity. The ornamentation is composed of spine-pits, which are, however, wanting in a zone along the abactinal border of the superomarginals. The abactinal side is covered by closely placed, polygonal ossicles which only extend in a narrow zone into the arm. Paxillae are not present. Long, low, bivalve pedicellariae are common.

Genotype.—*Ophryaster oligoplax* (SLADEN). Senonian.

Affinity with other genera.—The genus *Ophryaster* is stated by SPENCER to differ from *Nymphaster* in that the abactinal ossicles are closely placed, giving no room for papulae.

Occurrence.—Apart from *O. oligoplax* (SLADEN), the species *O. magnus* SPENCER and possibly *O. lunatus* (S. WOODWARD) also belong to this genus. *O. marginatus* (SLADEN) is mentioned here under the genus *Chomataster*, because of the character of the abactinal, and marginal ossicles. Senonian.

**Ophryaster magnus** SPENCER.

Plate 11, fig. 3.

1913 *Ophryaster magnus* SPENCER, p. 130, pl. 16, fig. 20-27.1943 *Ophryaster oligoplax*, BR. NIELSEN, p. 60, pl. 4, fig. 10-23,  
text fig. 13-15.

Diagnosis.—An *Ophryaster*, with superomarginals whose ornamentation consists of rather large, closely placed spine-pits, which are only wanting in an extremely narrow zone along the abactinal border.

Type.—The ossicle from the Upper Senonian of Rügen, figured by SPENCER, 1913, pl. 16, fig. 25, is the holotype. British Museum (N.H.).

Description.—There is a completely even transition from the narrow arm to the broadly rounded interradiar part of the body. R:r is measured as c. 90:45 mm. The superomarginals in the outermost part of the arm (from no. 10) have met in the mid-line of the arm. The median superomarginals are long, low and rather narrow with a slightly curved, squarish outer surface. The surfaces directed towards the abactinal ossicles, and towards the body-cavity are typical for the genus, and they form almost a right angle with each other. The superomarginals of the arm have a rounded outline towards the mid-line of the arm, and a more vertical facet towards the abactinal ossicles. The distal superomarginals are markedly shorter, and more tumid than the proximal. They are relatively broader, and the abactinal part of the outer surface is larger than the lateral. The surface of the inferomarginals is evenly curved, and not tumid. The ornamentation is composed of closely placed spine-pits which are often rather large particularly on the superomarginals. On the distal marginals the spine-pits are replaced by a granulation on the abactinal and actinal sides. There is only a narrow smooth zone along the abactinal border of the superomarginals.

The abactinal side has been covered by rather tall, more or less six-sided ossicles with a smooth surface. The actinal side has been covered by large, flat, oblique, polygonal ossicles bearing spine-pits. At the tip of the arm there has been a terminal ossicle with an irregular granulation of the surface, and spines at the apex. The adambulacral ossicles are irregularly bevelled at the ends, and are provided with a strong proximal, pointed extension which has protruded into the ambulacral groove. They bear a row of ten spines on the edge. There is a furrow in the actinal surface parallel with the edge, but otherwise this surface has been perfectly smooth. The ambulacral ossicles have had a marked extension where these ossicles have met one another over the ambulacral groove. The ossicles of the oral region are unknown. Long, bivalved pedicellariae are found on a number of the inferomarginal and actinal ossicles.



Affinity with *O. oligoplax*.—*Ophryaster magnus* is established on the basis of single ossicles which only differ from *oligoplax* to an extremely slight extent. Only the coarser ornamentation of the marginals, and the narrow abactinal border of the superomarginals seem to separate the two species. In none of them is the variation sufficiently well known.

Material.—The remains of three individuals, which agree with one another in appearance, and single ossicles of *Ophryaster* have been found in the White Chalk of Denmark. The most complete of the individuals is mentioned as *Ophryaster oligoplax* by BR. NIELSEN. The ornamentation of the ossicles seems, however, better to agree with the single ossicles described as *Ophryaster magnus*. BR. NIELSEN showed (1943, pl. 4, fig. 19) a reconstruction of the outermost part of the arm. The author has undertaken a more complete reconstruction of the Danish individual, which gives a better impression of the appearance of the animal and forms the basis of the present description.

The individuals are in the collection of the Mineralogical Museum.

Occurrence.—Upper Senonian. Rügen in Germany. Mön and Aalborg in Denmark.

### Family *Stauranderasteridae* SPENCER,

Genus *Stauranderaster* SPENCER 1907.

Diagnosis.—Asteroids whose ossicles have an ornamentation composed of scattered spine-pits restricted to the central part of the outer surface of the ossicle. The primary abactinal ossicles are very large and strongly tumid.

Genotype.—*Stauranderaster boysii* (FORBES). Senonian.

Affinity with other genera.—*Stauranderaster* is similar to *Valettaster* in the powerful development of the abactinal ossicles, but has a margin of well developed supero- and inferomarginals.

Occurrence.—Ten species are known, ranging from Cenomanian to Danian.

#### *Stauranderaster gibbosus* SPENCER.

1913 *Stauranderaster gibbosus* SPENCER, p. 135, pl. 13, fig. 11.

?1943 *Stauranderaster gibbosus*, BR. NIELSEN, p. 62.

Diagnosis.—A *Stauranderaster* whose arms are distally swollen. The primary abactinal ossicles are large with a strongly tumid outer surface whose ornamentation consists of a depressed border, and scat-



tered spine-pits. The superomarginals of the arm are large and evenly tumid, the inferomarginals are very low. The ornament of the marginals is, as in *Metopaster*, composed of scattered spine-pits and a depressed border.

Type.—As the type for this species SPENCER chose an individual collected by FABER and preserved in the British Museum (N.H.). The individual is unfortunately not figured, but an arm fragment of an other individual is shown by SPENCER (1913) pl. 13, fig. 11.

Material.—SPENCER does not mention this species from Denmark, but some ossicles of *Stauranderaster* from Denmark are, according to BR. NIELSEN (1943) p. 62, referred to this species. These particular ossicles are of a divergent appearance, and no asteroid remains have been found in Denmark which can with certainty be referred to this species.

Occurrence.—Senonian. England.

### ***Stauranderaster pyramidalis* SPENCER.**

Plate 10, fig. 15.

1913 *Stauranderaster gibbosus* var. *pyramidalis* SPENCER, p. 135, pl. 13, fig. 12-13, ? pl. 16, fig. 30.

1943 *Stauranderaster pyramidalis*, BR. NIELSEN, p. 63.

Diagnosis.—A *Stauranderaster* whose large abactinal ossicles have a semi-spherical or, more commonly bell-shaped outer surface. The ornamentation of the surface is usually composed of scattered spine-pits, which may be lipped. There can also be a weak rugosity on the peripheral part of the ossicle, together with a narrow somewhat depressed border.

Type.—The ossicle from the Lower Danian of Stevns Cliff figured by SPENCER, 1913, pl. 13, fig. 12—13 is chosen as the type. Collection of the Mineralogical Museum.

Description.—Only the large dorsal ossicles are known with certainty. The type specimen agrees exactly with this diagnosis, and the same is true of the majority of ossicles from the Danian. Only in a very few cases are the spine-pits without lips, or the ossicles without a rugosity.

Affinity with other species.—*Stauranderaster pyramidalis* differs from *S. gibbosus* in the much more powerful tumidity of the abactinal ossicle and presumably also in the ornamentation.

Material.—There are only rather few single marginals from the Danian which can with certainty be referred to this species.

Collection of the Mineralogical Museum.

Occurrence.—Lower and Upper Danian in Denmark.

**Stauranderaster mixtus** BR. NIELSEN.

Plate 10, fig. 16.

1943 *Stauranderaster mixtus* BR. NIELSEN, p. 63, pl. 4, fig. 26-28.

**Diagnosis.**—A *Stauranderaster* whose ossicles have a narrow depressed border and within this are smooth, or provided with very few spine-pits. Tall marginals, which are presumably from the swollen distal part of the arm, are found. Abactinally rounded, or strongly tumid ossicles do not seem to have been present. Long, bivalve pedicellariae are commonly present on the marginals.

**Type.**—The individual from the Upper Senonian of Stevns Cliff figured by BR. NIELSEN (1943) pl. 4, fig. 26—28 is the holotype. Collection of the Mineralogical Museum.

**Description.**—It is not possible to reconstruct the animal from the individual and ossicles known. Apart from the ossicles described by BR. NIELSEN there are found a few small ambulacral, and adambulacral ossicles, which do not, however, permit description.

**Affinity with other species.**—*Stauranderaster mixtus* is, like the species *coronatus*, *senonensis* and *speculum*, smooth, but it is separated from these by apparently not having had strongly swollen, or “breast-plate-shaped” ossicles.

**Material.**—Only very few single ossicles, and the remains of one individual have been found of this species.

Collection of the Mineralogical Museum.

**Occurrence.**—Upper Senonian. Stevns Cliff, Mön Cliff and Eerslev in Denmark.

**Stauranderaster miliaris** BR. NIELSEN.

Plate 10, fig. 17.

1943 *Stauranderaster miliaris* BR. NIELSEN, p. 63, pl. 4, fig. 35.

**Diagnosis.**—A *Stauranderaster* whose ossicles have an ornamentation consisting of a narrow depressed margin, and within this an area bearing a close and delicate granulation of the central area.

**Type.**—The superomarginal from the Upper Danian of Herfølge, figured by BR. NIELSEN (1943) pl. 4, fig. 35, is the holotype of this species. Collection of the Mineralogical Museum.

**Description.**—Only single plates of this species are known; they give no certain information concerning the appearance of the species.

**Affinity with other species.**—*Stauranderaster miliaris* is reminiscent of *S. squamosus* in its ornament, this form also bearing a granula-

tion. The marginals of *S. squamosus* are, however, imbricate, while the ossicles indicate that this has not been the case in *S. miliaris*.

Material.—A number of single ossicles of this species have been found.

Collection of the Mineralogical Museum.

Occurrence.—Lower and Upper Danian in Denmark.

### ***Stauranderaster speculum* BR. NIELSEN.**

Plate 10, fig. 18.

1943 *Stauranderaster speculum* BR. NIELSEN, p. 64, pl. 4, fig. 36.

Diagnosis.—A *Stauranderaster* which has had ossicles of a peculiar irregular outline, "breastplate-shaped". The outer surface of the ossicle has formed a small, smooth projecting portion.

Type.—The abactinal ossicle from the Upper Danian of Rejstrup, figured by BR. NIELSEN (1943) pl. 4, fig. 36, is the holotype. Collection of the Mineralogical Museum.

Affinity with other species.—*Stauranderaster speculum* is like *S. coronatus* in its smooth ossicles of very variable shape, but it differs in the limited extent of the strongly raised, smooth, central portion.

Material.—A number of single marginals of this species have been found.

Collection of the Mineralogical Museum.

Occurrence.—Lower and Upper Danian. Denmark.

## **Order Paxillosa PERRIER.**

### **Family Astropectinidae GRAY.**

Genus **Astropecten** GRAY 1840.

Synonym: *Lophidiaster* SPENCER 1913.

Diagnosis.—Asteroids with rather long and slender arms, the marginals short, and often provided with a powerful ridge. The abactinal side is covered by paxillae.

Genotype.—*Astropecten aurantiacus* (LINNÉ). Recent.

Description.—The arm is rather slender, and the adambulacral ossicles meet the inferomarginals over the greater part of the length of the arm. The abactinal side is covered by typical paxillae which also extend into the arm.

The Cretaceous individual which SPENCER used as the foundation for the genus *Lophidiaster* in 1913 was originally referred to this genus.



*Lophidiaster* was stated to differ from *Astropecten* in that the abactinal surface is covered by closely placed ossicles, not paxillae. According to VALETTE (1915, p. 62) the genotype for *Lophidiaster* is *L. ornatus*. The holotype for this species is the individual figured by SPENCER 1905, pl. 25, fig. 2. In this individual "Practically only the marginal plates are preserved". No ossicles, which could be abactinal ossicles can be seen in the figure. Of the remaining four individuals of *Lophidiaster ornatus* which I have had the chance of seeing, only two show abactinal ossicles. In both of these they have the form of typical paxillae, and I find it therefore dangerous to refer these individuals to any genus other than *Astropecten*. SPENCER's view of the structure of the abactinal side is based upon an individual of *A. ? pygmaeus*, which has, however, not been chosen as the genotype. MERCIER (1935, p. 45) characterizes *Lophidiaster* as species of Astropectinidae with a very narrow keel on the marginals. Such a diagnosis would, however, not be practical, as it would necessitate a division both of the recent genus *Astropecten*, and the genus *Lophidiaster* as SPENCER conceived it, and it would for that matter not form a sharp boundary. It seems therefore to be necessary to regard *Lophidiaster* as a synonym of the generic name *Astropecten*.

Occurrence.—This genus is represented by a number of species from the Jurassic to Recent.

#### ***Astropecten ornatus* (SPENCER).**

1905 *Astropecten* sp. SPENCER, p. 90, pl. 25, fig. 2.

1913 *Lophidiaster ornatus* SPENCER, p. 138, pl. 11, fig. 19 and 22.

?1937 *Astropecten betzensteinensis* LEHNER, p. 171, fig. 1.

1940 *Lophidiaster ornatus*, WRIGHT, p. 245.

1943 *Lophidiaster ornatus*, BR. NIELSEN, p. 66, text fig. 16.

Diagnosis.—An *Astropecten* whose short marginals have a powerful ridge, which—at least on some of the ossicles—forms a lateral wing. The surface of the ridge on the inferomarginals bears a granulation. There are spine-pits on the superomarginals. The superomarginals reach their greatest height nearest the disc.

Type.—SPENCER chose the individual from the Upper Greensand figured by SPENCER 1905, pl. 25, fig. 2 as the holotype for *Lophidiaster ornatus*. Collection of the Sedgwick Museum.

Description.—There are several fragments of individuals in WRIGHT's collection which may be referred to this species. They show that the arm has been narrow. The superomarginals have also made room for abactinal paxillae in the arm.

Occurrence.—This species is known from much of the English chalk, and is also found in the Senonian near Båstad in Sweden. It is not known from Denmark.

***Astropecten postornatus* (W. RASMUSSEN).**

Plate 10, fig. 21.

1945 *Lophidiaster postornatus* W. RASMUSSEN, p. 424, pl. 9, fig. 16.

Diagnosis.—An *Astropecten* whose short marginals have a rather powerful ridge which does not form lateral wings. The surface of the ridge bears a granulation on the inferomarginals, and is provided with spine-pits on the superomarginals. The superomarginals reach their greatest height near the outer margin.

Type.—The inferomarginals from the Upper Danian, near Svane-møllen, Copenhagen, figured by the author, 1944, pl. 9, fig. 16, is the type. Collection of the Mineralogical Museum.

Description.—This species was described by the author (1945) thus, p. 424: "Supra-marginalia: the proportions length/width/height are measured at 1,7/4,0/2,8 mm. The free surface consists of a lateral and abactinal part, which unite in an arch. The ornamentation consists of large rather deep spine-pits.

Infra-marginalia are of the same dimensions or a little lower. The free surface has an even and straight course from the actinal to the lateral border. The height of the ridge is about 0.5 mm. The ornamentation consists of a rather pronounced granulation".

Affinity with other species.—This species seems to be very close to *A. ornatus*, but differs by lacking the wing-like lateral extension of the ridge, and also by the rather great breadth. That the superomarginals are highest near the outer margin is also a difference. The same characters separate the species from *A. mirabilis* (VALETTE). The Lower Miocene *Astropecten salomacensis* VALETTE has marginals of similar form but differing in the extraordinarily fine granulation of the ridge.

Material.—Rather a large number of single marginals of this species are available.

Collection of the Mineralogical Museum.

Occurrence.—Upper Danian. Denmark.

***Astropecten punctatus* (BR. NIELSEN).**

Plate 10, fig. 20.

1943 *Lophidiaster punctatus* BR. NIELSEN, p. 67, pl. 4, fig. 38.1945 *Lophidiaster punctatus*, W. RASMUSSEN, p. 423, pl. 9, fig. 15.

Diagnosis.—An *Astropecten* whose supero- and inferomarginals have an ornamentation of spine-pits.

Type.—The marginal from the Upper Danian of Saltholm figured by BR. NIELSEN, 1943, pl. 4, fig. 38, is the holotype. Collection of the Mineralogical Museum.

Description.—As practically all the supero- and inferomarginals of *Lophidiaster*-type which are found in the Danian have spine-pits, but no granulation, they were referred to an independent species, *Lophidiaster punctatus*. Apart from single ossicles, there is only one specimen of associated ossicles from a single individual, this is, however, so badly preserved that it has not been possible to observe the character of the abactinal ossicles or those of the ambulacral system. Only marginals and the terminal ossicle are known.

Material.—There is a rather large number of marginals of this species from the Danian of Denmark.

Collection of the Mineralogical Museum.

Occurrence.—Lower and Upper Danian in Denmark.

***Astropecten ? pygmæus* (SPENCER).**

Plate 10, fig. 19.

1913 *Lophidiaster pygmæus* SPENCER, p. 139, 150, pl. 11, fig. 20, 21, pl. 16, fig. 17—19.1915 *Lophidiaster pygmæus*, VALETTE, p. 62, fig. 21.1943 *Lophidiaster pygmæus*, BR. NIELSEN, p. 66.

Diagnosis.—Asteroids whose marginals are provided with a ridge, as in the genus *Astropecten*. Ornamentation is weak, or wanting. Both supero- and inferomarginals may, however, be rugose.

Type.—The pair of ossicles from the Upper Senonian of Rügen, figured by SPENCER, 1913, pl. 11, fig. 20, is the holotype for the species. Both the supero- and the inferomarginal have a distinct ridge. The ornament on the superomarginal consists of spine-pits together with a granulation on the uppermost part of the ossicle. Collection of the British Museum (N.H.).

Description.—This species is described on the basis of material from Rügen. A number of single ossicles from the same locality, and from Danish White Chalk localities must be referred to this species.



Where ornament can be discerned on these ossicles, it seems to have been rugose both on supero-, and on inferomarginals. SPENCER (1913, p. 139) states that there is a specimen in the BRYDONE Collection (Cambridge) which shows that the abactinal side has been covered by flat ossicles, not paxillae. There is therefore the possibility that this species has not belonged to the genus *Astropecten*. It is unfortunately not possible to base the genus *Lophidiaster* on this species as according to VALETTE (1915, p. 62) *A. ornatus* is the genotype.

Material.—A small number of marginals of this species from the White Chalk of Denmark.

Collection of the Mineralogical Museum.

Occurrence.—Upper Senonian. Germany and Denmark.

## Order Spinulosa PERRIER.

### Family Sphaerasteridae SCHÖNDORF.

Genus *Valettaster* LAMBERT 1914.

Synonym: *Tholaster* SPENCER 1913.

Diagnosis.—The body is covered by large irregularly rounded ossicles, which have been almost embedded in the body so that only a very small flattened portion forms the exposed surface. The sides of the ossicles form irregularly sloping surfaces so that the ossicle has the form of a truncated irregular cone.

Genotype.—*Valettaster occellatus* (FORBES) is chosen as the type for this genus Senonian.

Historical.—The genus *Valettaster* was established as an independent genus under the name *Tholaster* by SPENCER in 1913. This name was, however, preoccupied and was replaced by the name *Valettaster* by LAMBERT in 1914.

Description.—Only single ossicles, and very incomplete remains of individuals of this genus are available. The arms and the outline of the body are therefore unknown. There do not appear to have been distinct marginals present, and the genus is therefore referred to the order Spinulosa.

Occurrence.—Three species are known from the Senonian and Danian, and one from the Jurassic.

**Valettaster ocellatus** (FORBES).

Plate 10, fig. 22—23.

1848 *Oreaster ocellatus* FORBES, p. 468.1850 *Oreaster ocellatus* FORBES (in DIXON), p. 329, pl. 21, fig. 13.1905 *Pentaceros ocellatus*, SPENCER, p. 85, pl. 25, fig. 4.1913 *Tholaster ocellatus*, SPENCER, p. 138, pl. 13, fig. 24.1915 *Valettaster ocellatus*, VALETTE, p. 57, fig. 19.1943 *Valettaster ocellatus*, BR. NIELSEN, p. 65, pl. 4, fig. 29.

**Diagnosis.**—A *Valettaster* whose actinal and abactinal ossicles bear a fine granulation on the flattened surface. On some of the ossicles the granulation becomes developed as a lineal ornament, but most often the arrangement is more irregular, giving the impression of a madreporite.

**Type.**—The individual figured by FORBES, 1850, pl. 21, fig. 13, is the holotype.

**Description.**—There are a number of specimens of *V. ocellatus*; they only show an extremely slight variation. The ossicles have been partly imbricate, and the sloping sides often bear eyelike depressions. The above mentioned variation in ornamentation can be met with in the same individual. The ambulacral ossicles are very short and broad.

**Material.**—Numerous ossicles of this species have been found both in the Senonian and Danian of Denmark. The remains of five individuals have in addition been found in the Danish White Chalk.

Collection of the Mineralogical Museum.

**Occurrence.**—Lower and Upper Senonian in England. Upper Senonian and Danian in Denmark.

**Valettaster granulatus** BR. NIELSEN.

Plate 10, fig. 24.

1943 *Valettaster granulatus* BR. NIELSEN, p. 65, pl. 4, fig. 37.

**Diagnosis.**—A *Valettaster* whose ossicles bear large scattered granules on the flattened outer surface.

**Type.**—The ossicle from the Upper Danian of Saltholm, figured by BR. NIELSEN, 1943, pl. 4, fig. 37 is the holotype. Collection of the Mineralogical Museum.

**Description.**—Only single ossicles are known; they do not allow a more exact description.

**Affinity with other species.**—*Valettaster ocellatus* can also have a simple granulation of the exposed surface, but the granulation is much coarser in the case of *V. granulatus*.

Material.—Only a small number of ossicles of this species have been found.

Collection of the Mineralogical Museum.

Occurrence.—*Valettaster granulatus* is now known not only from the Upper Danian, but also from the Lower Danian. That it is not found in the Senonian confirms the impression that it is an independent species.

## Order Forcipulata PERRIER.

### Family Asteriidae GRAY.

Genus *Asterias* LINNÉ 1766.

#### *Asterias* ? sp.

Plate 10, fig. 25.

1943 *Asterias* sp., BR. NIELSEN, p. 67, pl. 4, fig. 30—31.

In the genus *Asterias* and several other recent genera the abactinal surface is covered by a network formed of irregular stellate abactinal ossicles. The marginals are only poorly developed and inconspicuous. The only larger ossicle is the terminal ossicle, which forms the tip of the arm.

A number of irregular stellate abactinal ossicles of the above mentioned type have been found in the Danish White Chalk. In addition there have been found a number of rather large terminal ossicles, which may have belonged to a species without large marginals. The proximal articulation facet on some of the terminals has met four ossicles on each side whose size has decreased actinally. The actinal side is made up of a large furrow which forms the outermost part of the ambulacral groove. The ossicle is egg-shaped, with a delicate and regular granulation of the surface. A few slender spines seem sometimes to have been attached at the tip. These ossicles have been mentioned by BR. NIELSEN as *Asterias* sp.; very similar ossicles have been found in the Lower Danian near Kagstrup. In the collections of the British Museum similar ossicles from Lower Cretaceous deposits are found.

Occurrence. Upper Senonian. Mön, Aalborg.



## Ophiuroidea.

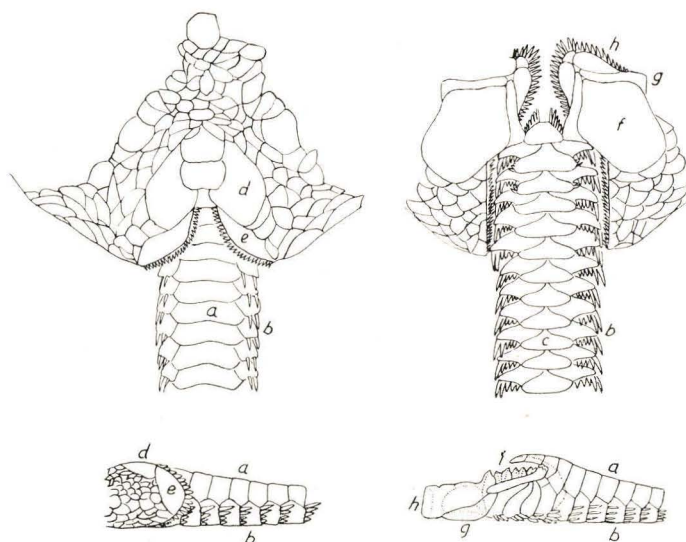
Ophiuroids are free-living, star-shaped, generally five-armed echinoderms, whose long thin arms are sharply demarcated from the round disc-shaped body. The arms are jointed, and provided with tube-feet which project through two rows of pores on the ventral sides of the arms. There is no open ambulacral furrow.

### Anatomy and Ontogeny of the Ophiuroids.

The ophiuroids, like the asteroids, have a skeleton composed of calcareous plates, which, under the microscope are seen to have a spongy, reticulate structure.

The arms are supported within by a row of calcareous plates reminiscent of a vertebral column. Each of the vertebrae is the product of the fusion of a pair of ambulacral plates. The vertebrae have a more or less disc-shaped appearance, and are provided with bosses on the central part of the articulating surface, while on the outer part muscles have been attached which bound the vertebrae two and two. The appearance of the vertebrae is different in the different groups of Brittle Stars. In individuals belonging to the order Euryalae there is found a raised hour-glass shaped boss on the central part of the articulating surface; this is vertically placed on the proximal face, and horizontally on the distal. This form of joint makes both horizontal and vertical movement and inrolling of the arms possible for the animals concerned. In the remaining Brittle Stars, Ophiurae, the connection between the joints is more complicated and allows mainly horizontal arm movement. The elevated central portion which has made up the vertebral articulation in these forms is composed of three bosses and three sockets. On the proximal face are found a median upper, and two lateral lower bosses. On the distal face, inversely, are found a median lower and two lateral upper bosses. Opposite the bosses on the one face are found sockets in the other. On the dorsal and ventral sides of the vertebrae are found two furrows, the dorsal and ventral furrows. Each of the two

lateral portions of the vertebra form an attachment for upper and lower muscles which connect the vertebrae of adjacent joints. Vertebrae are formed at the tip of the arm, and it is therefore here that the youngest vertebrae are found. In the course of growth the appearance of the vertebra is markedly changed. This change can be determined by following the change in appearance of the vertebrae from the tip to the



Text Figure 7.

*Ophiura texturata*. Dorsal, ventral, lateral, and lateral with the disc ossicles removed. Partly after Lütken and Berry.  $\times 2$ .

a, dorsal arm plate. b, lateral arm plate. c, ventral arm plate. d, radial shield. e, genital plate. f, oral shield. g, adoral shield. h, jaw. i, vertebra.

base of an arm of a single individual. The small distal vertebrae are relatively long and more or less cylindrical, while the large vertebrae from the proximal portion of the arm are relatively much shorter and discoid, with thin wing-like lateral parts. The proximal face of the innermost vertebra diverges a little in appearance from the articulation faces of the other vertebrae, and has four bosses. It articulates with a complicated pair of plates, the jaw plates, which bound the mouth and bear small calcareous spines, teeth.

The body and arms are as a rule covered by a dermal skeleton of calcareous plates. Each arm joint is encircled by four plates, a dorsal arm plate, a ventral arm plate, and on each side of the arm a lateral arm plate. The lateral arm plates generally bear spines on their distal edge, and the spines are most often directed outwards, but in some forms they are depressed. The plates are imbricate and like the vertebrae are formed at the tip of the arm. The small, youngest, lateral

arm plates are long and slender, while the older, which are found in the proximal part of the arm, are relatively shorter. The innermost arm plates are partly covered by the disc skeleton, and have therefore an appearance which differs somewhat from that of the other arm plates.

The aboral and adoral surfaces of the disc are generally covered by a number of plates. The most conspicuous among the aboral plates are the two radial shields which lie at the base of each arm. There are further found a central plate and one or two circels of primary aboral

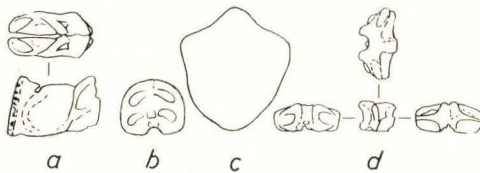


Fig. 8. Isolated ossicles of Ophiuroids from Denmark.  $\times 5$ .

a, jaw. Senonian, Eerslev. b, 1. vertebra, adoral surface. Danian, Saltholm. c, oral ossicle. Danian, Kagstrup. d, vertebra, „Platyarthra“-like. Senonian, Aalborg.

plates which often, especially in young individuals, are distinguished by their size. The genital plate, which lies near the margin of the disc, is separated from the arm by the genital slit. On the adoral surface are seen, apart from the jaw plates already mentioned, two adoral shields marginal to each jaw, and between these are seen the oral shields, one of which is the madreporite.

In some species parts of the superficial skeleton are vestigial. This is so, for example, with the dorsal and ventral arm plates in species of *Ophiomusium*, as well as with the arm plates and most of the disc plates in species of the order Euryalae.

The larvae of the Brittle Stars are small, generally pelagic animals whose appearance does not disclose their relation to the adults of the animal group under discussion. Metamorphosis occurs after the larval stage, and the young ophiuroid appears, but even this bears only slight resemblance to the adult animal. During growth both the number of the arm joints and the size of the skeletal parts are increased, and at the same time the form of the skeleton is altered, but, at the apex of the arm joints of juvenile form continue to be developed. The adult ophiuroid thus has arm joints representing all the growth-stages through which the oldest joint has passed.

## Historical.

Ophiuroids occur only infrequently in most of the deposits of the past, and this applies not least to those of Cretaceous and Tertiary times where they are nowhere common in even tolerably well preserved



condition. They have therefore left even less trace than the Asteroids in the literature of palaeontology.

In an account of the fossils of the North German Cretaceous in 1840—41, F. A. ROEMER described two Brittle Stars, *Ophiura serrata* and *Ophiura granulosa*, both from the Hanover district. These are the first described species of ophiuroid from the Cretaceous, but in the same year (1840) F. VON HAGENOW published part II of his monograph of the Cretaceous fossils of Rügen. In this he similarly describes two Brittle Stars, *Ophiura (Aspidura) granulosa* and *Ophiura (Aspidura) subcylindrica*. As will be seen, one of these names had already been employed by ROEMER, and HAGENOW's species *Ophiura granulosa* is therefore invalid.

In 1869 LÜTKEN made a critical evaluation of the generic determination of fossil ophiuroids.

In the following years Cretaceous ophiuroids were treated in several works, both in Europe and in America.

Part IV of SLADEN and SPENCER'S monograph of British Fossil Echinoderms from the Cretaceous appeared in 1907. In this SPENCER discusses seven ophiuroids from British localities, and of these six form the basis of new species.

VALETTE, in 1915, described seven species from the chalk around Sens in France, and five of these species were new.

The first reference to Brittle Stars in Danish geological literature is in 1926 when BR. NIELSEN described a new species, *Ophiomusium danicum*, in a paper on the limestone of Saltholm.

In 1932 KLINGHARDT published a biological investigation of living and fossil Brittle Stars, and in this discusses a Cretaceous form. KLINGHARDT attempts to explain the regular, symmetrical placing of the arms in these individuals, but the investigation is of a provisional character and does not result in any conclusion.

CHARLES T. BERRY published (1938) an investigation of Upper Senonian Brittle Stars from Holland. The material concerned is composed exclusively of single skeletal elements, which are described with great precision. They originate from four zones of the chalk, and on the basis of their relative frequency in these zones BERRY draws conclusions as to their mutual relations. This method is, however, for several reasons, not directly practicable. 1. Both arm plates and vertebrae vary very much in appearance from the proximal to the distal part of the same arm. 2. Several species and genera can have skeletal parts which it is difficult or impossible to separate from one another. This can apply both to vertebrae and to arm plates, and can give rise to a fundamental displacement of the relative frequency. 3. In some genera certain skeletal parts have been vestigial or absent. This applies, for instance,

to the ventral and dorsal arm plates in species of *Ophiomusium*, and arm plates in species of the order Euryalae. The radial shields of many Ophiuroids are also quite small and inconspicuous, and would scarcely be recognised as radial shields if found fossil. 4. Lastly, the more robust plates would be more easily preserved and, particularly, more easily found and recognized than the small, delicate plates. It is in fact the case that lateral arm plates of *Ophiomusium* are commonly found in the Danish Cretaceous deposits, while the rather small vertebrae of this genus are only occasionally found. In accumulations of associated plates from an individual it has been possible easily to identify and isolate the robust lateral arm plates, but extremely difficult to find an even tolerably complete and recognizable vertebra. In one instance I broke open a well preserved arm in order to extract the vertebra, but found this to be almost unrecognizable because of crystallization. The tendency to crystallization in Echinoderms is due to the single-crystal character of the ossicles. These sources of error will make most difficult any work for which only single plates are available. BERRY was not sufficiently attentive to these sources of error, when he combined the plates from the Dutch chalk on a statistical basis. In the species *Asteronyx valkenburgensis* vertebrae of the type found in *Asteronyx* (Euryalae) are combined with a radial shield (only three specimens found), and with lateral arm plates, in spite of the fact that such are wholly vestigial among the recent representatives of this group. In *Platyarthra jekeria* lateral arm plates of the type found in *Ophiomusium* are combined with a type of vertebra which could not possibly fit between these lateral arm plates. To the same species are also referred large, well developed dorsal and ventral arm plates, in spite of the fact that the lateral arm plates are of a type which has completely encircled the arm, and at most allowed quite small, vestigial dorsal and ventral arm plates. In the species *Dolicharthra belemnica* one finds a vertebra of a type which possibly can have belonged to *Ophiomusium* combined with rather small radial shields in spite of the fact that *Ophiomusium* at the present time has very large, well developed radial shields. To this species are further referred both dorsal, ventral and lateral arm plates of types which are not found in *Ophiomusium*. From our knowledge of recent ophiuroids it must be regarded as more likely that arm plates which have belonged to the vertebrae referred to *Asteronyx* have never been identified, and that the plates signified by BERRY as D, M and possibly T, have belonged to a species of the genus *Ophiomusium*. In 1942 BERRY described, similarly on the basis of single plates, an ophiuroid, *Ophiomusium stephensoni*, from the Vincentown limesand in America. Also in this case plates are united which can scarcely have



originated in the same species. The species will be further discussed in the following under *Ophiomusium danicum*.

From the Danish side BR. NIELSEN in his last years resumed the study of Cretaceous ophiuroids, but neither concluded his investigations, nor left notes on this subject. The investigations of which the following is an account are based chiefly upon the fossil material collected by Dr. K. BRÜNNICH NIELSEN.

## Material.

The occurrence of ophiuroid plates in Danish sediments has previously been regarded as very infrequent, and a significant material was first produced by BR. NIELSEN by systematic collection from the Cretaceous deposits over a period of many years. This collection is mainly composed of single plates, but includes a few accumulations of disarticulated plates from single individuals, and also a few fragments of arms with the plates still in their natural relative positions. Only by using material of the last mentioned type as a starting point is it possible to obtain a clear impression of those species which have lived in the Danish chalk seas.

The reason for there being proportionately so few specimens of Brittle Stars available is their small size. Normally one would not notice these small skeletal fragments while collecting fossils, and BR. NIELSEN's material is the result of the handpicking of large samples after they had been washed and sieved. There is therefore reason to believe that a more copious material will be available when the microfossils of these deposits have been collected and investigated.

A large amount of White Chalk was subjected to a natural process of washing by wave action after a cliff-fall on Mön in 1948, and many fossils were then washed out of the chalk. Mr. K. SKOU, while collecting fossils in this material for Professor A. ROSENKRANTZ, found a part of an arm of a Brittle Star, and at the same place the author found several collections of plates originating in single individuals.

A number of rather well preserved remains of Brittle Stars have been found in the English chalk, and an investigation of this material has contributed largely to the identification of the remains from Danish localities.



## Palaeontology.

An investigation of fossil Brittle Stars shows that these form characteristic species which it is possible to find and recognize from place to place. The shape and ornament of the skeletal parts are admirably suited to the application of palaeontological method. It is markedly more difficult to arrange the fossil species in natural genera. Those features on which one bases the zoological classification are particularly the skeleton about the mouth, and the armament of teeth and papillae. These characteristics can practically never be observed in fossil forms, and all generic determinations of Brittle Stars must therefore be accepted with the greatest reservation. Diagnoses and detailed descriptions of the genera will therefore be omitted. There can, however, in some genera, be secondary characters which are so characteristic that one may attach importance to them, and these are mentioned in the following. The introduction of special genera, based on the appearance of arm vertebrae or other frequently found parts of the skeleton, for fossil species, will hardly be advantageous as long as the number of fossil species is so small and there is no possibility of relating such a classification to recent ophiuroids.

It is a noteworthy fact that in the three granulated species discussed in the following the granulation shows strongly varying coarseness.

### Order Ophiuræ J. MÜLLER.

#### Family Ophiolepidæ LJUNGMAN.

#### Genus *Ophiomusium* LYMAN 1869.

Disc and arms covered by large, strong plates. Dorsal and ventral arm plates and spines are small and vestigial. Tentacle pores are not found on the free portion of the arm. The structure of the arm in this genus is so characteristic that it is certainly with justification that a number of fossil species are referred to the genus. Jurassic—Recent.

#### *Ophiomusium danicum* BR. NIELSEN.

Plate 12, fig. 1—6.

1926 *Ophiomusium danicum* BR. NIELSEN, p. 11, fig. 2—4.

?pars 1942 *Ophiomusium stephensoni* C. BERRY, p. 393, pl. 60, fig. 1, 4, 11, 22, 23, 24.

1942 *Ophiomusium rahbeki* nom. nud., BR. NIELSEN, p. 66.

Diagnosis.—An *Ophiomusium* with smooth plates. The radial shields are large, rounded triangular. Dorsal and ventral arm plates are

quite small and vestigial. The lateral arm plates are very well developed and have encircled the arm, near the distal edge they bear the impressions of four weak spines.

Type.—The remains of an individual from the Upper Danian of Saltholm, Denmark depicted by BR. NIELSEN in 1926 is the holotype. Collection of the Mineralogical Museum.

History.—*Ophiomusium danicum* was established by BR. NIELSEN in 1926 on the basis of the remains of a single individual. It has not since been mentioned in the literature. In 1942 BR. NIELSEN mentioned (p. 66) the discovery of a flint impression of an *Ophiomusium* which he named *rahbeki*. This species has, however, not been described, and the individual in question seems to have belonged to *Ophiomusium danicum* (Pl. 12, fig. 1.).

In the same year, 1942, C. BERRY established a species, *Ophiomusium stephensoni*, on the basis of single plates. Some of these plates seem to represent a species which is identical with, or very closely related to *O. danicum*.

Description.—The greater part of the aboral surface has been covered by the large radial shields. These have a triangular outline with rounded corners, and the length is about one and a half times the breadth. The plate is slightly tumid, and arched round the short axis. The surface is smooth. It has a depressed margin and bevelled edge. The inner, or adoral surface is nearly smooth, but can, however, bear a weak longitudinal ridge, and there is a prominent portion along the aboral margin which bears two bosses; it is here that the plate has its greatest thickness. No other disc plates are known with certainty. There have, however, been found other disc plates at localities where only this species is common (Saltholm and Svanemöllen). These are supposed to belong to the species, and are, from comparison with the species *Ophiomusium granulosum*, described below, interpreted as inter-radial marginal plates. The interradial marginal plate is short and broad, with a strongly rounded, triangular outline. It is tumid, and strongly arched so that the adoral (?) part forms nearly a right angle with the lateral. The sides are slightly convex. The lower (?) margin is straight, or with a weak embayment. The inwardly directed surface conforms to the outer, or is a little less curved, so that the plate has its greatest thickness in the middle.

The arm has an almost circular cross-section, and is completely encircled by the strong lateral arm plates which have been in contact on both dorsal and ventral sides, leaving room for only quite small dorsal and ventral arm plates. It appears from the shape of the lateral arm plates that these small, vestigial plates have been present, but the plates themselves have not been found, and are not visible in the individual found on Saltholm. It is quite inconceivable that such a small



plate should be found isolated, and identified, but on the flint impression referred to by BR. NIELSEN in 1942 there is confirmation that the plate has been present.

The lateral arm plates are semi-cylindrical in form; the plate being curved about the arm. The slightly depressed proximal margin has been hidden by the preceeding plate. The free part is smooth and slightly tumid. The distal margin is sharp, and near it are seen the weak impressions of four spines. The lateral arm plates from the right and left sides meet dorsally and ventrally in large articulations. Only the distal ends diverge slightly giving room for the vestigial dorsal and ventral arm plates. The two articulating surfaces lie in the same plane. The upper articulating surface is very large, and of nearly triangular outline as it stretches well in towards the centre of the arm. The ventral articulating surface forms a narrower border along the ventral margin of the plate. The concave inner surface of the plate, which faces the vertebra, is separated into two by a strong comb which stretches from the projection of the dorsal to the distal part of the ventral articulating surface. In the distal concavity, just behind the edge of the plate, is found a row of six small bosses which have been in contact with corresponding bosses on the depressed proximal part of the outer side of the following plate. BR. NIELSEN has erroneously given the number of these bosses as ten, and interpreted them as the impressions of spines.

If one holds two lateral arm plates together in their natural position it is seen that there has only been room for a very small vertebra between the robust plates. The vertebrae must have been long and thin like the distal arm vertebrae of other ophiuroids. It has been constricted in the middle opposite the strong combs of the lateral plates. No vertebrae which can be thought to have belonged to this species have been found, in spite of its frequent occurrence. This is, however, hardly surprising when one takes into consideration that no similar small vertebrae which can have belonged to the distal parts of the arms of other species in the Danian have been found. On the other hand large vertebrae from the proximal parts of the arms of these species occur with the expected frequency. Even in the Senonian White Chalk, where the condition of preservation is much better, only very few well preserved vertebrae of this small size have been found.

Affinity with *Ophiomusium stephensoni*.—*Ophiomusium stephensoni* was established by C. BERRY on the basis of finds of single plates of ophiuroids in the Vincentown limesand of New Jersey. Among these plates are a radial shield, a lateral arm plate, and an inter-radial marginal plate all of which, according to BERRY's description and figures, correspond exactly with the respective plates of *O. danicum* in appearance, and it may therefore be assumed that the two species are



identical or very closely related. BERRY further refers large, well developed dorsal and ventral arm plates, vertebrae and jaws found in the Vincentown limesand to this species. It clearly follows, however, from the shape of the lateral arm plates that the species cannot have had dorsal or ventral arm plates, or vertebrae of the given appearance, and these plates must therefore have belonged to other species. Whether the jaw plates have belonged to this species cannot be determined.

The Vincentown limesand has been referred by various geologists to the uppermost Cretaceous, but most American geologists now include it in the Eocene.

**Affinity with other species.**—*Ophiomusium danicum* differs from those species of the genus which are discussed in the following in the sharp distal margin and evenly arched surface of the lateral arm plates which is not sharply differentiated from the proximal part enclosed by the preceding joint; further by the smooth surface without granulation.

**Material.**—The Danish specimens are in the collection of the Mineralogical Museum. 1. Holotype. Remains of an individual showing arm fragments and a radial shield. Upper Danian, Saltholm in Denmark. Pl. 12, fig. 2.

2. Flint impression showing the dorsal surface of a small individual which has presumably belonged to this species. Found by RAHBEK, and mentioned by BR. NIELSEN in 1942 as *Ophiomusium rahbeki*. Dull black flint, presumably Danian. Erratic in Denmark. Pl. 12, fig. 1.

3. Several isolated lateral arm plates and radial shields found in Denmark. Upper Danian, Saltholm, Copenhagen (Svanemølle Bay).

4. To the same species possibly belong lateral arm plates, radial shields and inter-radial marginal plates from the Vincentown limesand in New Jersey. They are described by C. BERRY as *Ophiomusium stephensoni*.

**Occurrence.**—Upper Danian in Denmark. Danian? New Jersey.

### ***Ophiomusium granulosum* (ROEMER).**

Plate 13, fig. 1—4. Plate 14, fig. 1—3.

1840 *Ophiura granulosa* ROEMER, (non HAGENOW), p. 28, pl. 6, fig. 22.

1847 *Ophiura pustulosa* J. MÜLLER, p. 6.

1850 *Ophycoma granulosa*, d'ORBIGNY, p. 274.

1869 *Ophicoma granulosa*, LÜTKEN, p. 77.

1907 *Ophiura granulosa*, SPENCER, p. 111.

**Diagnosis.**—An *Ophiomusium* whose arms are completely encircled by strongly swollen lateral arm plates which give the arm joints a more

or less globular appearance. Dorsal and ventral arm plates are quite small and vestigial. The lateral arm plates and radial shields bear a scattered granulation.

Type.—The arm fragment described by ROEMER in 1840 from the Quadratus zone, Lindener Berge near Hanover in Germany.

History.—*Ophiura granulosa* was described by ROEMER in his monograph of the fossils in the North German Cretaceous area, 1840—41. The description is found in the first part, published in 1840. In the same year, 1840, HAGENOW published the second part of his monograph of the fossils of Rügen in which he similarly established an *Ophiura granulosa*. In this connection J. MÜLLER writes, (1847, p. 6) "Von Hagenow hat die Priorität des Namens granulosa für sich, die von Roemer beschriebne Art möchte daher um Verwirrung zu vermeiden, pustulosa zu benennen sein." An investigation shows, however, that it actually is ROEMER's name which has priority, since ROEMER's work was published so early that it is cited on page 591 of Neues Jahrbuch 1840, while HAGENOW's publication appears on page 660 of the same volume of this periodical.

On the basis of ROEMER's illustration d'ORBIGNY established a new genus, *Ophycoma*, characterised by the small dorsal arm plates. LÜTKEN, on the other hand, objects (p. 77) that one cannot establish a genus on so slight a basis. SPENCER, in 1907, interpreted the same arm fragment as the distal part of an arm supposedly belonging to the genus *Ophiotitanos*.

Description.—*Ophiomusium granulosum* has hitherto been known only from one specimen, and is thus described: "Die Arme sind walzenförmig und bestehen aus gewölbten, seitlich durch eine Furche getrennten, deutlich gekörnten Seitenschildern; wo sich deren vier berühren, liegt ein kleines, dreieckiges Schildchen dazwischen." It is seen from this description that a species with small, vestigial dorsal and ventral arm plates is concerned, and it is therefore likely that it has belonged to the genus *Ophiomusium*.

During a study visit to England I noticed in the collection of the Sedgwick Museum in Cambridge an arm fragment from the Lower Senonian of Kent which exactly matched ROEMER's figure. A short while later Dr. A. G. BRIGHTON sent me an unusually fine individual from the Senonian of Suffolk. This individual shows not only the appearance of the arm, but the oral surface of the disc as well. Finally, the connected remains of an individual from the Senonian of the Isle of Wight were found in the collection of the Mineralogical Museum in Copenhagen. On the basis of these individuals it is now possible to give a more exact description of the species.

The aboral surface is unknown. Among the remains from the Isle



of Wight is a large radial shield; it has a triangular outline with strongly rounded corners, a nearly smooth surface, bevelled margins and scattered, well developed granules.

The oral surface is seen in the well preserved individual from Suffolk, in this specimen the plates are somewhat disturbed, but in the sketch, plate 14, fig. 2, they are shown in their natural positions. The arms are prolonged on the oral surface by two well developed shield-shaped ventral arm plates with corresponding lateral arm plates. Between the ventral and lateral arm plates is found a large tentacle pore. In continuation of the innermost lateral arm plate lies the adoral shield. The genital plate lies in the interradius at the side of the arm; it meets a large, tumid interrarial marginal plate. Adoral to this are found two smaller plates. Between the adoral shields lies the oral shield. The jaws are unknown.

The arms have an almost circular cross section and are completely encircled by the powerful lateral arm plates which meet each other both dorsally and ventrally. Dorsal and ventral arm plates are quite small and triangular. Tentacle pores do not occur on the free part of the arm. The lateral arm plates are rather tumid, so that the individual arm joints are more or less spherical. The distal joints are, however, more slender, nearly cylindrical with a slight distal swelling. The proximal part of the lateral arm plate, which has been enclosed by the preceeding joint, is not sharply demarcated from the remainder of the plate. Near the distal margin of the plate are found the weak impressions of four spines. The free surface bears scattered granules. This granulation is slight on the individual from Suffolk while it is prominent on that from the Isle of Wight. The lateral arm plates from the two sides meet each other in two large articulations of which the upper, and larger, has a nearly triangular outline. From this a comb extends down towards the distal portion of the lower articulation leaving only place for a small vertebra. Four small bosses occur on the proximal outer, and distal inner margins of the lateral arm plates where these overlap. The distal arm joints are slender and cylindrical or with a slight distal swelling. The vertebrae have been small and slender, but none suitable for more exact description has been observed.

Affinity with other species.—*Ophiomusium granulosum* agrees in the structure of both arm and disc with the genus *Ophiomusium*; it differs from other species of this genus in the coarse granulation and swollen form of the lateral arm plates.

Material.—1. Holotype. Arm fragment. Upper Senonian. Zone of *Actinocamax quadratus*<sup>1)</sup> Lindener Berge near Hanover, Germany.

2. Individual showing ventral side of disc and arms. Upper Senonian,

1) Prof. dr. E. Voigt informed me of the stratigraphical position.



lower part of *Belemnitella mucronata* zone. Coe's Pit. Bramford, near Ipswich, Suffolk. Collection of the Sedgwick Museum, Cambridge. Pl. 13, fig. 1, 2. Pl. 14, fig. 1—3.

3. Connected lateral arm plates and radial shield. Upper Senonian, zone of *Belemnitella mucronata*. Isle of Wight.

Collection of the Mineralogical Museum. Pl. 13, fig. 3—4.

Occurrence.—Upper Senonian, Germany. Lower and Upper Senonian, England.

### ***Ophiomusium subcylindricum* (HAGENOW).**

Plate 14, fig. 4—6.

1840 *Ophiura* (*Aspidura*) *subcylindrica* HAGENOW, p. 661, pl. 9, fig. 7.

1869 *Ophiura* (*Aspidura*) *subcylindrica*, LÜTKEN, p. 78.

1907 *Ophiura filchii* SPENCER, p. 103, pl. 27, fig. 2.

Diagnosis.—An *Ophiomusium* whose arm joints are nearly cylindrical. The cylindrical free surface is sharply demarcated from the constricted proximal portion enclosed by the preceeding arm joint. The distal margin of the lateral arm plates is rounded, and there is no trace of spines. The dorsal arm plates are quite small and vestigial. Ventral arm plates are vestigial or wanting.

Type.—The arm fragment from the Upper Senonian of Rügen described by HAGENOW in 1840 is the holotype.

Description.—*Ophiura* (*Aspidura*) *subcylindrica* was described by HAGENOW as follows: "Die Arm-Stücke dieser Art sind ein wenig schwächer als die der vorigen (*O. granulosa*" HAG.), fast zylindrisch, und erscheinen stärker gegliedert, indem die Seiten-Schuppen als sehr vortretende geschlossene Ringe, von den sehr kleinen rautenförmigen Bauch- und Rücken-Schuppen nicht unterbrochen werden."

Neither HAGENOW's description nor his figure makes it possible to identify this species with certainty. There have, however, been found remains of an *Ophiomusium* in the Senonian of Denmark and Rügen; these agree rather well with HAGENOW's description and presumably are identical with *Ophiura subcylindrica*.

The body is unknown, but radial shields of similar appearance to those of other species of *Ophiomusium* have been found in the White Chalk. It is therefore possible that they belong to the same species as the arm fragment and lateral arm plates which have been found. The radial shields have a rounded triangular shape, and are slightly arched; they have a smooth surface and bevelled margin. The inner surface is provided with a pair of weak bosses on the broad, aboral end. An interrarial marginal plate which possibly also belongs to this species

has been found in the White Chalk; just as in *O. danicum* it is triangular with rounded corners; it is tumid and arched so that the aboral (?) portion is nearly at right angles to the lateral.

The arm is almost circular in cross-section; it is completely encircled by the strong lateral arm plates whose free portion forms a cylinder which is sharply demarcated from the strongly constricted proximal portion which has been overlapped by the preceeding joint. The distal margins of the lateral arm plates diverge on the dorsal side making room for a vestigial dorsal arm plate of triangular outline. The lateral arm plates meet ventrally over their whole length, and there appears to have been no ventral arm plate. The broad distal margin is evenly rounded and there are no impressions of spines. On the constricted proximal portion, and on the inner surface of the distal portion of the plate occur five weak bosses. The lateral arm plates from the two sides have met in large articulations connected by a strong comb on the inner surface; they only permit the presence of a very small vertebra. This has been observed by breaking open an arm joint; it is long and slender, cylindrical or slightly conical with the greatest thickness at the proximal end. Crystallization renders difficult any detailed investigation of the very small vertebra.

Affinity with other species.—*Ophiomusium subcylindricum* is distinguished particularly by the nearly cylindrical arm joints whose free portion is sharply demarcated from the strongly constricted proximal portion. This species is further distinguished from others of the same genus by the broad, blunt distal margin of the lateral arm plates.

In 1907 SPENCER described a species, *Ophiura fitchii*, which also appears to be an *Ophiomusium*. It has apparently had arm joints similarly cylindrical to those of *O. subcylindricum* and ventral arm plates appear to have been wanting, even in that part of the arm which is included in the oral side of the disc. It is possible that this species is identical with *Ophiomusium subcylindricum*.

Material.—The specimens mentioned belong to the collection of the Mineralogical Museum. 1. Arm fragment. Upper Senonian, Maastrichtian. Rørdal, near Aalborg, Denmark. Pl. 14, fig. 4.

2. Isolated plates. Upper Senonian, Maastrichtian. Aalborg, Mön, Dania near Mariager, Stevns Cliff and Enegaarde near Præstø.

3. A single large plate from the proximal part of an arm is available from Rügen. It has presumably belonged to the same species as the other plates described here. Upper Senonian, Maastrichtian.

Occurrence.—Upper Senonian in Denmark, and on Rügen in Germany.

**Ophiomusium sp.**

Plate 15, fig. 1—5.

Both in the Senonian and Danian of Denmark are found a number of radial shields which it does not seem possible to separate from the radial shields of *Ophiomusium granulosum*. In the same places are also found lateral arm plates of that type which occurs in *Ophiomusium*; they have a coarse granulation, but are not tumid and have a much more slender form than in the species mentioned. The granulation is most often rather conspicuous. The proximal margin of the lateral arm plate, which has been hidden by the distal portion of the next older plate, is not sharply separated from the exposed cylindrical surface. The distal margin of the lateral arm plate has projected slightly and is often particularly well supplied with large granules. On the margin, distal to this granulation, are often seen three or four weak spine impressions.

**Material.**—Isolated plates from Aalborg (Nørre Uttrup, Rørdal and Norden), Enegaarde near Præstø, Fakse, Kagstrup, Korporalskroen, Rejstrup and Saltholm.

Collection of the Mineralogical Museum.

**Occurrence.**—Senonian and Danian in Denmark.

**Genus *Ophiura* LAMARCK 1816.**

**Synonym:** *Ophioglypha* LYMAN 1865.

The body is covered with scales and often provided with a marginal embayment over the arms. The ventral arm plates are most often triangular, being broader than long and they do not touch one another. Arm spines are small, vestigial and compressed. The majority of lesser known mesozoic Brittle Stars have been referred to this genus, and similarly two species which cannot certainly be referred to any genus are mentioned here. Jurassic—Recent.



**Ophiura serrata** ROEMER.

Plate 16, fig. 1—8.

- 1840 *Ophiura serrata* ROEMER, p. 28, pl. 6, fig. 23.  
 1843 *Ophiura serrata*, FORBES, p. 234, fig. 2.  
 1846 *Ophiura serrata*, REUSS, II, p. 58, pl. 20, fig. 26.  
 1850 *Ophiura serrata*, FORBES (in DIXON), p. 337, pl. 23, fig. 2, 3.  
 1850 *Acroura serrata*, d'ORBIGNY, p. 274.  
 1869 *Ophioglypha serrata*, LÜTKEN, p. 73.  
 1907 *Ophiura serrata*, SPENCER, p. 102, pl. 27, fig. 3.  
 1907 *Ophiura parvisentis* SPENCER, p. 103, 134, pl. 27, fig. 4.  
 1915 *Ophioglypha parvisentis*, VALETTE, p. 7, fig. 2.  
 ?1915 *Ophioglypha gracilis* VALETTE, p. 11, fig. 3.

Diagnosis.—The disc and arms are covered by thin, smooth plates. The radial shields are rather large and pear-shaped. The dorsal arm plates are large and broad; they touch one another. The ventral arm plates are narrower, they also touch one another; their distal margins are broadly bowed. Lateral arm plates are not prominent, their indented distal margin has carried 4—8 spines; these are compressed, and about half as long as an arm joint.

Type.—The arm fragment figured by ROEMER in 1840 is the holotype; it originates from the Quadratus zone, Lindener Berge near Hanover in Germany.

History.—*Ophiura serrata* was established by ROEMER in 1840 on the basis of a small arm fragment from Upper Senonian of Hanover. This was described thus: "Die Arme sind walzenförmig, dünn, etwas zusammengedrückt und haben oben grob gezahnte und kleine Stacheln tragende Seitenschilder, welche einerseits von eiförmigen, kleineren Schildern seitlich getrennt werden."

FORBES, and later SPENCER have given more complete descriptions of the species, which is therefore now fairly well known.

Description.—A part of the disc showing the large pear-shaped radial shields is seen only in a single individual (SPENCER pl. 27, fig. 3). On this are also seen the remains of small scale-like plates which have presumably covered the greater part of the disc.

The arms, which are covered by thin, evenly arched, smooth, compressed plates, can be as much as 3.5 mm. wide at the base with a nearly circular cross-section. The dorsal arm plates, lateral arm plates and proximal ventral arm plates are imbricate. The proximal dorsal arm plates are very large and their breadth is greater than their length; the distal margin forms a broad, even bow. Distally these plates are relati-

vely smaller. The ventral arm plates are smaller than the dorsal arm plates, shield shaped, with a strongly bowed distal margin and weakly concave sides which form a long narrow V tapering proximally to a point. Between the distal margin and the side of the plate is found a quite small excision which has limited the tentacle pore. The proximal ventral arm plates are only slightly imbricate; only the proximal apex being covered by the preceding plate. The distal ventral arm plates are quite separate. The lateral arm plates are evenly arched about the arm and fit closely without a protruding margin. The margin is smooth where it meets the dorsal and ventral arm plates, while the free portion of the distal margin is indented. From four to eight indentations occur, the greatest number occurring on plates from the proximal part of the arm. Between the indentations on the distal margin are seen round impressions of spines. The spines are in several instances preserved, and their length is from one to two thirds of the length of an arm joint. Below the lowest indentation on the distal margin of the lateral arm plate is found a small embayment which, together with the corresponding embayment in the ventral arm plate has formed the margin of the small tentacle pore. The lateral arm plates are completely separated dorsally by the dorsal arm plates, but ventrally their proximal apices meet under cover of the ventral arm plates. In the distal part of the arm where the small ventral arm plates do not meet one another the lateral arm plates meet in a suture proximal to the ventral plate. On the inner surface of the lateral plate occurs a flange which runs from the proximal margin of the tentacle pore obliquely up towards the upper proximal corner of the plate. The arm plates are thin and allow the presence of a large vertebra, whose ventral furrow is deep, but whose dorsal furrow is shallow. The latter cuts slightly down into the adoral surface which here has also an embayment such that, when the vertebra is seen from the dorsal side the dorsal furrow appears to originate in a V-shaped depression. The dorsal part of the vertebra projects pointedly over the bosses of the aboral surface.

Affinity with *Ophiura parvisentis* and other species.—In 1907 SPENCER described a new species, *Ophiura parvisentis*, on the basis of a single individual which was said to differ from *O. serrata* in that the radial shields were small and inconspicuous, and that the dorsal arm plates were narrower. An investigation of this individual has shown that this is an incorrect interpretation. That side of the animal which is seen in the specimen is not the dorsal, but the ventral, and the tentacle pores are clearly seen on each side of the ventral arm plates. This is also seen in SPENCER's pl. 27, fig. 4 a, where they can at first sight be mistaken for those indentations which are found in the distal margins of the lateral arm plates. The identity of this species with *O. serrata* has



been established by a comparison of the actual specimens, and those characters which should separate the two species are a natural consequence of the faulty orientation.

In 1915 VALETTE referred two arm fragments to *O. parvisentis*, both are quite close to *O. serrata*, but differ, according to VALETTE, in their narrower dorsal and ventral arm plates. An investigation of the British examples shows, however, that the two French specimens fall within the range of variation exhibited by the species, and it is therefore reasonable to refer these two fragments to *O. serrata*.

A separate species, *Ophioglypha gracilis*, is based by VALETTE on an other arm fragment. According to the description this is close to *Ophiura serrata*, and strongly reminiscent of a distal arm fragment of this species. It seems to be distinguished, however, in the more proximal position of the tentacle pore on the arm joint, so that the lateral and ventral arm plates meet in a suture both distally and proximally to the pore.

Danish Occurrences.—A large number of isolated plates are known from the Senonian and Danian of Denmark. These were indeterminable on the basis of published descriptions, but by comparison with the well preserved English specimens of ophiuroids it has been determined that they wholly agree with *O. serrata*. It is the thin arm plates with smooth surface, the evenly cylindrical arching, the indented distal margin with the impressions of 4—8 spines, and the weak, oblique flange on the inner surface of the lateral arm plate which make these plates so characteristic and recognizable.

Material.—1. Holotype. Arm fragment. Upper Senonian, Quadratus zone. Lindener Berge near Hanover in Germany.

2. "*Ophiura parvisentis*", type specimen. Oral surface of an individual. Lower Senonian, Cor-anguinum zone. Kent, England. Collection of the British Museum (N.H.).

3. An individual and arm fragments from the Lower Senonian, Cor-anguinum zone, Kent. An arm fragment from the Cenomanian near Cambridge, England. British Museum (N.H.).

4. Arm fragments of "*Ophioglypha parvisentis*". Lower Senonian, Coniacian. Rosoy, France. Upper Senonian, Campanian. Sens, France.

5. Isolated arm plates and vertebrae. Senonian and Danian, Denmark. Collection of the Mineralogical Museum.

6. Isolated arm plates. Upper Senonian. Rügen, Germany. Mineralogical Museum.

Occurrence.—Cenomanian to Lower Senonian in England; Lower and Upper Senonian in France; Upper Senonian in Germany; Upper Senonian and Danian in Denmark.



**Ophiura ? hagenowi** n. sp.

Plate 17, fig. 1—5.

?1840 *Ophiura* (*Aspidura*) *granulosa* HAGENOW, (non ROEMER), p. 660, pl. 9, fig. 6.1900 *Ophiura* (?*subcylindrica* HAGENOW), BRYDONE, p. 12.

**Diagnosis.**—Brittle Stars, whose arms have a strongly rounded triangular cross-section and are covered by plates with a granulated surface. The dorsal arm plates are slightly arched and broadly rhomboidal; their two oblique distally directed sides are concave, producing a median and two lateral prominences. In the proximal part of the arm the ventral arm plates are broad, with a rounded, weakly bowed distal margin. The lateral arm plates project and have about eighteen indentations on the distal margin. Small spines have been attached between the lowermost of these indentations.

**Type.**—The presently described arm fragment from Trimmingham in England is the holotype. Sedgwick Museum, Cambridge.

**Description.**—This species is only known from arm fragments and isolated arm plates. The ventral surface of the arm is nearly flat, while the sides and dorsal surface are evenly arched. The plates are imbricate. The dorsal arm plates are large and broad with an evenly arched surface; their proximal margins are covered by the distal margins of the preceding plates, while the sides are concave and have met the upper margins of the lateral arm plates. This distal margin forms a broad, median, distally directed tongue which is separated from the lateral projections which meet the distal margin of the lateral arm plate by weak embayments. The ventral arm plates are rather large and broad, with a slightly undulating surface, there being a weak median, and two lateral depressions. The sides are straight and have notch for the tentacle pore slightly distal to the middle. The distal margin is slightly unevenly rounded. The lateral arm plates from the two sides meet neither dorsally nor ventrally; they are evenly arched with a fold between the lateral and ventral portions. The distal margin is indented, there being about eighteen indentations on each plate. The uppermost six of these are opposite the dorsal arm plate. Spines have been attached between the lowermost indentations, and the impressions of the lowermost of these spines are the most pronounced. The weakening of the impressions upwards has prevented the certain observation of more than six, although there may have been more. The distal margin is narrow dorsally, and broader ventrally; it has a smooth, bevelled portion distal to the spines. The proximal portion of the lateral arm plate is covered dorsally by the dorsal arm plate, on the side by the distal margin of the proximally next plate and ventrally by the ventral arm plate. On the proximal margin, where lateral and ventral portions

meet, are found a pair of bosses, and below these a depression which extends into the free portion of the plate. Granular ornament is only found on the exposed portion of the surface. The distal portion of the ventral margin of the lateral arm plate meets the ventral arm plate. A notch which, together with the corresponding notch in the ventral arm plate, forms the margin of the small tentacle pore, is found just proximal to the distal margin of the lateral arm plate, below the lowest spine. The length of the spines is from  $\frac{1}{3}$  to  $\frac{2}{3}$  that of a joint. The ornament of the arm plates is composed of granules, which seem to vary considerably in coarseness. This variation is seen both in the English material (arm fragments) belonging to this species, and in the isolated arm plates from Denmark and Rügen. On the lateral arm plates the granulation is often most coarse dorsally. The inner surface of the lateral arm plates bears a weak comb which extends from the proximal dorsal corner to the ventral margin just proximal to the tentacle pore. On the distal concave portion are found a pair of bosses which have been in contact with bosses on the proximal margin of the succeeding lateral arm plate. The comb is much weaker than in the species referred to *Ophiomusium*, and the plates from the two sides of the arm have, moreover, not met each other; there is room for a vertebra which is much larger than that of *Ophiomusium*.

The vertebra is, seen from the aboral side, high and narrow: nearly wedge-shaped, with the greatest breadth ventrally. Seen adorally the vertebra appears to have about the same height as breadth; this is caused by the wing-like expansion of the proximal margin of the vertebra. The upper canal furrow is shallow, but it extends with about the same depth to the distal end of the vertebra. The median upper articulation boss on the adoral surface is very large and is divided into right and left halves by a weak furrow. On each side of the ventral canal furrow is found a proximal and a distal concavity. In this species the distal concavity is of quite small size.

Affinity with other species.—F. VON HAGENOW established a species *Ophiura (Aspidura) granulosa* in 1840, from the White Chalk of Rügen. It was described thus: "Sehr ähnlich der bei Goldfuss abgebildeten *O. loricata*; die bisher nur gefundenen Bruchstücke der Arme gehören Individuen an, welche jene um das Doppelte und Dreifache an Grösse und Stärke übertreffen; sie sind ziemlich plattgedrückt und ihre Oberfläche ist zart gekörnt. Die Rücken-Schuppen aber laufen nach vorne in 3 Spitzen aus. Die Bauch-Schuppen sind queerrhomboidal, nach vorne ebenfalls etwas ausgezackt. Gelenk-Flächen abgefallener Stacheln sind nicht bemerkbar." The description and figures of "*O. granulosa*" do not make it possible to identify this species with certainty. The granulation of the plates and the triple division of the dorsal arm



plates suggest, however, that this species is identical with the presently established *O. hagenowi* of which remains have also been found at HAGENOW's locality, Rügen. As mentioned on p. 106 the name *O. granulosa* is not valid for this species.

*O. hagenowi* differs from *O. substriata*, both in the form of the arm plates and in the ornament of the ventral arm plates. There is no sure evidence for affinity with the genus *Ophiura*.

The Danish Finds.—Apart from a series of isolated arm plates, there has been found an arm fragment of this species in the White Chalk of Mön. The fragment shows a somewhat coarser ornamentation than in the rest of the Danish material, but it is, however, probable that it has belonged to the same species as these.

Material.—1. Holotype. Arm fragment. Mentioned by BRYDONE, 1900, p. 12, as *Ophiura* (? *subcylindrica* HAGENOW). Upper Senonian, Maastrichtian. Trimmingham, England. Sedgwick Museum Collection. Pl. 17, fig. 1—2.

2. Arm fragments. Upper Senonian, Mucronata zone. England. WRIGHT's Collection, London.

3. Isolated arm plates from the Upper Senonian, Maastrichtian. Denmark, and Rügen in Germany. Collection of the Mineralogical Museum.

4. An arm fragment possibly belonging to this species. Upper Senonian, Maastrichtian, Mön Cliff, Denmark. Collection of the Mineralogical Museum.

Occurrence.—Upper Senonian, England, Germany and Denmark.

### ***Ophiura* ? *substriata* n. sp.**

Plate 18, fig. 1—9.

Diagnosis.—Brittle Stars whose arms are oval in cross-section, being broader than high and with nearly flat dorsal and ventral surfaces. The proximal dorsal arm plates are short and broad; the distal, rhomboidal. The ventral arm plates are quite narrow and strongly arched about the long axis of the arm. The lateral arm plates project distally and bear marginal spines which are half as long as an arm joint. The surface of the dorsal and lateral arm plates is closely beset with granules, while that of the ventral arm plates is finely and irregularly longitudinally striated.

Type.—The presently described individual from the Lower Senonian of Kent, England is the holotype. British Museum (N.H.).

Description.—The body is unknown. The arms are oval in cross-section, being markedly broader than high. The dorsal surface is



nearly flat while the ventral arm plates project somewhat as a narrow longitudinal keel on the ventral side of the arm.

The dorsal arm plates are very broad and imbricate, particularly in the proximal part of the arm; they have a distally directed, rounded apex. The distal dorsal arm plates are rhomboidal.

The ventral arm plates are wedge-shaped or shield-shaped, quite narrow and tumid, and they are in contact. The distal margin is very strongly arched and is prolonged into a lateral apex at about the middle of the plate opposite the junction of two lateral arm plates. The ventral arm plate has a rather short concave side proximal to this apex. The proximal margin is V-shaped, but in the greater part of the arm it is covered by the distal margin of the adorally next plate. The plate is provided with oblong granules forming a lineal ornament.

The lateral arm plates are evenly arched, without any abrupt flexure between lateral and ventral portions. The lateral arm plates from the two sides are widely separated dorsally, while ventrally they are only slightly separated and in the distal portion even in contact proximal to the ventral arm plate. The distal margin of the lateral arm plate is somewhat projecting, the edge is rounded and has borne about eight spines. The free distal portion of the lateral arm plate is evenly arched and closely beset with granules; it grades into the proximal part which is covered by the distal margin of the preceding plate. Near the ventral edge of the proximal margin are found a pair of weak bosses, and a depression which extends distally to the free portion of the plate. Just proximal to the distal margin, below the lowest spine, is a notch, which together with the concave side of the ventral arm plate has formed the margin of the tentacle pore. The concave inner surface of the lateral arm plate is divided by a blunt comb which extends from the proximal dorsal corner to the ventral margin just below the tentacle pore.

A single vertebra has been observed: the adoral and aboral surfaces are markedly sloping, so that the dorsal side does not extend over the aboral articulations.

Affinity with other species.—In its granulation *Ophiura substriata* is reminiscent of *O. hagenowi*, but the lateral arm plates are more tumid and have a rounded distal margin without indentations; it diverges further in the breadth of the dorsal arm plate, the form and ornament of the ventral arm plate and in the appearance of the vertebra.

There is no basis for a certain generic determination.

The Danish specimens.—A large number of granulated lateral arm plates similar to the corresponding plates of *O. substriata* have been found in the White Chalk near Aalborg. They differ from the English specimen in a coarser granulation. The plates are evenly arched and slightly tumid. The dorsal margin is straight, and the ventral

has a notch which has bounded the tentacle pore, close to the distal margin. The distal margin is evenly bowed, and the exposed surface is closely beset with very coarse granules. The proximal portion of the lateral arm plate is smooth; it has been covered by the distal margin of the preceding plate. There is a suggestion of a pair of bosses on the proximal margin, the distal margin is smooth. At the junction between the outer surface and the distal margin, are eight particularly powerful double granules which have formed the points of attachment of eight spines. There is a weak furrow on the inwardly directed surface; it runs from the tentacle pore notch up towards the proximal part of the dorsal margin of the plate. Proximal to the furrow is found a weak keel, here the plate has its greatest thickness and from here it slopes steeply towards the proximal margin, more gently towards the distal.

Apart from these lateral arm plates, shield-shaped ventral arm plates with the characteristic longitudinal striation of this species, and also broad, V-shaped dorsal arm plates are found in the chalk near Aalborg. These plates collectively show with certainty that *Ophiura substriata* has lived in the Senonian sea about Aalborg. Isolated arm plates have also been observed in the White Chalk of Rügen.

Material.—1. Holotype. Arm fragment. Dover, Kent, England. C. F. COCKBURN Bequest. British Museum (N.H.).

2. Arm fragment. Lower Senonian, Cor-anguinum zone. High Stack Bay, England. WRIGHT's Collection, London.

3. Isolated arm plates. Upper Senonian, Maastrichtian. Rügen, Germany. Aalborg (N. Uttrup, Blegkilde), Denmark. Collection of the Mineralogical Museum.

Occurrence.—Lower Senonian, England. Upper Senonian, Germany and Denmark.

## Family **Amphiuridae** LJUNGMAN.

Genus **Amphiura** FORBES 1842.

Brittle Stars with long thin arms provided with short uniform erect spines. Cretaceous—Recent.

### **Amphiura** (?) *senonensis* (VALETTE).

Plate 15, fig. 6—10.

1915 *Amphiura senonensis* VALETTE, p. 16, fig. 6.

Diagnosis.—A Brittle Star whose arms are oval in cross-section, the breadth being distinctly greater than the height. Dorsal arm plates are large and broad; ventral arm plates shield-shaped, widespread



distally. The lateral arm plates are broad proximally, and meet the oblique proximal margin of the ventral arm plates, the distal portion projects and has borne three outwardly directed spines.

Type.—*Amphiura senonensis* is established on the basis of the individual from the Campanian at Sens, figured by VALETTE, 1915, p. 16, fig. VI, 1. This individual is the type.

Description.—Apart from the two arm fragments described by VALETTE, an arm fragment from the Upper Senonian in England, and another from the Upper Senonian of Denmark are known. Associated skeletal parts and single arm plates are furthermore found at a number of Danish localities.

The disc is unknown. The arms are oval in cross-section, the breadth being greater than the depth, but the degree of depression is, however, very different in the two individuals figured by VALETTE. The individual from Aalborg lies between these two extremes of arm depression. The dorsal arm plates are large, broad and more or less wedge-shaped, with a bowed distal margin; they are imbricate. The ventral arm plates are shield-shaped and tumid; in the English specimen they are weakly ridged. The distal margin is strongly bowed and produced in lateral processes; the sides are markedly concave, and the proximal margin broadly V-shaped. The plate is arched about the long axis of the arm, the inner surface having the form of a furrow. The ventral arm plates are slightly imbricate. The lateral arm plates are divided by a depression parallel to the proximal margin into a broad proximal portion and a more narrow, projecting, distal portion. The broad proximal portion meets the proximal margin of the ventral arm plate; the narrower distal portion, together with the concave side of the ventral arm plate has limited the large tentacle pore. Along the distal margin of the lateral arm plate are attached three strong spines. VALETTE states that the impression of the middle spine is the strongest, but no marked difference has been determined in the material investigated by the author. The spines have been strong and as long as one or two arm joints. The vertebra agrees with the arm in being rather broad and shallow. The upper canal furrow cuts rather deeply on the proximal articulation surface and interrupts the projecting edge of the upper muscle attachment. This interruption is also clearly seen on the distal articulation surface.

Affinity with other species, and with the genus *Amphiura*.—*Amphiura senonensis* is referred to the genus *Amphiura* on the basis of a certain similarity with *A. cretacea* SPENCER. The long, powerful arm spines are, however, an argument against this reference, for they are not known in this genus. The presently described species differs from the rather older *A. cretacea* in only possessing three arm spines while



*A. cretacea* has five according to SPENCER (1907, p. 107). During an investigation of *A. cretacea*, the author could, however, only observe four spines.

Material.—1. Two arm fragments described by VALETTE, Upper Senonian, Campanian. Sens and Michery, France.

2. Arm fragment. Upper Senonian, zone of *Actinocamax quadratus*. Palching Hill, Worthing, England. Collection of the British Museum (N.H.). Pl. 15, fig. 6—8.

3. Arm fragment. Upper Senonian, Maastrichtian. Blegkilde near Aalborg in Denmark. Collection of the Mineralogical Museum. Pl. 15, fig. 9.

4. Associated remains of individuals from the Upper Senonian, Maastrichtian, in Denmark. Aalborg (Rördal, Blegkilde, "Danmark", Norden and Nörre Uttrup), Eerslev and Stevns Cliff. Mineralogical Museum.

5. Single plates from the Upper Senonian, Maastrichtian. Rügen in Germany. Aalborg, Eerslev, Stevns and Enegaarde in Denmark. Mineralogical Museum.

Occurrence.—Upper Senonian of France, England, Germany and Denmark.

### Family **Ophiacanthidae** PERRIER.

Genus **Ophiacantha** MÜLLER & TROSCHEL 1842.

Brittle Stars whose lateral arm plates are provided with powerful erect spines, of which the uppermost are generally the longest. Tentacle pores are small. Cretaceous—Recent.

#### **Ophiacantha ? sp.**

Plate 18, fig. 10.

A number of lateral arm plates belonging to a hitherto unknown Brittle Star have been found in the Senonian and Danian deposits of Denmark. I will only describe the appearance of the plates since so far only lateral arm plates (most of which have been damaged) have been found. It would not be advantageous to establish a species on so slight a basis.

Description.—The lateral arm plates are rather short and strongly arched round the arm. The distal part of the plate is sharply demarcated from the constricted proximal part; it forms an evenly sloping surface which ends in the sharp distal margin. Proximally on this sloping surface are found seven or eight powerful bosses which have formed the

points of attachment of projecting spines. In the adoral part of the arm the lateral arm plates have met in a suture both dorsally and ventrally, while aborally they have diverged sufficiently to allow the presence of dorsal and ventral arm plates. A notch for the tentacle pore is seen in the ventral margin of the plate just proximal to the distal projection. The inner surface of the plate bears a weak ridge just proximal to the tentacle pore and parallel with the proximal margin. From this the surface slopes steeply towards the proximal margin, and more gently towards the distal.

Certain generic determination is not possible.

Material.—1. Lateral arm plates. Upper Senonian, Maastrichtian. Aalborg (Rördal and N. Utrup), Mön. Mineralogical Museum.

2. Lateral arm plates. Danian. Fakse, Herfølge and Stevns Cliff. Mineralogical Museum.

Occurrence.—Senonian and Danian in Denmark.

## Order **Euryalae** J. MÜLLER.

### Family **Asteronychidae** VERRILL.

Genus **Asteronyx** MÜLLER & TROSCHEL 1842.

Brittle Stars with unbranched arms. Vertebrae with hour-glass shaped articulation facets. Large radial shields. Dorsal arm plates wanting; lateral arm plates vestigial. Cretaceous—Recent.

A number of vertebrae which must be referred to the order Euryalae because they bear hour-glass shaped articulation facets have been found in the Danish Cretaceous deposits. There has not been found any trace of those hooks which occur on the arms of one of the families referred to the Euryalae. Also, there have not been found any vertebrae which show that the arms have been branched, as is the case in some of the genera of Euryalae. Only simple vertebrae are known, and no corresponding arm plates have been found; this agrees with the fact that recent representatives of this order have quite small, vestigial arm plates. The vertebrae found in the Cretaceous deposits can, with reservation, be referred to the genus *Asteronyx*.

### **Asteronyx ? ornatus** n. sp.

Plate 18, fig. 11.

Diagnosis.—A Brittle Star whose vertebrae have hour-glass shaped articulation facets and an irregular coarse granulation on the outer margin.

Type.—The presently described plate from the White Chalk of Stevns Cliff is the holotype. Mineralogical Museum, Copenhagen.

**Description.**—The outline of the vertebrae is circular to oval, height being greater than breadth. The adoral surface bears a vertical hour-glass shaped articulation facet on the central slightly raised portion. The aboral articulation surface slopes proximally below so that the length of the vertebra is greater dorsally than ventrally; it is provided with a horizontally placed hour-glass shaped articulation facet. The nearly cylindrical outer surface is broken only by the dorsal and ventral furrows; it is provided with a strong, coarse ornamentation of irregular round and oblong granules.

No other plates have been found which can be presumed to belong to this species, and it is likely that the superficial plates of the disc and arms have been vestigial as they are in recent species.

**Material.**—Isolated vertebrae. Upper Senonian, Maastrichtian. Rügen in Germany. Aalborg (N. Uttrup, Rørdal and "Danmark"), Eerslev, Enegaarde and Mön in Denmark.

Collection of the Mineralogical Museum.

**Occurrence.**—Upper Senonian, Germany, Denmark.

### ***Asteronyx* ? sp.**

Plate 18, fig. 12.

Only a few vertebrae of the type occurring in *Asteronyx* have been found in the Danish Danian deposits. It is, however, remarkable that they are all clearly different from the common type in Danish Senonian White Chalk, and there is therefore reason to believe that they have belonged to an other species.

**Description.**—The adoral surface of the arm vertebra is nearly circular, with notches for the dorsal and ventral furrows. On the central slightly raised portion is found a projecting hour-glass shaped vertical articulation facet. On the ventral part of the surface, on each side of the ventral furrow notch, occurs a large, often deep socket. The aboral surface has an outline similar to that of the adoral, on the central part is found a projecting hour-glass shaped, horizontal articulation facet, whose two projecting portions continue downwards into a weak elevation on the surface of the vertebra on each side of the ventral furrow. The outer surface is smooth and strongly concave, so that it attains the character of a furrow running round the vertebra, broken only by the dorsal and ventral furrows. There is a constriction of the outer surface on each side of the ventral furrow, caused by the two sockets on the adoral surface.

Collection of the Mineralogical Museum.

**Occurrence.**—Senonian and Danian in Denmark.



## Stratigraphy.

The infrequent occurrence of Brittle Stars, and their rather great vertical distribution in Cretaceous deposits cause the majority of them to be unsuitable for the stratigraphical determination of Cretaceous zones. On the other hand, asteroids seem to be particularly valuable in this respect, as SPENCER (1913) has stressed.

In practice, however, they seem to have been very little used in stratigraphical work. This is without doubt due to the fact that the diagnoses and descriptions of these complicated animals have not been very satisfactory, just as knowledge of their morphology, growth and variation has been very incomplete.

The occurrence of certainly determined asteroids and ophiuroids at a series of well known Danish localities is shown in Table 1. It is seen that only two species of asteroids, and one ophiuroid, are common to the Senonian and Danian. The Senonian includes only Maastrichtian (with *Discoscaphites constrictus*), while there have as yet neither been collected asteroids nor ophiuroids from the small occurrence of Campanian (with *Botrychoceras polyplocum* and *Acanthoscaphites tridens*). There can be distinguished between a Lower and an Upper Maastrichtian, or Mönian and Stevnsian (TROELSEN, 1937. BROTZEN, 1945, p. 59), on the basis of the fauna. *Metopaster tumidus* gives way in the Upper Maastrichtian to *M. poulsenii*, and there seems to be a few other differences in the asteroid faunas of these two zones, but the material is not sufficient to draw sure conclusions. It does not seem, as was previously thought (SPENCER, 1913, p. 119), as though a smooth, younger variety of *Metopaster undulatus* exists, but this species continues with its common granulous form right to the top of the Senonian.

No asteroids are known from the lowermost zone of the Danian, the Cerithium-limestone (ÖDUM's zone A). The remainder of the Lower Danian and the Middle and Upper Danian (ÖDUM's zones B, C and D) are characterized by the echinoids *Tylocidaris ödumi* + *abildgaardi*, *T. brünnichi* and *T. vexillifera*. The distribution of asteroids is in full agreement with this division of the Danian.

A series of Danian localities, whose stratigraphical position is determined on the basis of the asteroids, is shown in Table 2. The majority of the localities given in the table have been described by ÖDUM (1926).

It is of interest that the only asteroid and the only ophiuroid which are known from the Vincentown limesand in New Jersey seem to be identical with, or very closely related to species from the Danish Danian. This, and similar conditions in other elements of the fauna, indicates that the Vincentown limesand should be referred to the Danian, and not, as is now generally the case, to the Eocene.

**Table 1.**

Distribution of certainly determined Asteroidea and Ophiuroidea in the Danish Cretaceous deposits<sup>1)</sup>

	Turonian	Lower Maastrichtian	Upper Maastrichtian	Lower Danian	Middle Danian	Upper Danian	Number of Individuals found with associated ossicles.
	Arnager	Aalborg Mön Cliff	Eerslev Stevns Cliff	Stevns Cliff Bulbjerg Kagstrup Korporalskroen	Fakse Rejstrup Damhus Aa	Copenhagen Saltholm Trælløse Herfølge Klintholm	
<b>Asteroidea</b>							
Metopaster cf. thoracifer .	×	.	.	.	.	.	2
poulsenii . . . . .	.	.	×	×	.	.	17
tumidus . . . . .	.	×	×	.	.	.	7
laevis . . . . .	.	.	×	×	.	.	3
undulatus . . . . .	.	×	×	×	.	.	4
angulatus . . . . .	.	.	.	.	.	.	0
kagstrupensis . . . . .	.	.	.	×	×	×	2
spencerii . . . . .	.	.	.	×	×	×	0
elevatus . . . . .	.	.	.	.	×	×	0
planus . . . . .	.	.	.	×	×	×	0
carinatus . . . . .	.	.	.	.	×	×	0
maculatus . . . . .	.	.	.	.	×	.	0
Ceramaster dividiuus . . . . .	.	.	.	.	.	×	0
granulatus . . . . .	.	.	.	.	×	.	0
Recurvaster radiatus . . . . .	.	×	×	×	.	.	28
mammillatus . . . . .	.	.	.	×	×	×	1
Teichaster favosus . . . . .	.	×	×	×	.	.	1
anchylus . . . . .	.	.	.	×	×	×	0
retiformis . . . . .	.	.	.	.	×	×	1
Pycinaster crassus . . . . .	.	.	×	.	.	.	2
danicus . . . . .	.	.	.	.	×	.	1
cornutus . . . . .	.	.	.	.	.	×	0
? rosenkrantzii . . . . .	.	.	.	.	.	×	0
Chomataster acules . . . . .	.	×	×	×	×	×	0
spenceri . . . . .	.	×	×	.	.	.	1
wrighti . . . . .	.	×	×	×	.	.	6
Ophryaster magnus . . . . .	.	×	×	.	.	.	3
Stauranderaster							
pyramidalis . . . . .	.	.	.	×	×	×	0
mixtus . . . . .	.	×	×	×	.	.	1
miliaris . . . . .	.	.	.	.	×	×	0
speculum . . . . .	.	.	.	×	×	.	0
Astropecten postornatus . . . . .	.	.	.	.	×	×	0
punctatus . . . . .	.	.	.	×	×	×	1
? pygmæus . . . . .	.	×	×	.	.	.	0
Valettaster ocellatus . . . . .	.	×	×	×	×	×	5
granulatus . . . . .	.	.	.	.	.	.	0
<b>Ophiuroidea</b>							
Ophiomusium danicum . . . . .	.	.	.	.	.	×	2
subcylindricum . . . . .	.	×	×	.	.	×	1
Ophiura serrata . . . . .	.	×	×	×	×	.	0
? hagenowi . . . . .	.	×	×	.	.	.	2
? substriata . . . . .	.	×	.	.	.	.	0
Amphiura ? senonensis . . . . .	.	×	×	.	.	.	9
Asteronyx ? ornatus . . . . .	.	×	×	.	.	.	0

<sup>1)</sup> The Lower Cretaceous, Cenomanian, Campanian, and the Lower Danian Cretaceous Limestone have yielded no determinable Asteroids or Ophiuroids and are not included in this table.



**Table 2.**

Some Danian localities zoned by characteristic Asteroidea.

	Lower			M.	Upper			
	Metopaster kagstrupensis	Metopaster spencerii	Teichaster anchylus	Metopaster elevatus	Ceramaster dividiuus	Pycinaster cornutus	Pycinaster rosenkrantzii	Astropecten postornatus
Aggersborg I . . . . .	×	.	.	.	.	.	.	.
Aggersborggaard . . . . .	.	.	.	.	.	.	×	.
Barner I . . . . .	×	×	×	.	.	.	.	.
Bjerger I . . . . .	.	.	×	.	.	.	.	.
Bredstrup Klint . . . . .	.	.	.	.	.	.	.	×
Brøndum I . . . . .	.	.	×	.	.	.	.	.
Bulbjerg . . . . .	×	×	.	.	.	.	.	.
Farstrup . . . . .	×	.	.	.	.	.	.	.
Hulemölle, Nibe . . . . .	×	×	×	.	.	.	.	.
Kastbjerg I . . . . .	.	×	.	.	.	.	.	.
Kjölby II . . . . .	×	×	.	.	.	.	.	.
Klim I . . . . .	×	×	.	.	.	.	.	.
Klim Bjerger I . . . . .	.	.	×	.	.	.	.	.
Lundgaard I . . . . .	×	.	×	.	.	.	.	.
Lögsted I . . . . .	×	×	×	.	.	.	.	.
Lønnerup I . . . . .	.	.	×	.	.	.	.	.
Mönsted . . . . .	.	.	.	.	.	.	.	×
Nystrup . . . . .	.	.	×	.	.	.	.	.
N. Bjergergaard I . . . . .	×	.	.	.	.	.	.	.
Ove I . . . . .	×	.	×	.	.	.	.	.
Raasted . . . . .	.	.	×	.	.	.	.	.
Sangstrup Klint . . . . .	.	×	.	.	.	.	.	.
Torup Klöv I . . . . .	×	.	.	.	.	.	.	.
Torup Strand . . . . .	×	×	×	.	.	.	.	.
Veggerbro I . . . . .	×	×	.	.	.	.	.	.
Vormark . . . . .	.	.	.	.	×	.	.	.
Voxlev . . . . .	.	.	×	.	.	.	.	.
Ö. Hornum I . . . . .	.	×	.	.	.	.	.	.

## Dansk sammendrag.

### Kridttidens søstjerner og slangestjerner med særlig hensyntagen til de i Danmark fundne arter.

Ved studiet af engelske og danske samlinger og et stort nyindsamlet dansk materiale er kendskabet til kridttidens søstjerner og slangestjerner udvidet, og det er blevet muligt at give mere nøjagtige beskrivelser og diagnoser end hidtil, ligesom det er muligt at få et indtryk af vækststadierne og den individuelle variation hos enkelte arter.

På grundlag af de nye iagttagelser gennemgås de danske og enkelte udenlandske søstjerner og slangestjerner fra kridttidens aflejringer.

Foruden isolerede skeletdele kendtes tidligere rester af 11 individer fra Danmarks skrivekridt. Disse var beskrevet som 10 arter. Nu kendes fra skrivekridtet rester af 78 individer fordelt på 12 arter. De to dominerende arter er repræsenteret med 28 og 17 individer. De nye fund viser, at flere af de tidligere beskrevne "arter" kun repræsenterer individuelle variationer i størrelse og ornamentering. Ved den nye tolkning af arterne får også faunaens sammensætning et mere troværdigt præg.

Der beskrives 39 tidligere kendte og tre nye arter samt rester af yderligere tre arter af søstjerner. 5 af de beskrevne arter kendes ikke fra Danmark.

I de senere år er beskrevet en del arter af slangestjerner på grundlag af isolerede skeletdele, som er kombineret i overensstemmelse med deres relative hyppighed. Denne metode synes ikke umiddelbart anvendelig. Flere af de kombinerede skeletdele er anatomisk uforenelige, og yderligere viser det danske materiale, at skeletdelenes relative hyppighed afhænger ikke blot af arternes hyppighed, men tillige af hvor store og robuste skeletdelene er.

Der beskrives 5 tidligere kendte og 3 nye arter samt rester af yderligere tre arter af slangestjerner. Een af de beskrevne arter kendes ikke fra Danmark.

Stratigrafisk er både søstjerner og slangestjerner egnede til at adskille senon og danien. Søstjernerne er tillige velegnede til at adskille nedre og øvre maastrichtien og nedre, mellem og øvre danien i Danmark.

Den fra Vincentown limesand i New Jersey beskrevne søstjerne og

slangestjerne synes at være identisk med eller ganske nært beslægtet med arter fra danien i Danmark og taler for at henhøre Vincentown limesand til danien.

### Søstjerner.

Metopaster.—De til denne slægt henregnede arter står de recente slægter *Pentagonaster*, *Tosia* og *Ceramaster* ganske nær. Arterne *Metopaster dividius* og *Ravniaster granulatus* henføres her til *Ceramaster*. De øvrige som arter af *Ravniaster* og *Mitraster* beskrevne søstjerner er enten selvstændige arter af slægten *Metopaster* (*Ravniaster planus*, *R. carinatus*, *R. maculatus*, *Mitraster hunteri* og delvis *M. hunteri lævis*) eller er unge individer af allerede kendte arter af denne slægt og kan indordnes i nedenstående vækstrækker:

*Ravniaster simplex* → delvis *Mitraster hunteri lævis* → *Metopaster poulsenii* → *Metopaster stevensensis*.

*Ravniaster virgineus* → *Metopaster tumidus*.

*Ravniaster lævis* → *Metopaster lævis*.

*Mitraster compactus* → *Metopaster parkinsoni*.

„*Mitraster rugatus*” → *Metopaster cingulatus* → *Metopaster uncatus*.

*Mitraster rugatus* → *Metopaster hunteri*.

*Ceramaster*.—Til slægten *Metopaster* har været henført enkelte arter, som afviger fra det normale udseende hos denne slægt ved ikke at have nogen stor sidste øvre randplade svarende til flere nedre randplader. Nogle af disse arter minder i udseende om den recente *Ceramaster placenta* og tildels om slægten *Sphaeriodiscus*. De omtales her under slægten *Ceramaster*.

*Recurvaster*.—Undersøgelsen af et stort nyindsamlet materiale viser, at arterne *R. stevensensis* og *R. echinatus* begge er identiske med den tidligere beskrevne *Metopaster tumidus radiatus*. Der beskrives en ny art *R. blackmorei* fra Englands senon. De to som *R. communis* beskrevne nedre randplader kan ikke på grundlag af det foreliggende materiale skelnes fra tilsvarende plader af arter af *Metopaster* og *Recurvaster*.

*Teichaster*.—Den nære relation til slægten *Crateraster* bekræftes ved fundet af et ungt individ af *T. favosus*. Den af SPENCER påviste simple udvikling fra *T. favosus* til *T. retiformis* hviler på en fejltagelse, idet skeletdelene af førstnævnte hos SPENCER er forkert orienteret. Samhørigheden mellem de som *T. retiformis* beskrevne øvre og nedre randplader bekræftes ved et nyt fund.

*Pycinaster*.—*P. lamberti* er identisk med *P. crassus*, og de tilsyneladende forskelligheder beror på en fejl orientering af forsteningen. Et nyt fund af *P. danicus* bekræfter og supplerer BR. NIELSEN'S beskrivelse af denne art. I skrivekridtet på Mön er fundet randplader af en



*Pycinaster*, som står *P. cornutus* fra det øverste danien nær. *P. rosenkrantzii* minder i flere henseender om slægten *Chomataster*.

*Chomataster*.—De som *C. acules* beskrevne randplader er ikke glatte, men har båret skælformede pigge og er således identiske med den senere beskrevne *C. brünnichi*. *C. præcursor* kendes kun fra Köpingsandstenen i Sverige, og de til denne art henvorte randplader fra England og Danmark beskrives som en ny art, *C. spenceri*. Der er fundet flere velbevarede individer af en ny art *C. wrighti* i det danske skrivekridt. Den som *Nymphaster* (senere *Ophryaster*) *marginatus* beskrevne engelske søstjerne henføres til slægten *Chomataster*.

*Ophryaster*.—*O. marginatus* henføres til slægten *Chomataster*. Den til *O. oligoplax* henvorte søstjerne fra Danmark henføres her til *O. magnus* og danner grundlag for en ny beskrivelse af denne art.

*Stauranderaster*. — *S. gibbosus* er ikke med sikkerhed kendt fra Danmark.

*Astropecten*.—Slægten *Lophidiaster* er blevet opstillet for arter, som angaves at afvige fra *Astropecten* ved dorsalsidens flade, tætstillede plader. Imidlertid har typearten typiske paxiller og svarer også på andre punkter til *Astropecten*.

*Valettaster*.—Der er fundet rester af flere individer af *V. ocellatus* visende formen af kroppladerne og ambulakralpladerne.

*Asterias*.—I tilknytning til denne slægt omtales rester af en enkelt art.

#### Slangestjerner.

*Ophiomusium*.—De som *O. stephensoni* beskrevne skeletdele hidrører fra flere arter, hvoriblandt er een, som synes at være identisk med *O. danicum*. Nyt engelsk materiale danner grundlag for en beskrivelse af *O. granulosum*, der hidtil kun kendtes fra ROEMERS figur (1840). *Ophiura fitchii* er antagelig identisk med *O. subcylindrica* og tilhører slægten *Ophiomusium*.

*Ophiura*.—*O. parvisentis* er identisk med *O. serrata*. *O. ? substriata* og *O. ? hagenowi* er nye arter. Sidstnævnte er formentlig identisk med HAGENOWS ugyldige art "*O. granulosa*".

*Amphiura*.—Til denne slægt er henvort den franske *A. senonensis*, der nu også kendes fra England, Tyskland og Danmark.

*Ophiacantha*.—I tilknytning til denne slægt omtales armsideplader af en slangestjerne fra Danmark.

*Asteronyx*.—Der er i Danmark fundet to typer af armhvirvler af slangestjerner hørende til ordnen Euryalae og antagelig til slægten *Asteronyx*.

## Bibliography.

- Alexander, C. J.: A New Lower Cretaceous Ophiuroid. *Jour. Paleontology*. Vol. 5. Menasha, Wis. 1931.
- Berry, C. T.: Miocene and Recent Ophiura skeletons. *John Hopkins Univ. Stud. Geol.* No. 11. Baltimore 1934.
- Ophiurans from the Upper Senonian of South Limburg, Holland. *Jour. Paleontology*. Vol. 12. Menasha, Wis. 1938.
- Cretaceous Ophiurans from Texas. *Jour. Paleontology*. Vol. 15. Tulsa, Okla. 1941.
- A New Ophiuran from the Eocene of New Jersey. *Jour. Paleontology*. Vol. 16. Tulsa, Okla. 1942.
- Bonnesen, E. P., O. B. Bøggild & J. P. J. Ravn.: *Carlsbergfondets Dybdoboring*. København 1913.
- Brotzen, F.: De geologiska resultaten från borrharna vid Höllviken. I. *Sveriges Geol. Unders.*, Ser. C. No. 465. Stockholm 1945.
- Brydone, R. M.: *The Stratigraphy and Fauna of the Trimmingham Chalk*. London 1900.
- Chapman, F.: A Lower Cretaceous Brittle-star from Queensland. *Proc. Royal Soc. Victoria*. Vol. 46 (N. S.), Part 2. Melbourne 1934.
- Clark, W. B.: *The Mesozoic Echinodermata of the United States*. *Bull. U. S. Geol. Surv.* No. 97. Washington 1893.
- & M. W. Twitchell.: *The Mesozoic and Cenozoic Echinodermata of the United States*. *U. S. Geol. Surv. Monographs*. Vol. 54. Washington 1915.
- Cottreau, J.: *Un Stellerides de la craie de Meudon*. *Compte rendu sommaire Soc. geol. France*. 1937. Paris 1937.
- Dixon, F.: *The Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*. London 1850.
- Durham, J. W. & W. A. Roberts.: *Cretaceous Asteroids from California*. *Jour. Paleontology*. Vol. 22. Tulsa, Okla. 1948.
- Fisher, Walter K.: *New Genera of Starfishes*. *Annals and Mag. Nat. Hist.* Vol. 5, No. 26. Eighth Ser. London 1910.
- *Asteroidea of the North Pacific and Adjacent Waters*. Part 1. *U. S. Nat. Mus. Bull.* 76. Washington 1911.
- Forbes, E.: *On the Fossil Remains of Starfishes of the order Ophiuræ, found in Britain*. *Proc. Geol. Soc. London*. Vol. 4, Part 2. No. 97. London 1843.
- *On the Asteriadae found fossil in British Strata*. *Mem. Geol. Surv. Great Britain*. Vol. II. London 1848.
- Fourtau, R.: *Catalogue des Invertébrés Fossiles de l'Égypte*. No. 2. *Geol. Surv. Egypt*. Cairo 1914.
- Gabb, W. M.: *Note on the Discovery of Representatives of Three Orders of Fossils new to Cretaceous Formations of North America*. *Proc. Acad. Nat. Sci. Philadelphia*. Philadelphia 1876.
- Geinitz, H. B.: *Das Elbthalgebirge in Sachsen*. *Palaeontographica*. Vol. 20, Part 1. Cassel 1871.
- Goldfuss, G. A.: *Petrefacta Germaniæ*. Part 1. Düsseldorf 1826.

- Gray, J. E.: Description of some New Genera and Species of Asteridæ. Proc. Zool. Soc. London. Part 15. London 1847.
- Synopsis of the Species of Starfish in the British Museum. London 1866.
- Hagenow, F. von.: Monographie der Rügen'schen Kreide-Versteinerungen. Abt. 2. Neues Jahrb. f. Mineralogie etc. Stuttgart 1840.
- Jessen, A. & H. Ödum.: Senon og Danien ved Vøxlev. Danmarks Geol. Unders. II. Rk. Nr. 39. København 1923.
- Klinghardt, F.: Beobachtungen an lebenden und fossilen Schlangen-Seesternen, Quallen und Rudisten. Jahrb. preussischen geol. Landesanst. Berlin. Vol. 53. 1932. Berlin 1933.
- Lambert, J.: Revue critique de Paleozoologie. 1914.
- Lehner, L.: Fauna und Flora der Frankischen Albüberdeckenden Kreide II. Palaeontographica. Vol. 87. Part A. Stuttgart 1937.
- Lieberkind, I.: Asteroidea, Part I. The Danish Ingolf-Expedition. Vol. 4, Part 10. København 1935.
- Livingstone, A. A.: The Australian Species of Tosia (Asteroidea). Rec. Australian Mus. Vol. 18. Sydney 1932.
- Loriol, P. de.: Note sur quelques Stellérides du Santonien d'Abou-Roach. Bull. Inst. Egyptien. Ser. V. Vol. 2. Cairo 1909.
- Lütken, C. F.: Addimenta ad historiam Ophiuridarum. III. Det Kongelige danske Vidensk. Selsk. Skrifter, 5. Rk. naturv. math. Afd. 8, Vol. 11. København 1869.
- Mercier, J.: Les Stellérides Mésozoïques du Bassin de Paris. Mém. Soc. linnéenne Normandie. N. S. Géol. Vol. 1. Part 2. Caen 1935.
- Les Astéries du Coniacien d'Aulnay-s-Iton. Bull. Soc. linnéenne Normandie. Ser. 8. Vol. 8. Caen 1936.
- A propos de deux genres de Stellérides. Bull. Soc. linnéenne Normandie. Ser. 8. Vol. 8. Caen 1936.
- Mortensen, Th.: Echinoderms of New Zealand and the Aucland-Cambell Islands. Vidensk. Medd. Dansk Naturhist. Foren. Vol. 79. København 1925.
- Handbook of the Echinoderms of the British Isles. Edinburgh 1927.
- Müller, J.: Monographie der Petrefacten der Aachener Kreideformation. Bonn 1847.
- Müller, J. & F. H. Troschel.: System der Asteriden. Braunschweig 1842.
- Nielsen, K. Brünnich.: Cerithiumkalken i Stevns Klint. Danmarks Geol. Unders. IV. Rk. Vol. 1. Nr. 7. København 1917.
- En Hydrokoralfauna fra Faxe og Bemærkninger om Danienets geologiske Stilling. Danmarks Geol. Unders. IV. Rk. Vol. 1. Nr. 10. København 1919.
- Kalken paa Saltholm. Danmarks Geol. Unders. IV. Rk. Vol. 1. Nr. 20. København 1926.
- Faunaen i ældre Danium ved Korporalskroen. Meddelelser f. Dansk Geol. Foren. Vol. 9. No. 2. 1937. København 1938.
- En ny Ophiur fra Danmark. Meddelelser f. Dansk Geol. Foren. Vol. 10. No. 1. 1941. København 1942.
- The Asteroids of the Senonian and Danian Deposits of Denmark. Det Kongelige danske Vidensk. Selsk. Biol. Skrifter. Vol. II, Nr. 5. København 1943.
- Ödum, H.: Studier over Daniet i Jylland og paa Fyn. Danmarks Geol. Unders. II. Rk. Nr. 45. København 1926.
- Orbigny, M. Alcide d': Prodrôme de paléontologie stratigraphiques universelle. Vol. 2. Paris 1850.
- Cours élémentaire de Paléontologie et de Géologie stratigraphiques. Vol. 2. Paris 1852.
- Rasmussen, H. Wienberg.: Observations on the Asteroid Fauna of the Danian. Meddelelser f. Dansk Geol. Foren. Vol. 10. No. 4. 1944. København 1945.



- Rasmussen, H. Wienberg.: An Oligocene Asteroid from Denmark. To be printed in: Meddelelser f. Dansk Geol. Foren. Vol. 11. No. 5. 1950. København 1951.
- Ravn, J. P. J.: Kridtaflejringerne paa Bornholms Sydvestkyst og deres Fauna. II. Danmarks Geol. Unders. II. Rk. Nr. 31. København 1918.
- Reuss, A. E.: Die Versteinerungen der böhmischen Kreideformation. Vol. II. Stuttgart 1846.
- Rosenkrantz, A.: Craniakalk fra Kjøbenhavns Sydhavn. Danmarks Geol. Unders. II. Rk. Nr. 36. København 1920.
- Roemer, A. F.: Die Versteinerungen des Norddeutschen Kreidegebirges. I. Hannover 1840.
- Sladen, W. Percy.: Report on the Asteroids. Rep. on the Sci. Results of the Voyage of H. M. S. Challenger. Zoology. Vol. 30. London 1889.
- A Monograph on the British Fossil Echinodermata from the Cretaceous Formations. Vol. II. The Asteroidea and Ophiuroidea. Part 1 & 2. London 1891 & 1893.
- Spencer, W. K.: A Monograph on the British Fossil Echinodermata from the Cretaceous Formations. Vol. II. The Asteroidea and Ophiuroidea. Part 3, 4 & 5. London 1905, 1907 & 1908.
- The Evolution of the Cretaceous Asteroidea. Phil. Trans. Royal Soc. London. Ser. B. Vol. 204. London 1913.
- Troelsen, J.: Om den stratigrafiske Inddeling af Skrivekridtet i Danmark. Meddelelser f. Dansk Geol. Foren. Vol. 9. No. 2. 1937. København 1938.
- Umbgrove, J. H. F.: Asteroidea uit het Maastrichtsche Tufkrijt. Verh. Geol. Mijnbouwk. Genootschap Nederland en Koloniën. Geol. Ser. 7. S-Gravenhage 1925.
- Valette, Dom Aurelien.: Note sur quelques stellérides de la craie sénonienne du Département de l'Yonne. Bull. Soc. Sci. Hist. et Nat. de l'Yonne. Auxerre 1902.
- Nouvelle note sur les stellérides de la craie blanche du Département de l'Yonne. Bull. Soc. Sci. Hist. et Nat. de l'Yonne. Auxerre 1915.
- Les Ophiures de la craie des environs de Sens. Bull. Soc. Sci. Hist. et Nat. de l'Yonne. Auxerre 1915.
- Note sur les debris de stellérides fossiles du sud-ouest de la France. Act. Soc. linéenne Bordeaux. Vol. 76. Bordeaux 1925.
- Note sur la presence de trois stellérides fossiles recueillies dans le Bassin de Paris. Bull. Soc. Geol. France. 4. Ser. Vol. 25. Paris 1925.
- Voigt, E.: Die Lithogenese der Flach- und Tiefwassersedimente des jüngeren Oberkreidemeeres. Jahrb. d. Halleschen Verbandes z. Erforschung d. mitteldeutschen Bodenschätze. Vol. 8. N. F. Halle 1929.
- Wade, Bruce.: The Fauna of the Ripley Formation on Coon Creek, Tennessee. U. S. Geol. Surv. Prof. Paper. 137. Washington 1926.
- Wright, C. W. & E. V.: Note on Cretaceous Asteroidea. Quart. Jour. Geol. Soc. London. Vol. 96. London 1940.

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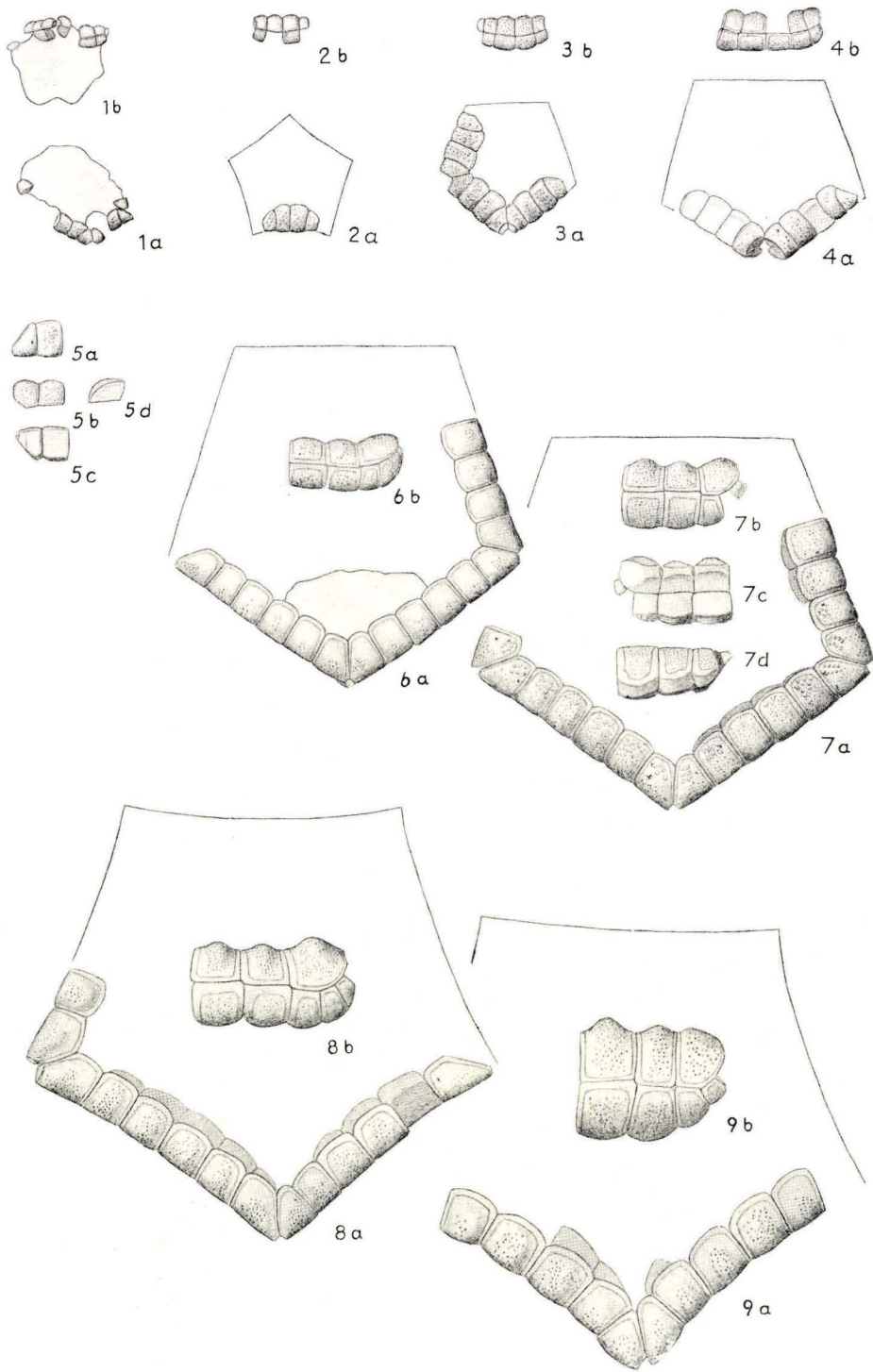
## PLATES

**Plate 1.**

*Metopaster poulsenii* BR. NIELSEN.  
Upper Senonian. Stevns Cliff, Denmark.

- Fig. 1. Individual 1. a, abactinal; b, lateral.  
» 2. Individual 2. "Ravniaster simplex". a, abactinal; b, lateral.  
» 3. Individual 3. a, abactinal; b, lateral.  
» 4. Individual 5. a, abactinal; b, lateral.  
» 5. Individual 6. Superomarginals 2 and 3. a, abactinal; b, lateral; c, actinal;  
d, profile.  
» 6. Individual 7. a, abactinal; b, lateral.  
» 7. Individual 8. a, abactinal; b, lateral; c, internal; d, actinal.  
» 8. Individual 10. a, abactinal; b, lateral.  
» 9. Individual 11. Holotype. a, abactinal; b, lateral.

All figures  $\times 1$ .



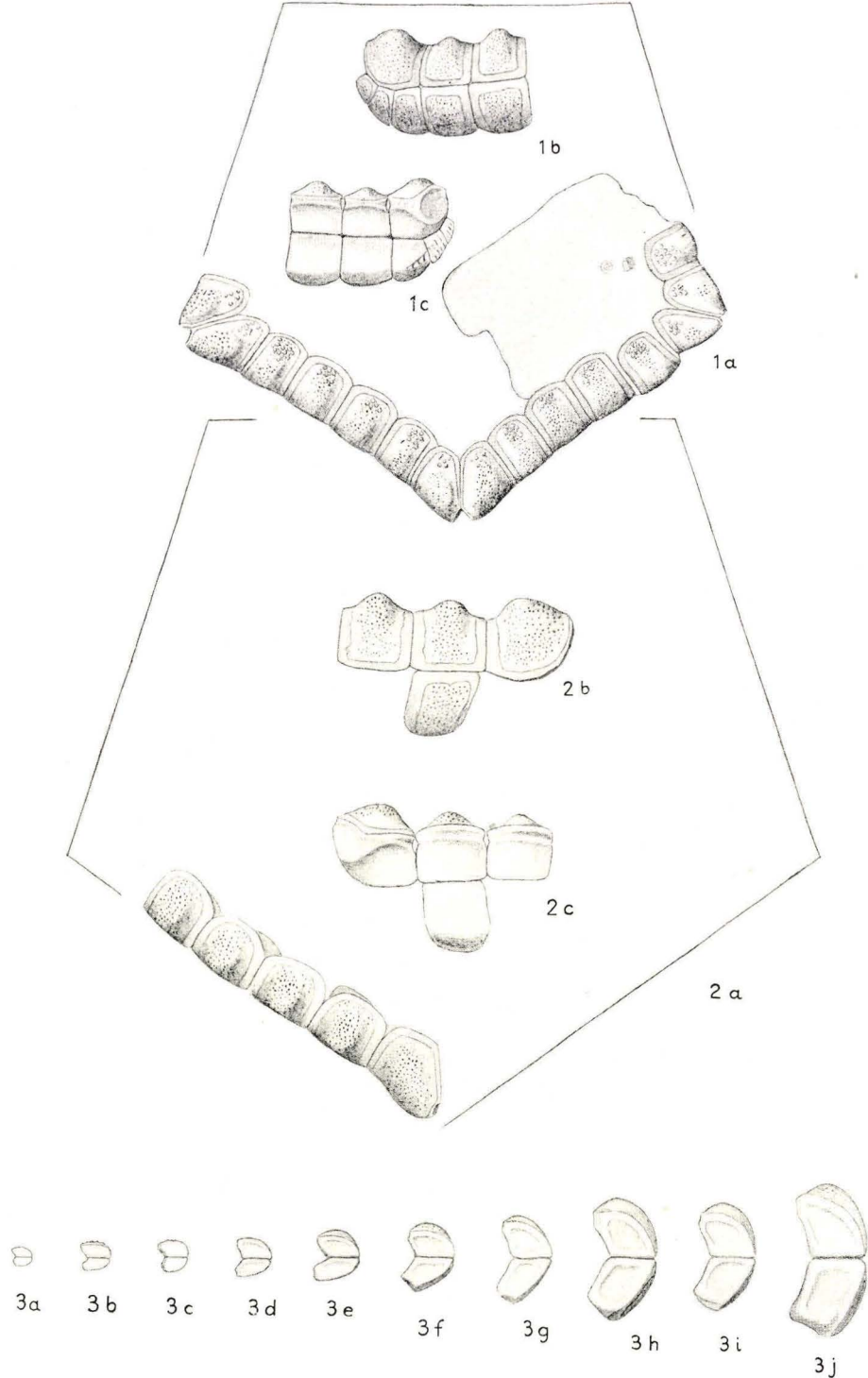


**Plate 2.**

*Metopaster poulsenii* BR. NIELSEN.  
Upper Senonian. Stevns Cliff, Denmark.

- Fig. 1. Individual 12. a, abactinal; b, lateral; c, internal.  
» 2. Individual 13. a, abactinal; b, lateral; c, internal.  
» 3. Marginal profile. a, individual 1; b, 2; c, 3; d, 5; e, 7; f, 8; g, 10; h, 11; i, 12; j, 13.

All figures  $\times 1$ .



**Plate 3.**

*Metopaster poulsenii* BR. NIELSEN.  
Upper Senonian. Stevns Cliff, Denmark.

- Fig. 1. Abactinal and lateral views of abactinal ossicles. a, individual 1; b, 8; c, 10; d, 12.  $\times 5$ .  
» 2. Abactinal and lateral views of primary abactinal ossicles. a, individual 8; b, 12.  $\times 5$ .  
» 3. Actinal view and profile of actinal ossicles. a, individual 1; b, 8; c, 10; d, 12.  $\times 5$ .  
» 4. Ambulacral ossicles. a, individual 1; b, 8; c, 12.  $\times 5$ .  
» 5. Actinal and lateral views of adambulacral ossicles. a, individual 1; b, 8; c, 10; d, 12.  $\times 5$ .  
» 6. Lateral and terminal views of a terminal ossicle. Individual 12.  
» 7. Abactinal view of one side of an arm. Individual 1.  $\times 5$ .  
» 8. Abactinal view of one side of an arm. Individual 3.  $\times 5$ .

Young Stages of Asteroids.

- » 9. Individual from Upper Chalk. Margate, Kent. Abactinal view.  $\times 5$ .  
» 10. Individual from Upper Chalk. Margate, Kent. a, abactinal; b, actinal.  $\times 5$ .

*Metopaster laevis* (BR. NIELSEN).  
Upper Senonian. Stevns Cliff, Denmark.

- » 11. Individual 1. "Ravniaster laevis". Holotype. a, abactinal; b, lateral.  $\times 1$ .  
» 12. Reconstruction. Specimen 2.  $\times 1$ .  
» 13. Individual 3. a, abactinal; b, lateral; c, profile.  $\times 1$ .  
» 14. Individual 4. a, abactinal; b, lateral; c, profile.  $\times 1$ . d, abactinal and lateral views of abactinal ossicle; e, abactinal and lateral views of primary abactinal ossicles; f, actinal and lateral views of actinal ossicle; g, actinal view and profile of adambulacral ossicle.  $\times 5$ .

*Metopaster undulatus* SPENCER.  
Upper Senonian. Aalborg, Denmark.

- » 15. Small individual.  $\times 1$ .  
» 16. Reconstruction. Holotype of "Metopaster granulatus". a, abactinal; b, profile of superomarginal.  $\times 1$ .

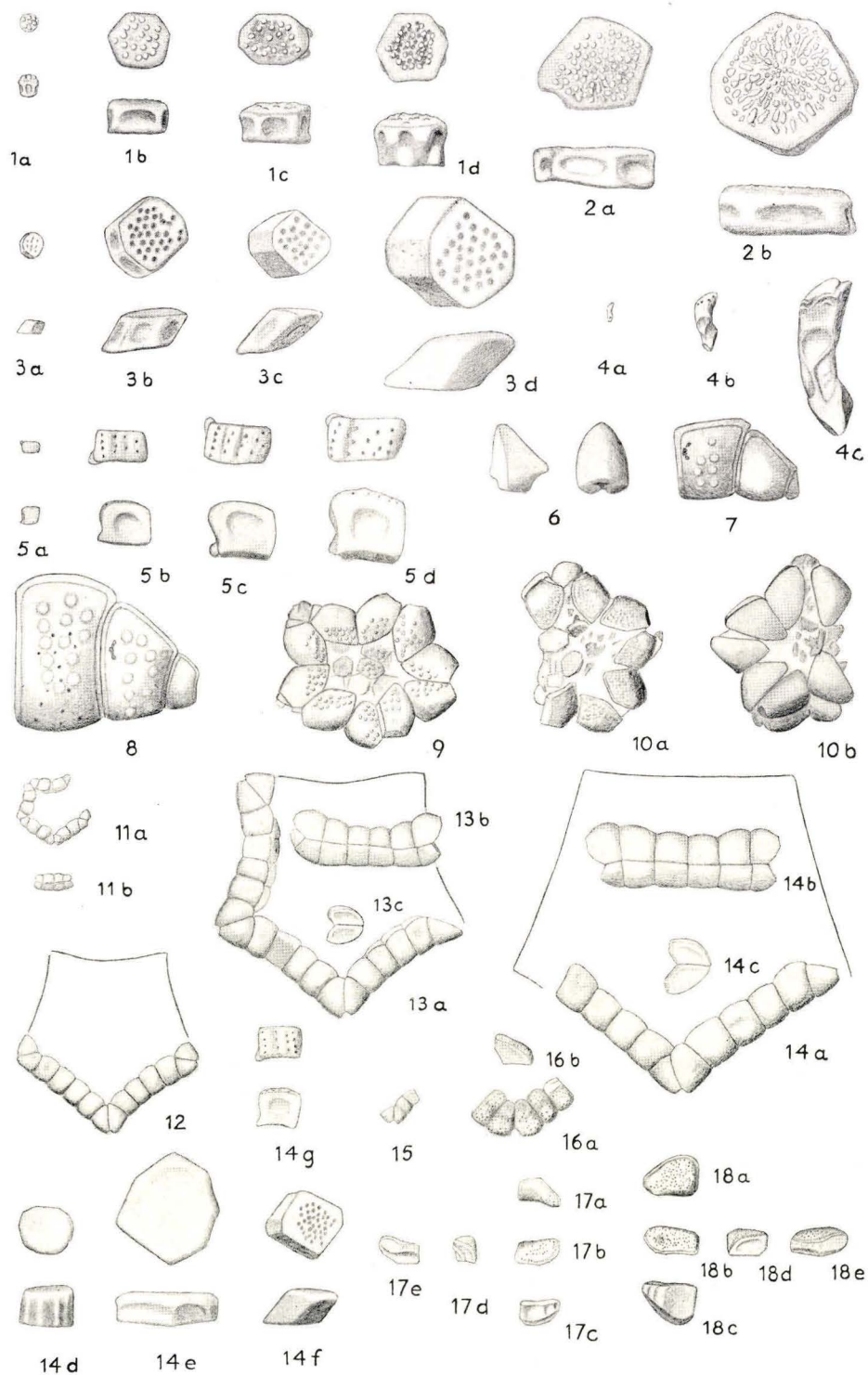
*Metopaster angulatus* BR. NIELSEN.  
Upper Senonian. Enegaarde, Denmark.

- » 17. Ultimate superomarginal. Holotype. a, abactinal; b, lateral; c, actinal; d, profile; e, internal.  $\times 1$ .

*Metopaster cf. thoracifer* (GEINITZ).

- » 18. Ultimate superomarginal. a, abactinal; b, lateral; c, actinal; d, profile; e, internal.  $\times 1$ .





**Plate 4.**

*Metopaster tumidus* SPENCER.

- Fig. 1. "Ravniaster virgineus", holotype. Upper Senonian. Mön Cliff, Denmark. Abactinal.  $\times 1$ .
- » 2. Individual 1. Upper Senonian. Mön Cliff. a, abactinal; b, lateral.  $\times 1$ .
  - » 3. Individual 2. Upper Senonian. Aalborg, Denmark. a, abactinal; b, lateral; c, profile.  $\times 1$ .
  - » 4. Individual 3. Upper Senonian. Aalborg. a, abactinal; b, lateral.  $\times 1$ .
  - » 5. Individual 4. Upper Senonian. Mön Cliff. a, abactinal; b, lateral; c, actinal; d, profile.  $\times 1$ . e, abactinal ossicle; f, actinal ossicle; g, ambulacral ossicle; h, adambulacral ossicle; i, oral ossicle.  $\times 5$ .

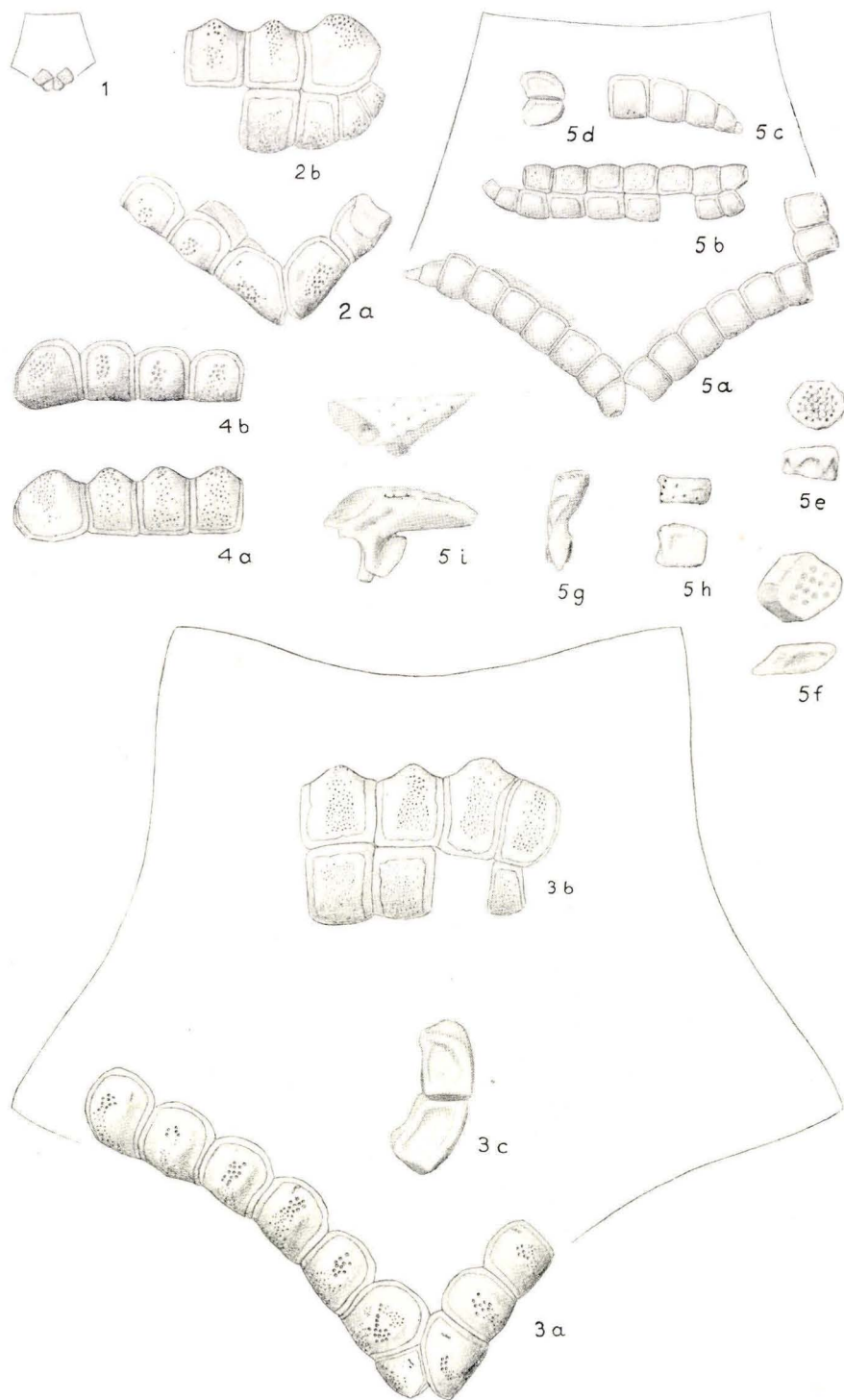




Plate 5.

*Metopaster kagstrupensis* BR. NIELSEN.

- Fig. 1. Ultimate superomarginal of a small individual. "Ravniaster" stage. Lower Danian. Korporalskroen, Denmark. a, abactinal; b, lateral.  $\times 1$ .
- » 2. Ultimate superomarginal. Lower Danian. Kagstrup, Denmark. a, abactinal; b, lateral; c, actinal; d, profile; e, internal.  $\times 1$ .
- » 3. Ultimate superomarginal. Lower Danian. Korporalskroen. a, abactinal; b, lateral; c, profile; d, internal.  $\times 1$ .
- » 4. Remains of an individual in flint; erratic. Danian? a, abactinal; b, lateral.  $\times 1$ .

*Metopaster spencerii* BR. NIELSEN.

- » 5. Ultimate superomarginal. Lower Danian. Kagstrup. a, abactinal; b, lateral; c, profile; d, internal.  $\times 1$ .
- » 6. Superomarginals. Lower Danian. Kagstrup. a, abactinal; b, lateral; c, profile; d, internal.  $\times 1$ .
- » 7. Ultimate superomarginal. Lower Danian. Stevns Cliff. a, abactinal; b, lateral; c, actinal; d, profile; e, internal.  $\times 1$ .
- » 8. Ultimate superomarginal. Lower Danian. Kagstrup. a, abactinal; b, lateral; c, profile.  $\times 1$ .

*Metopaster elevatus* BR. NIELSEN.

- » 9. Ultimate superomarginal. Middle Danian. Rejstrup, Denmark. a, abactinal; b, lateral; c, profile; d, internal.  $\times 1$ .
- » 10. Ultimate superomarginal. Middle Danian. Rejstrup. a, abactinal; b, lateral; c, profile; d, internal.  $\times 1$ .

*Metopaster planus* (BR. NIELSEN).

- » 11. Part of individual. Type. Lower Danian. Korporalskroen. a, abactinal.  $\times 1$ . b, abactinal; c, lateral; d, profile; e, internal.  $\times 5$ .

*Metopaster carinatus* (BR. NIELSEN).

- » 12. Ultimate superomarginal. Holotype. Upper Danian. Herfølge, Denmark. a, abactinal.  $\times 1$ . b, abactinal; c, lateral; d, profile; e, internal.  $\times 5$ .
- » 13. Ultimate inferomarginal. Upper Danian. Herfølge. a, actinal; b, lateral; c, abactinal; d, profile.  $\times 5$ .

*Metopaster maculatus* (BR. NIELSEN).

- » 14. Ultimate superomarginal. Type. Middle Danian. Fakse, Denmark. a, abactinal; b, lateral; c, profile.  $\times 1$ .
- » 15. Distal part of arm. Middle Danian. Fakse. a, abactinal; b, lateral.  $\times 5$ .

*Metopaster sp.*

- » 16. Ultimate superomarginal. Upper Danian. Herfølge. a, abactinal; b, lateral; c, profile.  $\times 1$ .

*Ceramaster dividius* (W. RASMUSSEN).

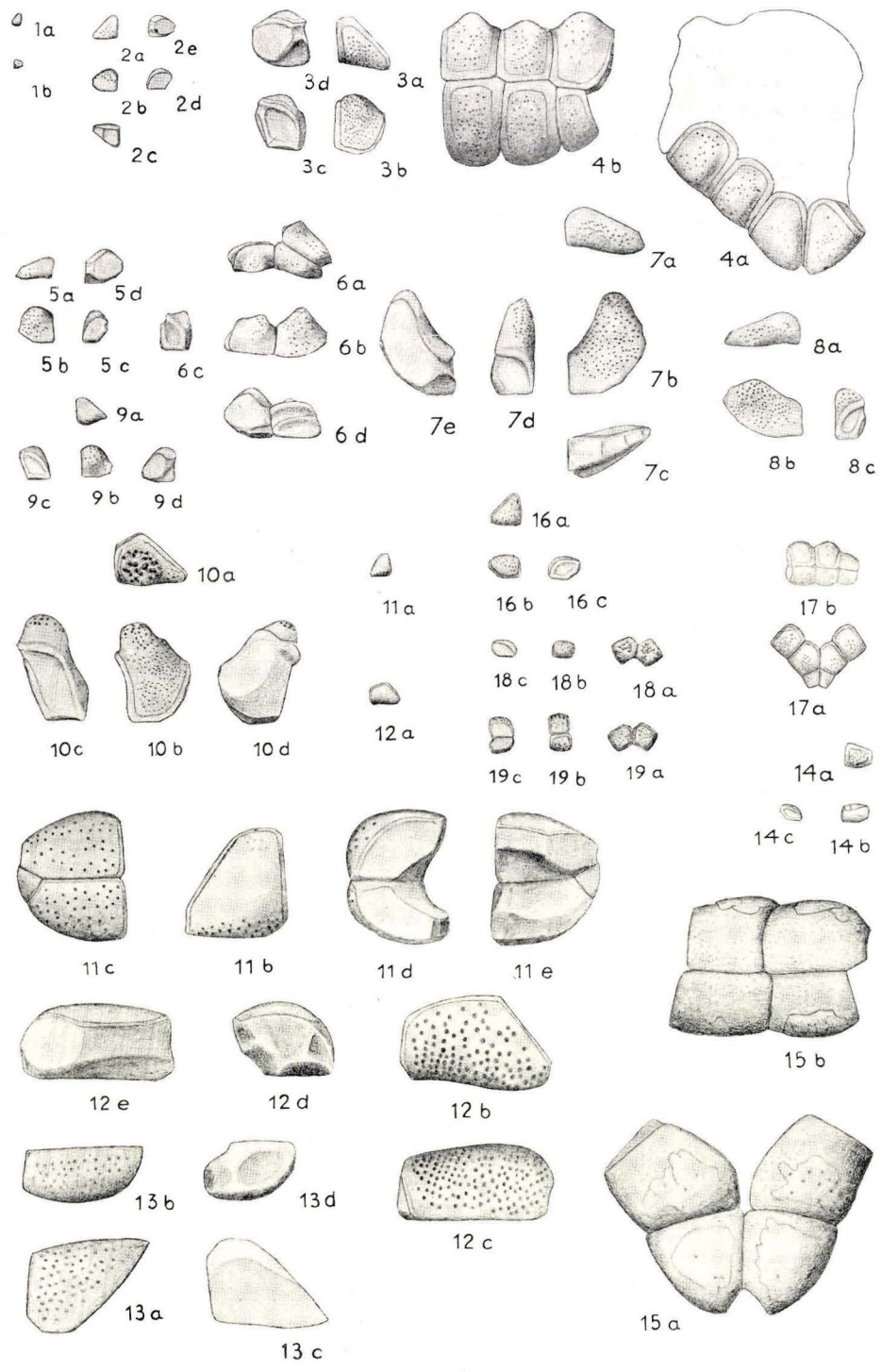
- » 17. Distal part of arm. Upper Danian. Svanemøllen, Copenhagen. a, abactinal; b, lateral.  $\times 1$ .

*Ceramaster granulatus* (W. RASMUSSEN).

- » 18. Distal part of arm. Middle Danian. Fakse. a, abactinal; b, lateral; c, profile.  $\times 1$ .

*Ceramaster cf. granulatus* (W. RASMUSSEN).

- » 19. Distal part of arm. Middle Danian. Fakse. a, abactinal; b, lateral; c, profile.  $\times 1$ .



**Plate 6.**

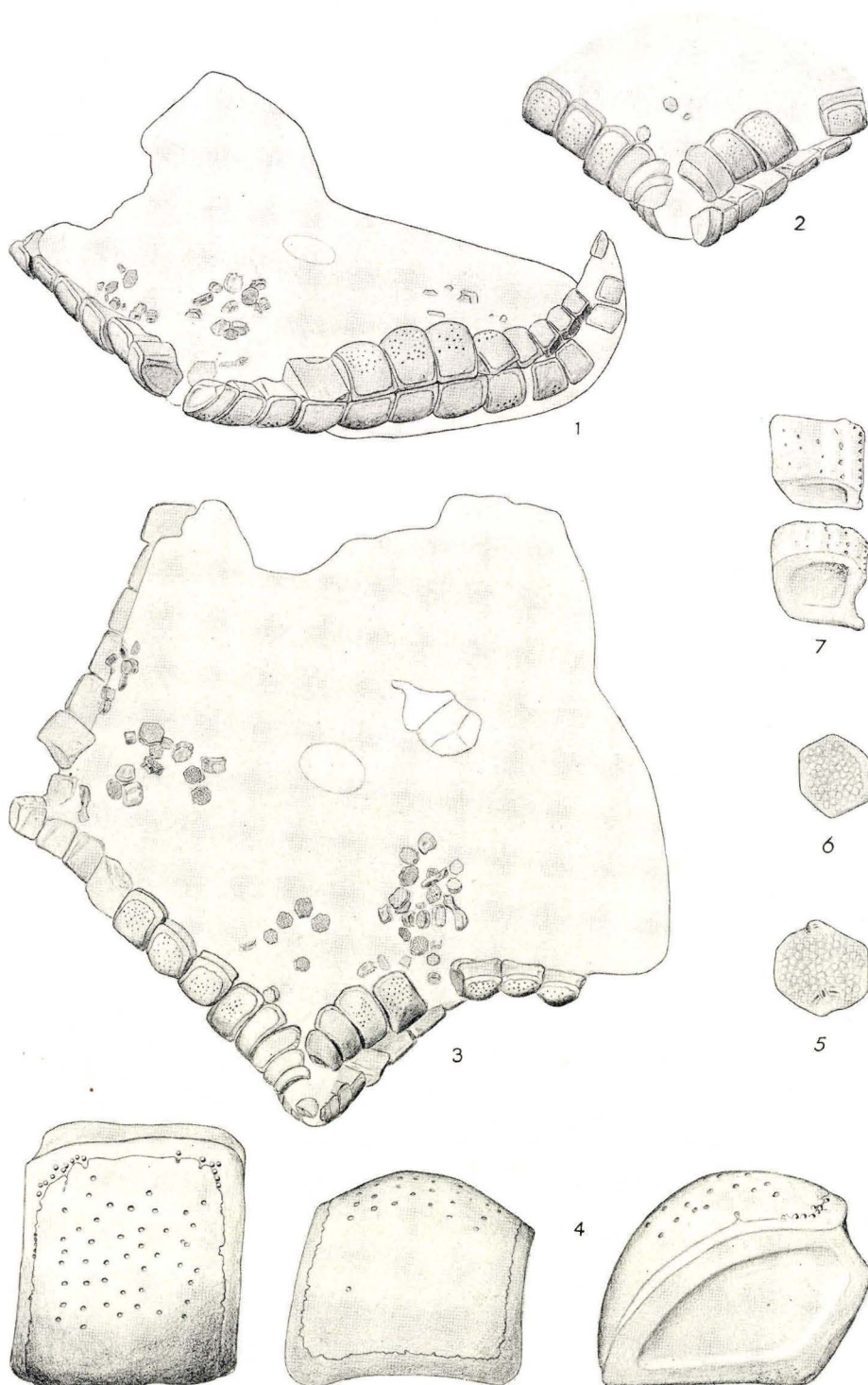
*Recurvaster blackmorei* n. sp.

Middle Senonian. East Harnham, Wiltshire, England.

Fig. 1. Lateral view.  $\times 1$ .

- » 2. View from apex of arm. The distal part of the arm is removed.  $\times 1$ .
- » 3. Abactinal.  $\times 1$ .
- » 4. Median marginal.  $\times 5$ .
- » 5. Abactinal ossicle.  $\times 5$ .
- » 6. Abactinal ossicle.  $\times 5$ .
- » 7. Adambulacral ossicle.  $\times 5$ .



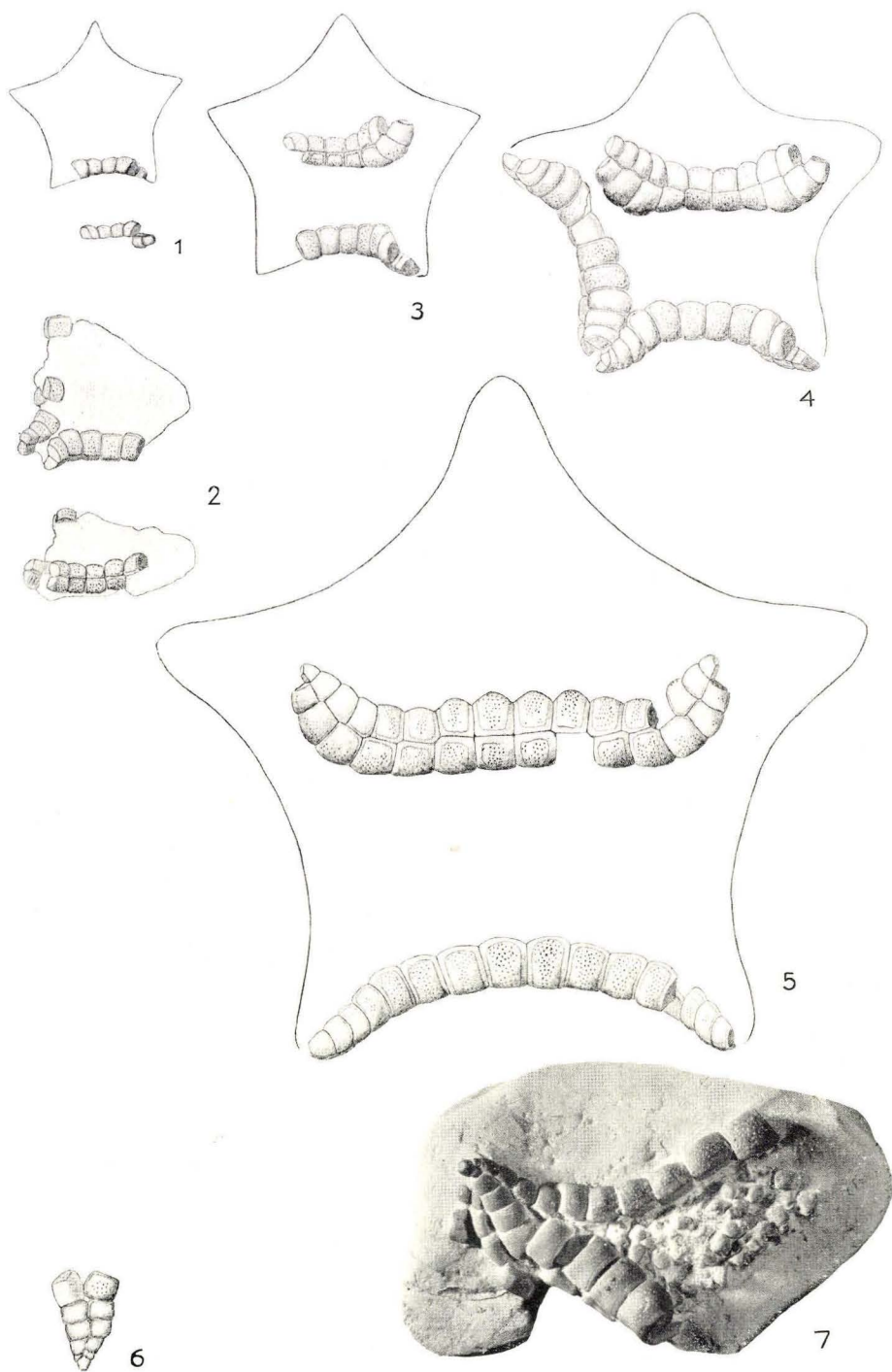


**Plate 7.**

*Recurvaster radiatus* (SPENCER).

- Fig. 1. Individual 1. Upper Senonian. Aalborg, Denmark.  
» 2. Individual 2. Upper Senonian. Mön Cliff. Denmark.  
» 3. Individual 4. Upper Senonian. Stevns Cliff, Denmark.  
» 4. Individual 5. Upper Senonian. Stevns Cliff.  
» 5. Individual 7. Upper Senonian. Stevns Cliff.  
» 6. Individual 10. Upper Senonian. Stevns Cliff.  
» 7. Individual 11. Upper Senonian. Stevns Cliff.

All figures  $\times 1$ .





**Plate 8.**

*Recurvaster radiatus* (SPENCER).

Fig. 1. Individual 14. Upper Senonian. Stevns Cliff. a, abactinal; b, lateral; c, internal; d, profile of marginals 1—10.  $\times 1$ .

» 2. Remains of an individual. Upper Senonian. Trimingham, England. a, abactinal; b, lateral.  $\times 1$ .

*Recurvaster mammillatus* (GABB).

Upper Danian. Saltholm, Denmark.

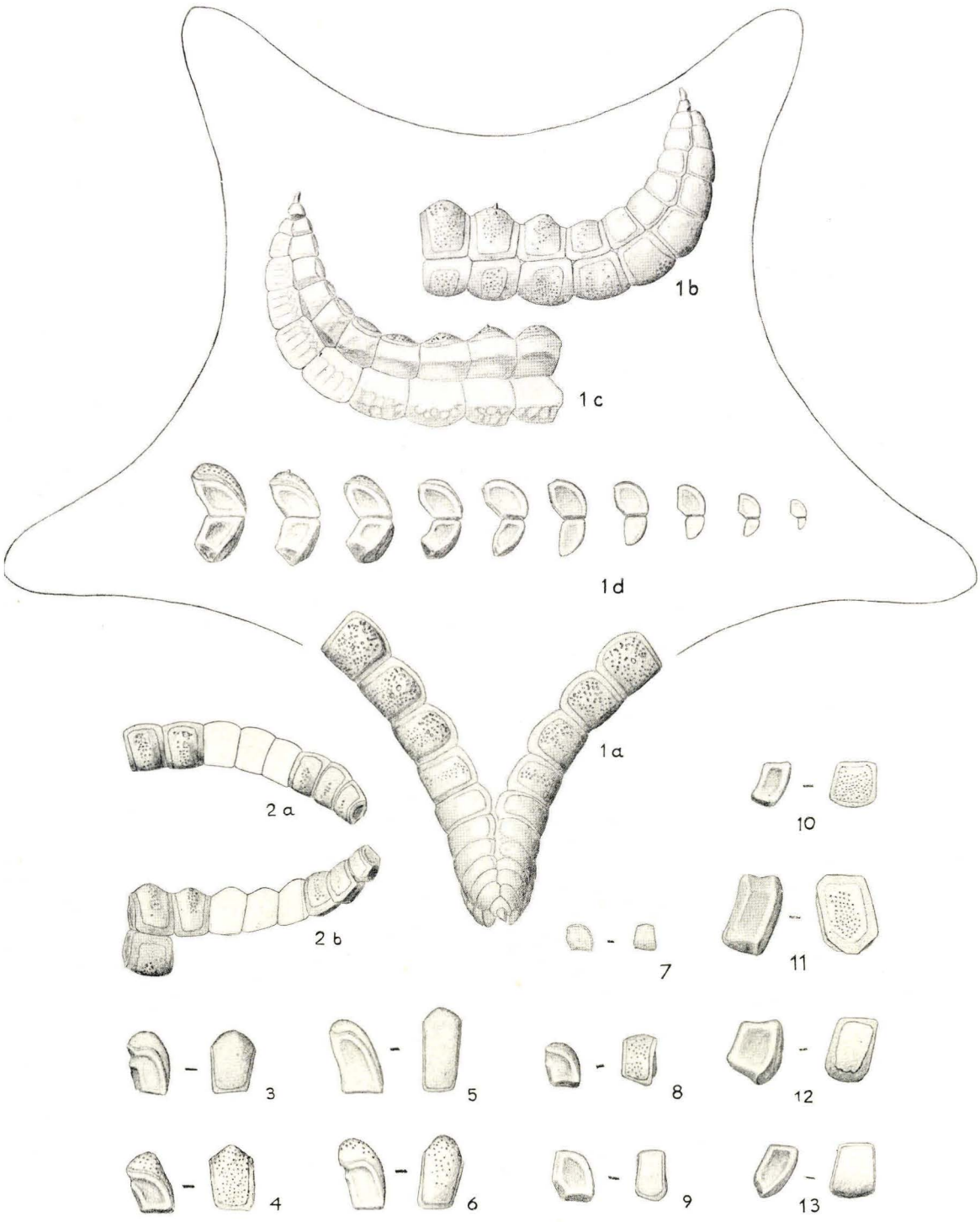
» 3—6. Median superomarginals.

» 7—9. Distal superomarginals.

» 10—12. Median inferomarginals.

» 13. Distal inferomarginal.

All figures  $\times 1$ .



**Plate 9.**

*Recurvaster radiatus* (SPENCER).

- Fig. 1. Individual 7. a, abactinal ossicle; b, actinal ossicle; c, ambulacral ossicle; d, adambulacral ossicle; e, oral ossicle.
- » 2. Individual 14. a, abactinal ossicle; b, abactinal ossicle; c, actinal ossicle; d, ambulacral ossicle ( $a_1 + a_2$ ); e—h, proximal — distal adambulacral ossicles; i, oral ossicle ( $ad_1$ ); j, k, proximal and distal ambulacral ossicles; l, interrarial ossicle.
- » 3. Individual 9. Terminal ossicle.

*Recurvaster mammillatus* (GABB).

- » 4. Terminal ossicle. Upper Danian. Saltholm.

All figures  $\times 5$ .



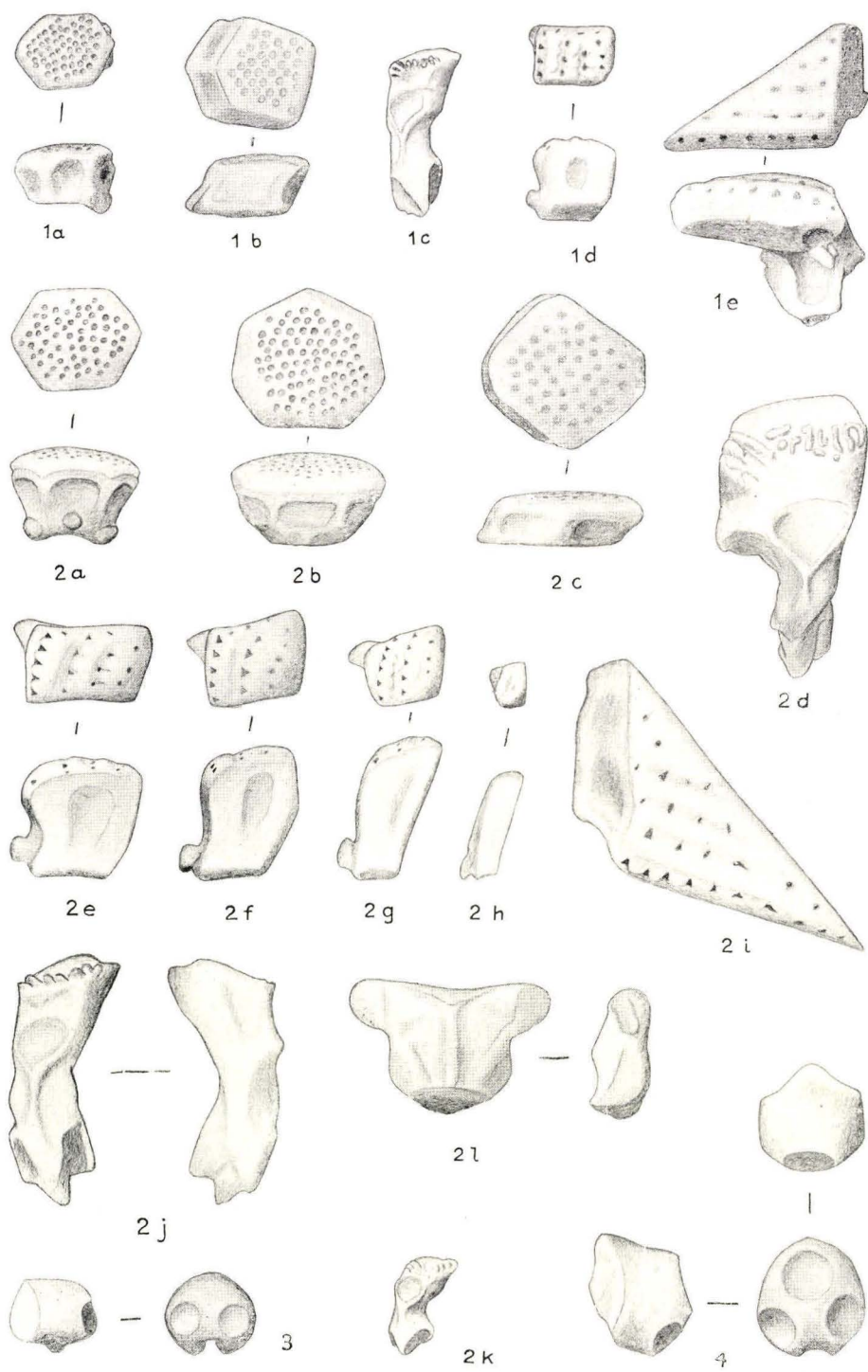


Plate 10.

*Teichaster favosus* SPENCER.

- Fig. 1. Superomarginal. Upper Senonian. Mön Cliff.  $\times 1$ .  
» 2. Remains of a small individual. Upper Senonian. Stevns Cliff. a, abactinal; b, lateral; c, profile.  $\times 1$ . d, actinal ossicle; e, ambulacral ossicle; f, adambulacral ossicle.  $\times 5$ .

*Teichaster anchylus* BR. NIELSEN.

- » 3. Superomarginal. Lower Danian. Stevns Cliff.  $\times 1$ .  
» 4. Inferomarginal. Lower Danian. Kagstrup.  $\times 1$ .

*Teichaster retiformis* SPENCER.

- » 5. Individual. Upper Danian. Legind, Denmark. a, lateral; b, profile of margin.  $\times 1$ . c, ambulacral ossicle; d, adambulacral ossicle.  $\times 5$ .

*Pycinaster crassus* SPENCER.

- » 6. Superomarginal. Upper Senonian. Stevns Cliff.  $\times 1$ .  
» 7. Inferomarginal. Upper Senonian. Stevns Cliff.  $\times 1$ .

*Pycinaster danicus* BR. NIELSEN.

- » 8. Individual. Upper Danian. Helligkilde, Denmark. a, lateral; b, profile of margin.  $\times 1$ .

*Pycinaster cornutus* W. RASMUSSEN.

- » 9. Superomarginal. Type. Upper Danian. Svanemöllen, Copenhagen.  $\times 1$ .

*Pycinaster aff. cornutus* W. RASMUSSEN.

- » 10. Supero- and inferomarginals. Upper Senonian. Mön Cliff.  $\times 1$ .

*Pycinaster? rosenkrantzii* (BR. NIELSEN).

- » 11. Superomarginal. Type. Upper Danian. Teglhølm, Copenhagen.  $\times 1$ .

*Chomataster acules* SPENCER.

- » 12. Superomarginal. Upper Senonian. Mön Cliff.  $\times 1$ .

*Chomataster spenceri* n. sp.

- » 13. Superomarginal. Holotype. Upper Senonian. Mön Cliff. a, abactinal; b, lateral; c, profile.  $\times 1$ . d, abactinal.  $\times 5$ .

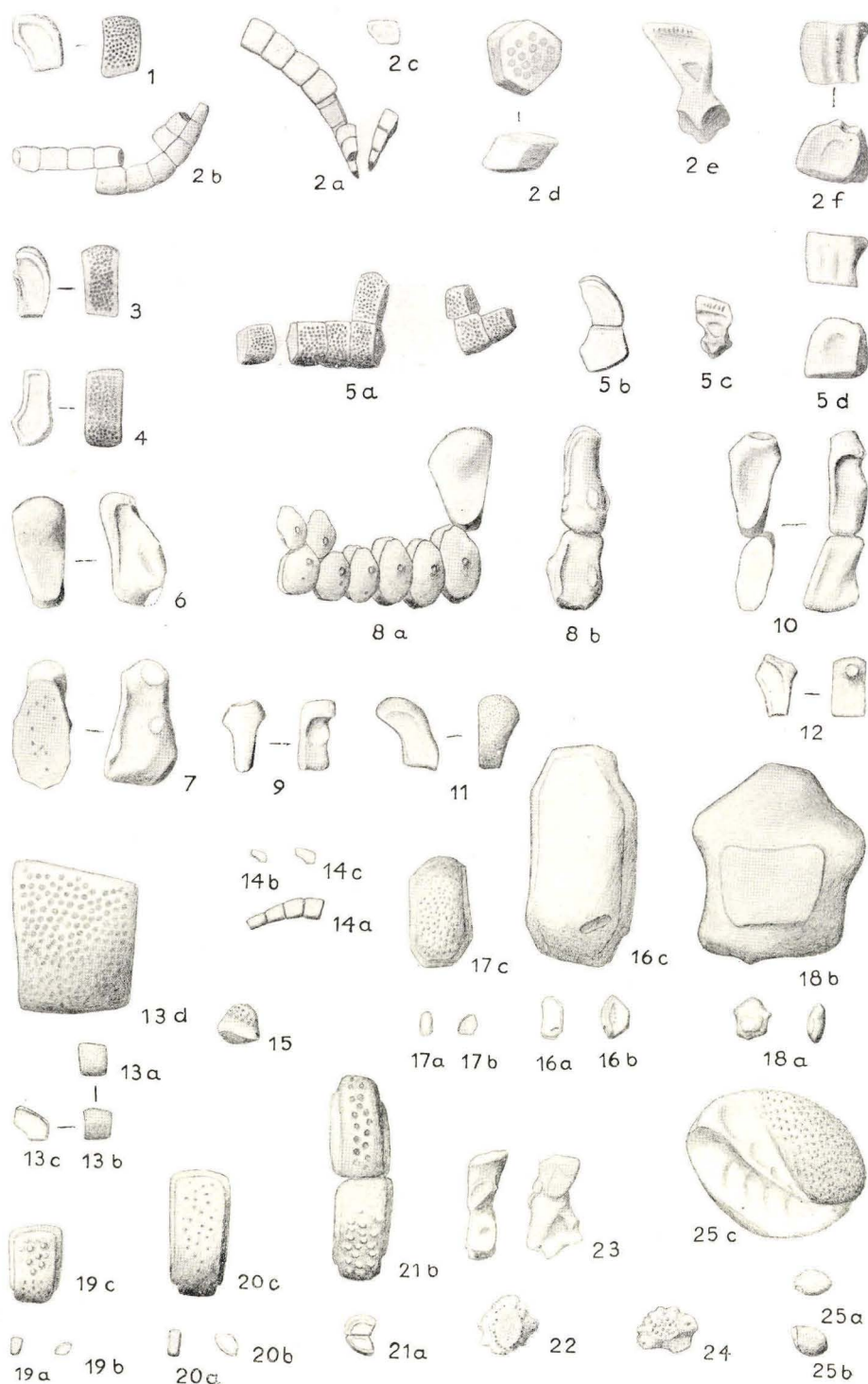




Fig. 14. Remains of an individual. Upper Senonian. Mön Cliff. a, abactinal; b—c, profile.  $\times 1$ .

*Stauranderaster pyramidalis* SPENCER.

» 15. Abactinal ossicle. Type. Lower Danian. Stevns Cliff.  $\times 1$ .

*Stauranderaster mixtus* BR. NIELSEN.

» 16. Marginal. Holotype. Upper Senonian. Stevns Cliff. a, lateral; b, profile.  $\times 1$ . c, lateral.  $\times 5$ .

*Stauranderaster miliaris* BR. NIELSEN.

» 17. Marginal. Upper Danian. Herfølge. a, lateral; b, profile.  $\times 1$ . c, lateral.  $\times 5$ .

*Stauranderaster speculum* BR. NIELSEN.

» 18. Ossicle. Holotype. Upper Danian. Saltholm. a,  $\times 1$ . b,  $\times 5$ .

*Astropecten ? pygmaeus* (SPENCER).

» 19. Superomarginal. Upper Senonian. Aalborg. a, abactinal; b, profile.  $\times 1$ . c, abactinal.  $\times 5$ .

*Astropecten punctatus* (BR. NIELSEN).

» 20. Inferomarginal. Holotype. Upper Danian. Saltholm. a, actinal; b, profile.  $\times 1$ . c, actinal.  $\times 5$ .

*Astropecten postornatus* (W. RASMUSSEN).

» 21. Supero- and inferomarginals. Holotype. Upper Danian. Copenhagen. a, profile.  $\times 1$ . b, lateral.  $\times 5$ .

*Valettaster ocellatus* (FORBES).

» 22. Ossicle. Upper Senonian. Stevns Cliff.  $\times 1$ .

» 23. Ambulacral ossicle. Upper Senonian. Aalborg.  $\times 5$ .

*Valettaster granulatus* BR. NIELSEN.

» 24. Ossicle. Holotype. Upper Danian. Saltholm.  $\times 1$ .

*Asterias ? sp.*

» 25. Terminal ossicle. Upper Senonian. Aalborg. a, abactinal; b, lateral.  $\times 1$ . c,  $\times 5$ .

#### Plate 11.

*Chomataster wrighti* n. sp.

Upper Senonian. Stevns Cliff.

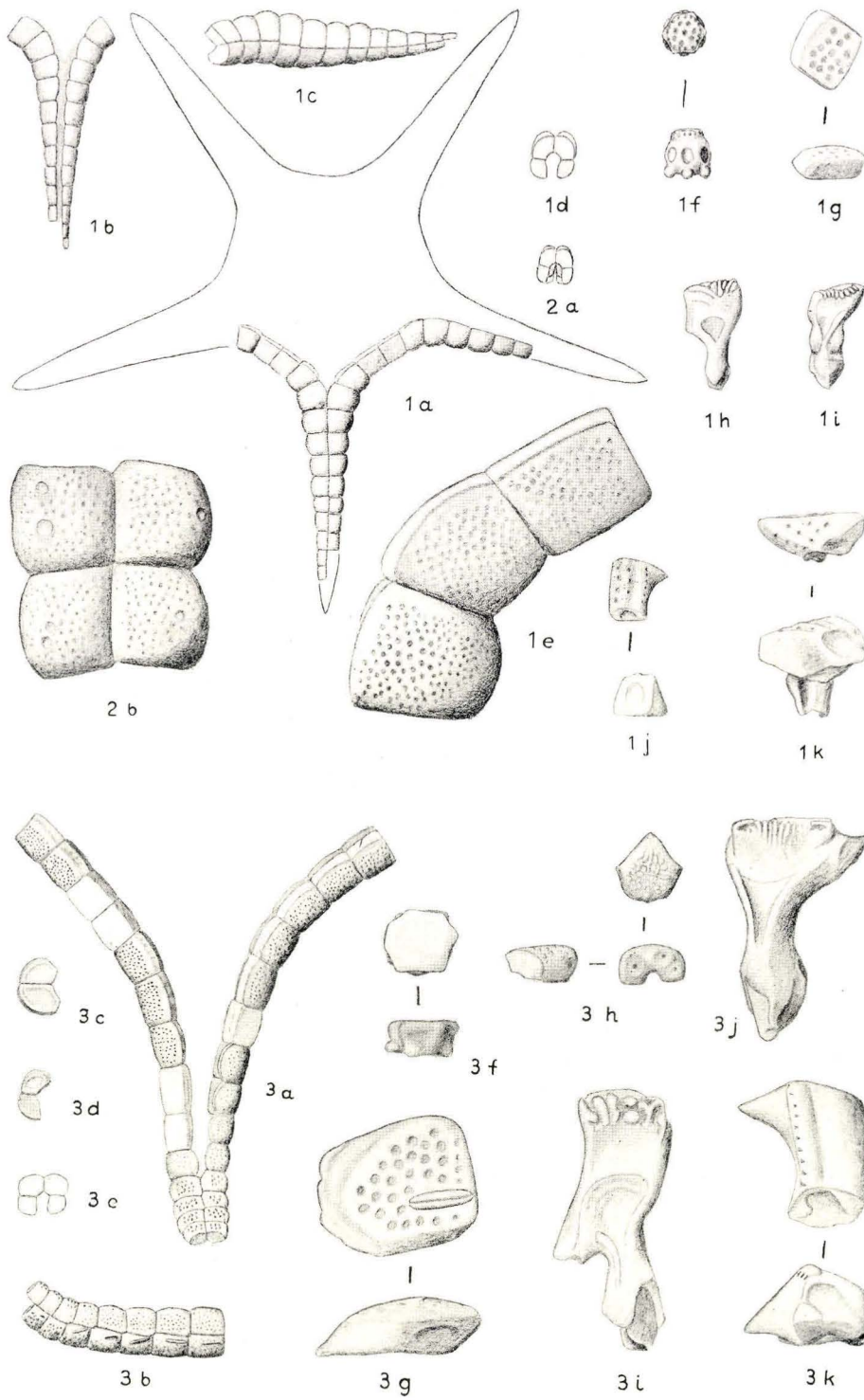
Fig. 1. Individual 1. Holotype. a, abactinal; b, actinal; c, lateral; d, profile of arm.  $\times 1$ . e, superomarginals 1—3; f, abactinal ossicle; g, actinal ossicle; h, ambulacral ossicle ( $a_1 + a_2$ ); i, ambulacral ossicle; j, adambulacral ossicle; k, oral ossicle.  $\times 5$ .

» 2. Individual 2. a, profile of arm.  $\times 1$ . b, arm fragment.  $\times 5$ .

*Ophryaster magnus* SPENCER.

Upper Senonian. Mön Cliff.

» 3. Individual 1. a, abactinal side of arm; b, distal part of arm, lateral aspect; c, profile of arm at marginal 1; d, the same at marginal 7; e, the same at marginal 13.  $\times 1$ . f, abactinal ossicle; g, actinal ossicle; h, terminal ossicle; i, ambulacral ossicle ( $a_1 + a_2$ ); j, ambulacral ossicle; k, adambulacral ossicle.  $\times 5$ .



**Plate 12.**

*Ophiomusium danicum* BR. NIELSEN.

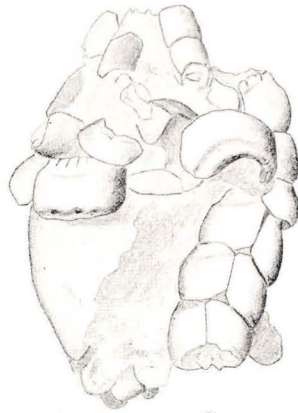
- Fig. 1a. Cast of an impression in flint of a small individual. Erratic. Denmark.
- » 1b. The same. Part of an arm showing the small dorsal arm plates.
  - » 2. Holotype. Radial shield and part of an arm. Upper Danian. Saltholm, Denmark.
  - » 3. Lateral arm plate from the proximal part of the arm. Upper Danian. Saltholm, Denmark. a, dorsal; b, internal; c, ventral; d, distal end; e, lateral.
  - » 4. Radial shield. Upper Danian; Saltholm, Denmark. a, dorsal; b, edge; c, internal.
  - » 5. Inter-radial marginal plate. Upper Danian. Saltholm, Denmark. a, internal; b, edge; c, outer surface.
  - » 6. A large radial shield. Upper Danian in the Paleocene basal conglomerate at Svanemøllen, Copenhagen, Denmark. a, dorsal; b, edge; c, internal.

fig. 1a,  $\times 2$ . fig. 1b—6,  $\times 5$ .

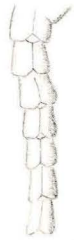




1a



2



1b



3a



3b



3d



3e



3c



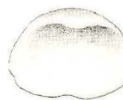
4a



4b



4c



5a



5b



5c



6a



6b



6c

**Plate 13.**

*Ophiomusium granulosum* (ROEMER).

- Fig. 1. Individual showing the adoral surface. Upper Senonian. Suffolk, England.
- » 2. The same individual: the upper right arm in fig. 1. a, lateral; b, dorsal; c, distal end.
  - » 3. A lateral arm plate from a find of connected plates. Upper Senonian. Isle of Wight, England. a, dorsal; b, internal; c, distal end; d, lateral.
  - » 4. A radial shield from the same individual. a, internal; b, edge; c, dorsal.

Fig. 1,  $\times 2$ . Fig. 2—4,  $\times 5$ .



Chr. Halkier phot. W. Rasmussen del.



**Plate 14.**

*Ophiomusium granulosum* (ROEMER).

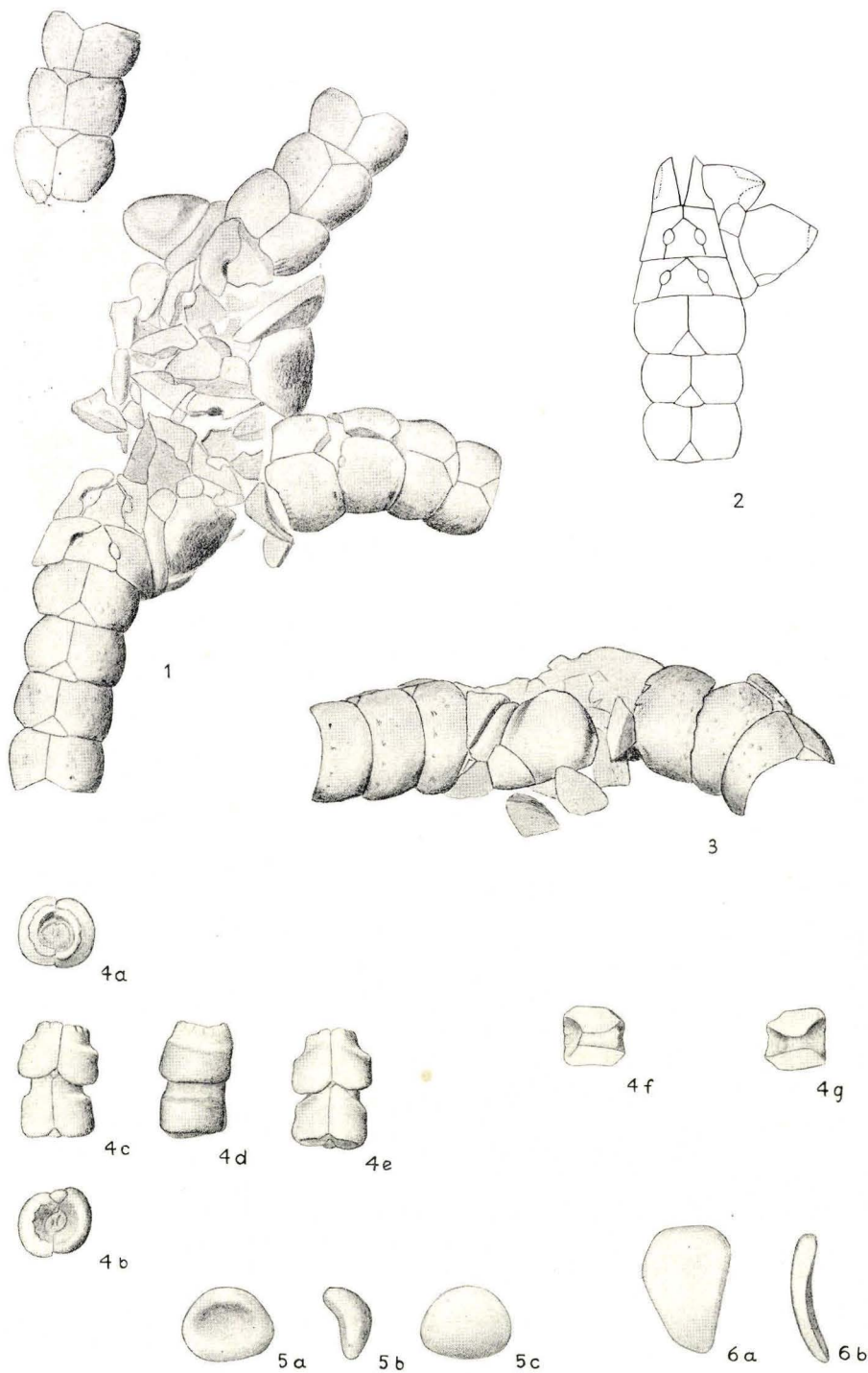
Fig. 1. Adoral aspect of the same individual as Plate 13, fig. 1—2.

- » 2. The structure of the ventral surface of the same individual. Sketch.
- » 3. Lateral aspect of the same individual.

*Ophiomusium subcylindricum* (HAGENOW).

- » 4. Part of an arm. Upper Senonian. Aalborg, Denmark. a, proximal end; b, distal end; c, dorsal; d, lateral; e, ventral; f, inner aspect of arm plate with vertebra in position; g, inner surface of arm plate.
- » 5. Interradial marginal plate. Upper Senonian. Enegaarde, Denmark. a, inner surface; b, edge; c, outer surface.
- » 6. Radial shield. Upper Senonian. Mön, Denmark. a, dorsal; b, edge.

All figures  $\times 5$ .



**Plate 15.**

*Ophiomusium* sp.

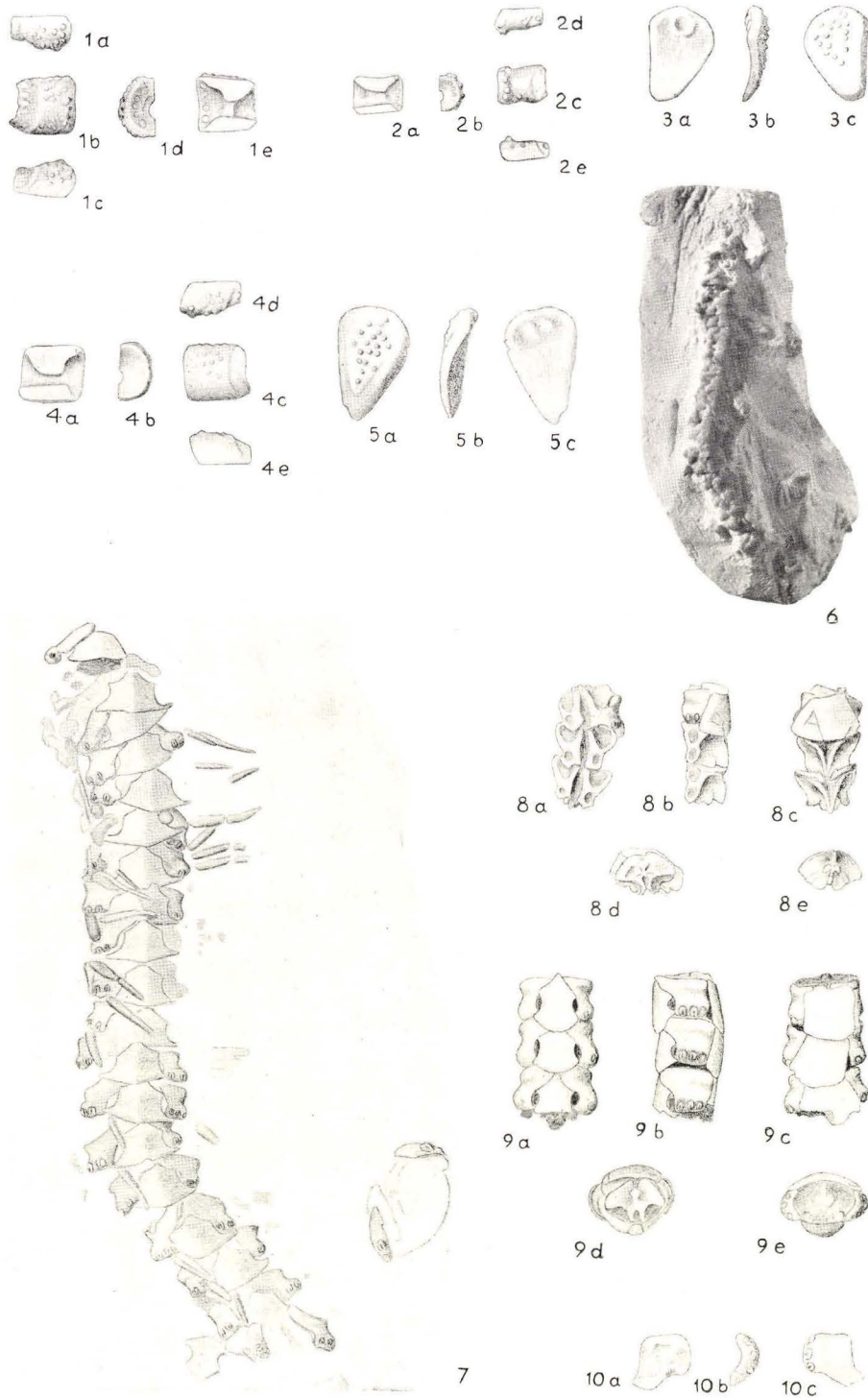
- Fig. 1. Lateral arm plate. Upper Senonian. Rørdal, Aalborg, Denmark. a, dorsal; b, lateral; c, ventral; d, distal end; e, internal.
- » 2. Lateral arm plate from the more distal part of the arm. Upper Senonian. Rørdal, Aalborg, Denmark. a, internal; b, distal end; c, lateral; d, dorsal; e, ventral.
- » 3. Radial shield. Upper Senonian. Rørdal, Aalborg, Denmark. a, internal; b, edge; c, dorsal surface.
- » 4. Lateral arm plate. Lower Danian. Korporalskroen, Denmark. a, internal; b, distal end; c, lateral; d, dorsal; e, ventral.
- » 5. Radial shield. Upper Danian. Rejstrup, Denmark. a, dorsal; b, edge; c, internal.

*Amphiura* ? *senonensis* (VALETTE).

- » 6. Part of an arm. Upper Senonian. Worthing, England. Ventral aspect.
- » 7. The same.
- » 8. Vertebral ossicles from the same individual. a, ventral; b, lateral; c, dorsal; d, proximal end; e, distal end.
- » 9. Part of an arm. Upper Senonian. Blegkilde, Aalborg, Denmark. a, ventral; b, lateral; c, dorsal; d, proximal end; e, distal end.
- » 10. Lateral arm plate. Upper Senonian. Blegkilde, Aalborg, Denmark. a, internal; b, distal end; c, lateral.

Fig. 1—5, and 7—10,  $\times 5$ . Fig. 6,  $\times 2$ .



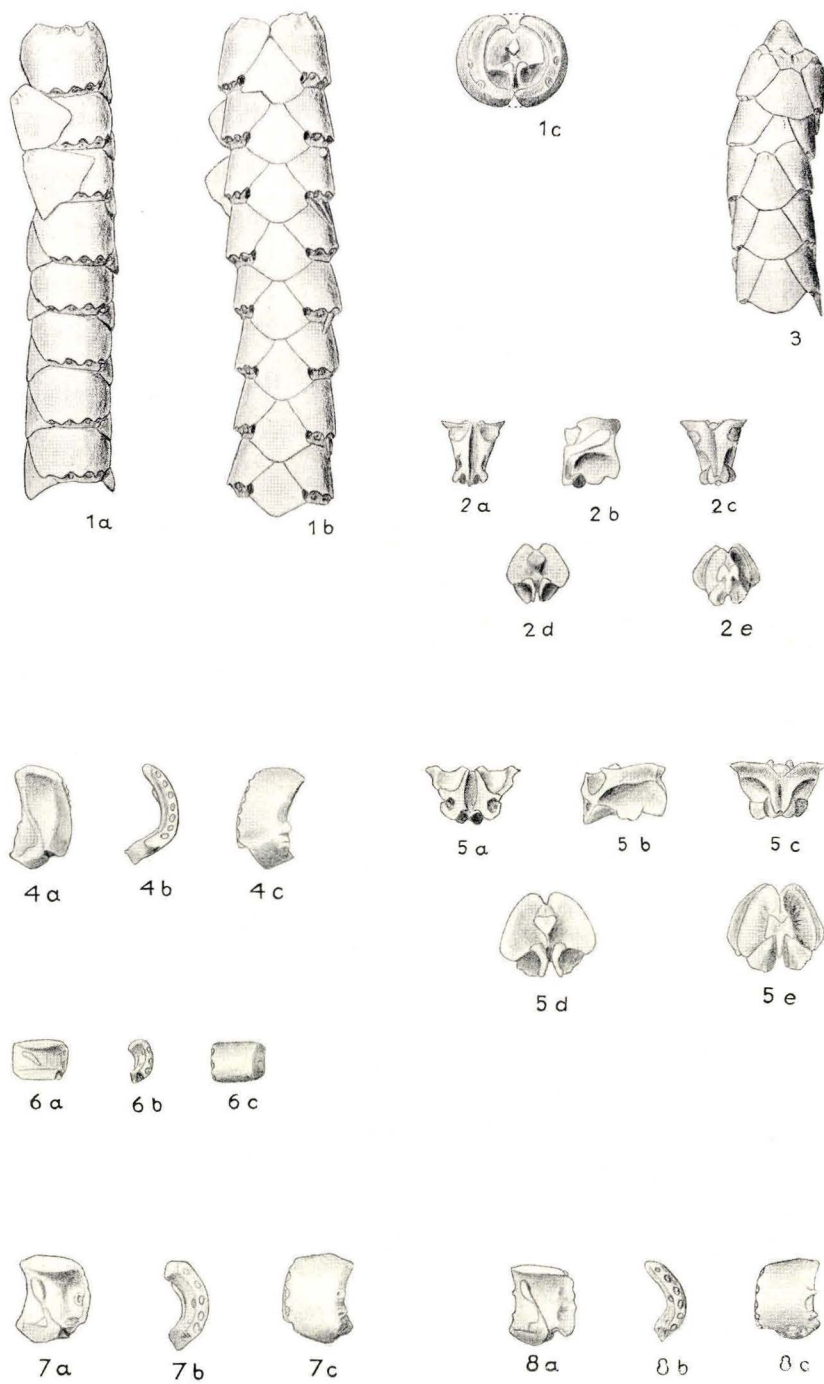


**Plate 16.**

*Ophiura serrata* ROEMER.

- Fig. 1. Arm fragment. Lower Senonian. Kent, England. a, lateral; b, ventral; c, proximal end.
- » 2. The same individual. Vertebra from the distal part of the arm. a, ventral; b, lateral; c, dorsal; d, proximal end; e, distal end.
  - » 3. Arm fragment. Hampshire, England. Dorsal.
  - » 4. Lateral arm plate from the proximal part of an arm. Dover, Kent, England. a, internal; b, distal end; c, lateral.
  - » 5. The same individual. Vertebra from the proximal part of an arm. a, ventral; b, lateral; c, dorsal; d, proximal end; e, distal end.
  - » 6. Lateral arm plate from the distal part of an arm. Upper Senonian. N. Uttrup, Aalborg, Denmark. a, internal; b, distal end; c, lateral.
  - » 7. Lateral arm plate from the middle part of the arm. Upper Senonian. N. Uttrup, Aalborg, Denmark. a, internal; b, distal end; c, lateral.
  - » 8. Lateral arm plate from the middle part of an arm. Lower Danian. Korporalskroen, Denmark. a, internal; b, distal end; c, lateral.

All figures  $\times 5$ .



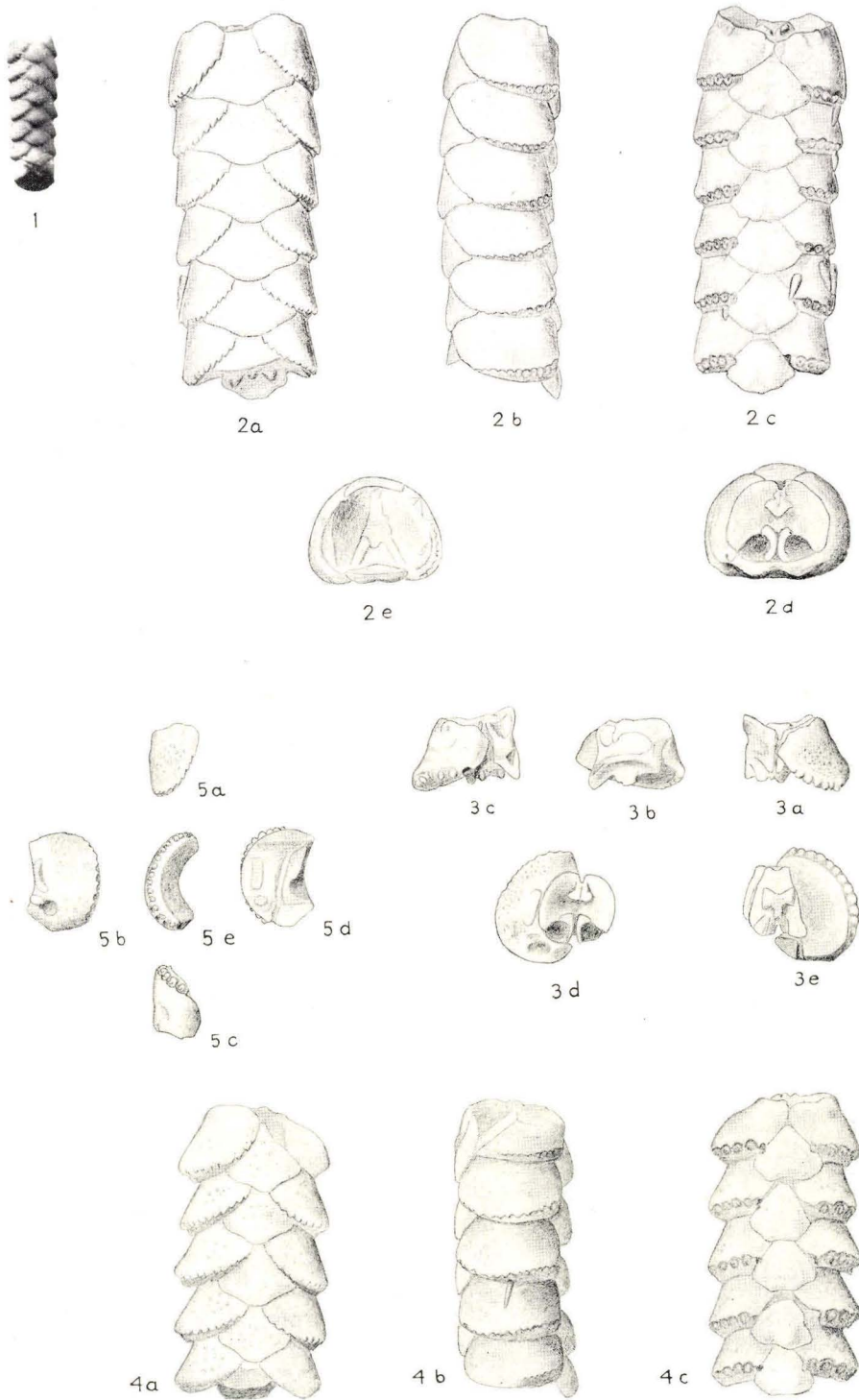


**Plate 17.**

*Ophiura ? hagenowi* n. sp.

- Fig. 1. Part of an arm. Upper Senonian. Trimingham, England.
- » 2. The same. a, dorsal; b, lateral; c, ventral; d, proximal end; e, distal end.
  - » 3. Lateral arm plate and vertebra. Upper Senonian. Trimingham, England. a, dorsal; b, lateral; c, ventral; d, proximal end; e, distal end.
  - » 4. Arm fragment. Upper Senonian. Mön Cliff, Denmark. a, dorsal; b, lateral; c, ventral.
  - » 5. Lateral arm plate. Upper Senonian. Rördal, Aalborg, Denmark. a, dorsal; b, lateral; c, ventral; d, internal; e, distal end.

Fig. 1,  $\times 2$ . Fig. 2—5,  $\times 5$ .



**Plate 18.**

*Ophiura ? substriata* n. sp.

- Fig. 1. Arm fragments embedded in chalk. Dover, Kent, England.  
» 2. The same. Proximal arm fragment. a, lateral; b, dorsal.  
» 3. The same. Fragment from the middle part of an arm. a, ventral; b, proximal end.  
» 4. The same. Distal arm fragment. Dorsal.  
» 5. The same. Lateral arm plate. a, lateral; b, distal margin; c, internal; d, dorsal; e, ventral.  
» 6. The same. Vertebral ossicle. a, proximal end; b, lateral; c, distal end; d, dorsal; e, ventral.  
» 7. Lateral arm plate. Upper Senonian. N. Uttrup, Aalborg, Denmark. a, internal; b, distal margin; c, lateral.  
» 8. Dorsal arm plate. Upper Senonian. N. Uttrup, Aalborg, Denmark.  
» 9. Ventral arm plate. Upper Senonian. Rørdal, Aalborg, Denmark.

*Ophiacantha ? sp.*

- » 10. Lateral arm plate. Upper Senonian. Rørdal, Aalborg, Denmark. a, lateral; b, distal margin; c, internal; d, dorsal; e, ventral.

*Asteronyx ? ornatus* n. sp.

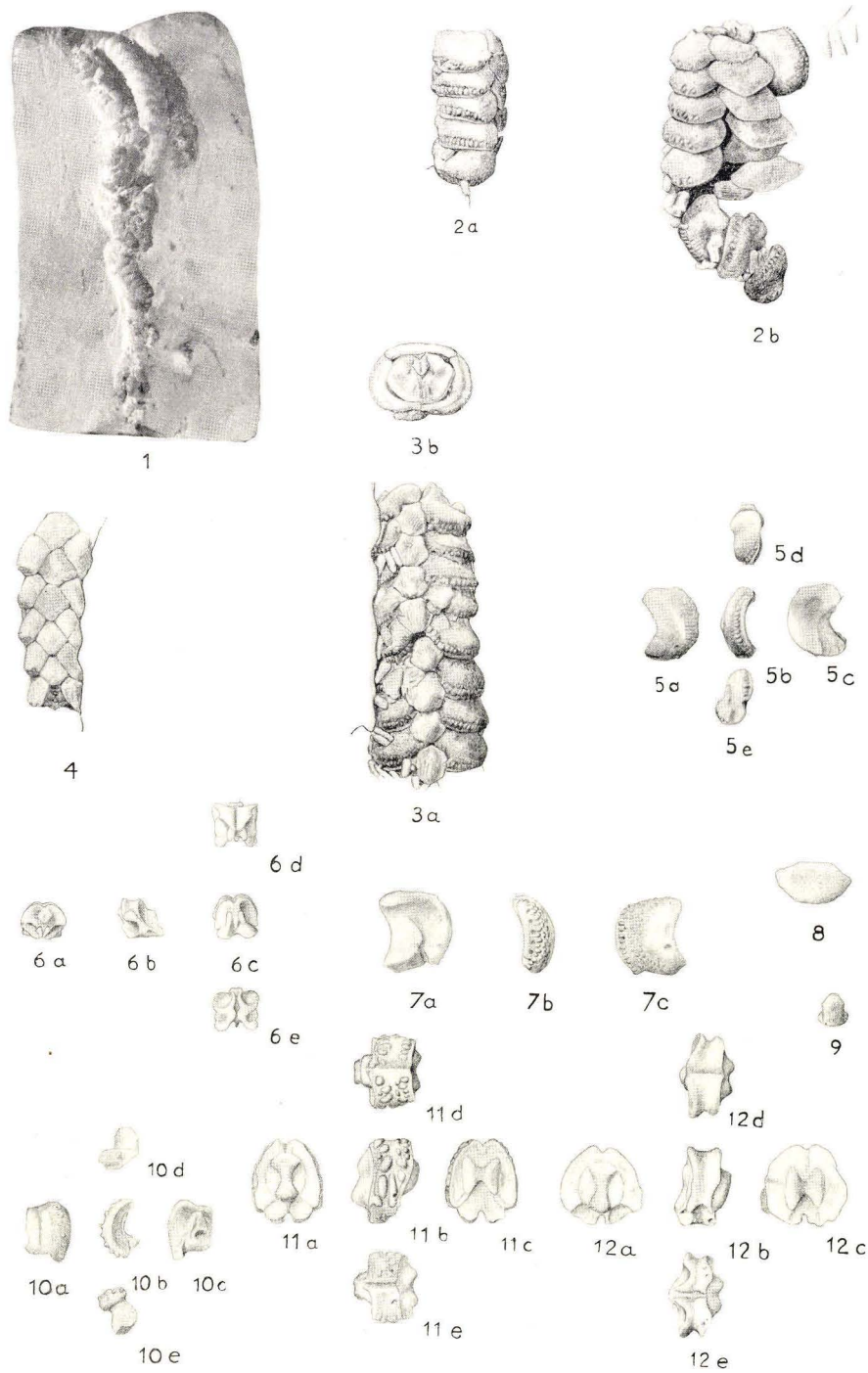
- » 11. Arm vertebra. Upper Senonian. N. Uttrup, Aalborg, Denmark. a, proximal end; b, lateral; c, distal end; d, dorsal; e, ventral.

*Asteronyx ? sp.*

- » 12. Arm vertebra. Upper Danian. Holckenhavn, Denmark. a, proximal end; b, lateral; c, distal end; d, dorsal; e, ventral.

Fig. 1,  $\times 2$ . Fig. 2—12,  $\times 5$ .





Chr. Halkier phot. Fig. 2-5. J. Birket Smith del. Fig. 6-12. W. Rasmussen del.

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NIELSEN & LYDICHE (M. SIMMELKJER)  
KØBENHAVN