

A MONOGRAPH ON THE BRITISH  
FOSSIL ECHINODERMATA FROM  
THE CRETACEOUS FORMATIONS.

W. PERCY SLADEN



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VOLUME SECOND.  
THE ASTEROIDEA.

1891  
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THE ASTEROIDEA.

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INTRODUCTORY REMARKS.

It was the intention of the late Dr. Thomas Wright to have continued his magnificent series of Monographs on the British Fossil Echinodermata of the Oolitic and Cretaceous Formations, which have already appeared in the volumes of the Palæontographical Society, by the publication of a Monograph on the Cretaceous Asteroidea. With this object in view a number of plates had been prepared under Dr. Wright's directions, and some preparatory notes for the letterpress had been written, when the work was cut short by the lamented death of the author. Subsequently the Council of the Palæontographical Society did me the honour of inviting me to undertake the memoir. The plates and notes above mentioned were placed at my disposal, but the latter proved to be for the main part merely summaries or transcripts of descriptions already published, and were unfortunately unsuitable to form part of the letterpress. For the whole of the latter I am

therefore responsible. The plates which were drawn on stone have all been utilised, although the specimens illustrated were not in every case those which I should have selected, nor the order in which the figures are associated on some of the plates that which I should have followed. This, however, is a comparatively small matter, and the remark is not intended in any way as disparaging the excellence of the illustrations. Indeed, I would here bear unqualified testimony to the careful and accurate way in which the fossils have been delineated by Mr. A. H. Scarle. His plates are monuments of patient study of morphological detail, and of exquisite technical execution as examples of lithographic drawing.

In his Monograph on the Oolitic Asteroidea, Dr. Wright gave as an introduction a general account of the structure of the main divisions of the Asteroidea then known, recent as well as fossil, with special reference to the calcareous framework; and he also gave a summary of the different systems of classification which had been formulated by previous writers on the subject. It would therefore, in my opinion, be out of place, and in a certain measure superfluous, to preface the present memoir with a similar introduction; but, as the knowledge of recent Starfishes has been considerably extended since the date of Dr. Wright's contribution, I propose to give in an appendix to this monograph my views on the classification of the Asteroidea, with special reference to the fossil forms.

At the commencement of his splendid Monograph on the Cretaceous Echinoidea—to which the present memoir is a sequel—Dr. Wright gave a valuable stratigraphical summary of the Cretaceous Formations in Britain. It is consequently altogether needless to burden the pages of the Society's publications with a repetition of these details. I shall, however, if necessary on the completion of my work, give a synopsis of the distribution in time of the various species dealt with, together with such remarks on their occurrence and associations as occasion may require.



# FOSSIL ASTEROIDEA.

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## DESCRIPTION OF THE CRETACEOUS SPECIES.

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*Sub-class*—EUASTEROIDEA, *Sladen*, 1886.

*Order*—PHANEROZONIA, *Sladen*, 1886.

*Family*—PENTAGONASTERIDÆ, *Perrier*, 1884.

Phanerozonte Asterids, with thick and massive marginal plates, which may be either naked, or bear granules or spiniform papillæ. Disk largely developed. Apical plates often increscent. Abactinal surface tessellate, with rounded, polygonal or stellate plates, which may be tabulate or paxilliform. Actinal inter-radial areas largely developed, covered with pavement-like plates, which may be naked or covered with membrane, or may bear granules or spinelets.

The family *Pentagonasteridæ*, as defined by Prof. Edmond Perrier<sup>1</sup> in 1884, was separated from a larger and more comprehensive group of genera which had been previously recognised by him<sup>2</sup> as constituting the family *Goniasteridæ*. The name *Goniasteridæ* was not retained for any of the groups or families into which that incongruous series of genera was divided. Previous to 1875, even the generic name of *Goniaster* had been very loosely and incorrectly applied. The vaguest notions as to the limits or characters of the genus seem to have been held. The mere form of the body, and the applicability of the significant name, irrespective of structural details, appear to have alone determined the reference of a large number of the species which have at different times borne the generic name of *Goniaster*.

<sup>1</sup> *Nouv. Archives Mus. Hist. Nat.*, 2e série, 1884, t. vi, p. 165.

<sup>2</sup> '*Révis. Stell. Mus.*,' p. 25 ('*Archives de Zool. expér.*,' 1875, t. iv, p. 289).

## FOSSIL ASTEROIDEA.

M. Perrier showed that none of the recent species ranked as *Goniaster* previous to 1875 had any right to be so called. He consequently employed the name in a new and restricted sense, taking the *Asterias obtusangula* of Lamarek as the type of the genus. No other species is at present known which can be regarded as congeneric with that form.

A large number of fossil Starfishes have been named as species of *Goniaster*, but none of them present characters which justify their reference to that genus in its new sense, and none of them invalidate the course taken by Prof. Perrier. It will therefore be unnecessary in the following pages to discuss in each case separately the reasons for removing the large number of species which have from time to time been ranked under the name of *Goniaster*.

### *Subfamily*—PENTAGONASTERINÆ, *Sladen*.

PENTAGONASTERINÆ, *Sladen*. Zool. Chall. Exped., part li, Report on the Asteroidea, 1889, pp. xxxi, 262.

Pentagonasteridæ with the abactinal area paved with rounded, polygonal, or paxilliform plates. Granules or spinelets when present co-ordinated.

### *Genus*—CALLIDERMA, *Gray*, 1847

CALLIDERMA, *Gray*. Proc. Zool. Soc. Lond., part xv, 1847, p. 76; Ann. and Mag. Nat. Hist., 1847, vol. xx, p. 198; Synop. Spec. Starf. Brit. Mus., 1866, p. 7.

Marginal contour stellato-pentagonal. General form depressed. Disk large and flat. Rays moderately elongated and tapering. Marginal plates forming a broad border to the disk, and may be united along the median abactinal line of the ray throughout [or, in some fossil species, may be separated by one or more series of medio-radial plates, at least at the base of the ray]. The marginal plates of both series are granulated. [In recent species the supero-marginal plates bear some small papilliform spinelets on the margin where the abactinal and lateral surfaces of the plate unite; and the infero-marginal plates have a number of similar, but larger and more fully developed, spinelets irregularly distributed amongst the granulation of the actinal surface.] Abactinal area of the disk covered with small and regularly arranged plates, hexagonal in the radial areas bearing co-ordinated granules, and some with a lateral

tubercle-like granule. Actinal interradial areas large, confined to the disk. Actinal intermediate plates large, covered with granules [and in the recent species bearing one or occasionally two compressed acute papilliform spinelets]. Armature of the adambulacral plates arranged in longitudinal series.

This genus was established by Dr. J. E. Gray for the reception of a recent Starfish, the type of which is preserved in the British Museum. It was described under the name of *Calliderma Emma*. In his remarks which follow the diagnosis, Dr. Gray observes<sup>1</sup> that "there is a fossil species, very like the one here described, found in the chalk, and figured in Mr. Dixon's work on the fossils of Worthing, which I propose to call *Calliderma Dixonii*." I have not been able to trace which of the fossil species is here referred to, but that is a circumstance of no great importance, as the forms figured in Mr. Dixon's work on 'The Geology of Sussex' were described and named by the late Prof. Edward Forbes. It is interesting, however, to note that the resemblance of some of the Cretaceous forms to the genus *Calliderma* had actually been observed by the author of that genus.

Thanks to the careful study and critical insight of Mr. J. Walter Gregory, of the British Museum, a number of the examples which now form part of the National Collection have been correctly, as I think, referred to the genus *Calliderma*, and already bear that name upon the manuscript labels attached by him to the specimens.

There are, however, some differences between the fossil forms and the recent type. The most notable perhaps being the character presented by the spinulation of the marginal, the abactinal, and the actinal intermediate plates in the recent species, as compared with the fossil examples, whose state of preservation does not permit of our positively asserting whether the same character was present in their case or not. I am inclined to think that this uncertainty does not necessarily invalidate the reference of the fossil forms to the genus, and I consider it highly probable that species might exist which did not bear incipient spinelets on the plates in which they are found in the solitary existing species with which we are acquainted. The peculiar pits found upon the plates in some of the fossil examples may indicate the former presence of these spinelets, although, for my own part, I am more disposed to believe that in the majority of cases the depressions in question are structures associated with a pedicellarian apparatus. (See, for example, Pl. I, figs. 1 *a*, 1 *b*, 1 *c*, 1 *d*; Pl. III, fig. 3 *a*; Pl. V, figs. 2 *a*, 2 *b*, 2 *d*.) In other cases it is certain that little spinelets did exist, as in the tip of the ray shown in Pl. VIII, fig. 2 *a*; also, but perhaps more doubtfully, in Pl. VII, figs. 4 *a*, 4 *c*.

<sup>1</sup> 'Proc. Zool. Soc. Lond.,' part xv, 1847, p. 76; 'Synop. Spec. Starf. Brit. Mus.,' London, 1866, p. 7.

Another point of difference is to be found in some of the fossil forms which are referred in the following pages to the genus *Calliderma*; and this consists in the separation of the supero-marginal plates, at least at the base of the ray, by one or more series of medio-radial plates. It is a character whose importance is not to be under-estimated, but too little as yet is known of the morphological plasticity of the genus to justify in my opinion the separation of the forms on this ground alone. I prefer, therefore, to regard this extension of the abactinal plating as a transitional character, and I believe that this opinion is warranted by the range of plasticity observed in other genera of recent Asteroidea.

1. CALLIDERMA SMITHIÆ, *Forbes*, sp. Pl. I, figs. 1 *a*—1 *f*; Pl. VIII, figs, 2 *a*—2 *c*.

- GONIASTER (ASTROGONIUM) SMITHII, *Forbes*, 1848. *Memoirs of the Geological Survey of Great Britain*, vol. ii, p. 474.
- — — — 1850. In *Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 4to., p. 334, pl. xxii, figs. 1 and 2.
- — — SMITHIÆ, *Morris*, 1854. *Catalogue of British Fossils*, 2nd ed., p. 80.
- ASTROGONIUM SMITHII, *Dujardin and Hupé*, 1862. *Hist. Nat. Zooph. Échin.* (Suites à Buffon), p. 399.
- GONIASTER SMITHI, *Quenstedt*, 1876. *Petrefactenkunde Deutschlands*, I. Abthl., Bd. iv, p. 64.
- (ASTROGONIUM) SMITHIÆ, *Forbes*, 1878. In *Dixon's Geology of Sussex* (new edition, Jones), p. 367, pl. xxv, figs. 1, 2, 2 *a*.

Body of large size. General form depressed. Abactinal area probably capable of slight inflation, and more or less flexible: a slight carination being present in the radial abactinal regions. Actinal surface flat. Marginal contour stellato-pentagonal, the major radius measuring rather more than twice the minor radius. Rays broad at the base and tapering gradually to the extremity. Interbrachial arcs well rounded and forming a regular curve. Margin thick, with a well-defined channel traversing the line of junction of the supero-marginal and infero-marginal series of plates, formed by the tumid character of the marginal surface of both series of plates.

The infero-marginal plates are about twenty or twenty-one in number, counting

from the median interradial line to the extremity. They form a broad conspicuous border to the actinal area, the breadth of which diminishes gradually from the median interradial line to the extremity. The largest infero-marginal plates near the median interradial line measure 9 mm. in breadth, and 4 mm. in length; the length increases a little between this point and the base of the ray, where it is again 4 mm. The breadth decreases step by step from the median interradial line, and at the base of the ray is less than 4 mm., and further out the breadth of the plates is less than the length. The height of the infero-marginal plates as seen in the margin is greater than the length of the plate, the proportions near the median interradial line being as 3 : 2 approximately. The proportion of the height decreases at the extremity of the ray. The infero-marginal plates are slightly convex on their actinal surface and distinctly tumid on their marginal surface. The whole superficies is covered with small, hexagonal, closely-placed punctations, upon which granules were previously borne, probably uniform in size and compactly placed. On a number of the plates are one or more subcircular or irregular shallow concavities, quite irregular in size, position, and occurrence, which I believe to have been caused by the presence of a pedicellarian apparatus, perhaps the cavities of ordinary foraminate pedicellariæ enlarged by weathering. These are seen in Pl. I, figs. 1 *a*, 1 *b*, 1 *c*, 1 *d*. I scarcely think that they are the marks left by tubercles or enlarged granules. In the example, however, figured on Pl. VIII, fig. 2 *a*, small spinelets were undoubtedly present.

The adambulacral plates are broader than long, their dimensions at a short distance from the mouth being 3.25 mm. broad and 1.75 mm. long. They bear upon their surface four or five ridges, parallel or sub-parallel to the ambulacral furrow, each with five or six articulatory elevations upon which spines had previously been borne. A number of these spines are still preserved, irregularly strewn over the surface of the plates. They are short, tolerably robust, slightly flattened, slightly tapering and abruptly rounded at the tip. The longest measures about 1.5 mm. in length, or a little more; their surface is finely striate, in fact so fine that the character is perhaps mainly due to the effect of weathering upon the structural texture of the spine.

The actinal interradial areas are large and are covered with a great number of small, regular, quadrangular or rhomboid intermediate plates, which are arranged in series parallel to the ambulacral furrow, and form a compact tessellated pavement. The average size of the plates is about 2 mm. in diameter, but the plates of the series adjacent to the adambulacral plates are somewhat broader, and the plates near to the infero-marginal plates become smaller and irregular. The plates extend at the base of the ray to about the eighth infero-marginal plate, counting from the median interradial line. The surface of the plates is covered with large, rather widely spaced, hexagonal punctations—the marking left by the granules

previously borne upon the plates, which appear to have been rather large and uniform.

Very few, if any, pedicellariæ appear to have been borne on the actinal intermediate plates.

The character of the mouth-plates and their armature cannot be made out in any of the examples I have examined.

The supero-marginal plates are only exposed in the marginal view of the example under description. Their height is seen to be less than that of the infero-marginal plates, and they are also rather smaller both in length and breadth; about twenty-two appear to be present between the median interradial line and the extremity of the ray. In their general character and ornamentation they resemble closely those of the infero-marginal series.

From another example, also contained in the British-Museum Collection, and bearing the registration mark "E. 2037," in which the abactinal surface is shown, the following details are supplemented.

The abactinal area is covered with small, regular, hexagonal plates or paxillar tabula, which are slightly rounded superficially, and a little bevelled on the margin of the tabulum. The surface of the tabulum is covered with punctations or marks left by the granules originally borne on the plate, and here and there small pedicellarian foramina may be seen, usually near the margin of the plate. The plates (or paxillæ) of the median radial series are broader than any of the others, the largest measuring about 2 mm. in breadth, and a little more than 1 mm. in length. The other tabula are true hexagons, measuring about 1 mm. in diameter or a trifle more, and they are arranged in longitudinal series parallel to the median radial series. Eight or nine series are present on each side of the median radial series on the disk. Opposite the eighth supero-marginal plate, counting from the median interradial line, only the median radial series and one lateral series of tabula on each side of it are present. The median radial series then extends alone and is present at the fourteenth plate, where the ray is broken in the example under description—and looks like continuing further—probably reaching to the extremity of the ray.

*Dimensions.*—In the type specimen (figured on Pl. I) the major radius is 98 mm., the minor radius 48 mm., the thickness of the margin from 9 to 10 mm. The breadth of a ray between the fifth and sixth infero-marginal plates measures about 28 mm.

*Locality and Stratigraphical Position.*—The specimen figured on Pl. I is from the Lower or Grey Chalk at Burham, in Kent. The species has also been obtained from the Upper Chalk at Brighton (Coll. Brit. Mus.); and it is sometimes

found in ferric sulphide at Amberley Pit, Sussex. The fragment figured on Pl. VIII, figs. 2 *a*, 2 *b*, 2 *c*, is from the Lower Chalk of Dover.

*History.*—The type specimen, from which this species was originally described by the late Edward Forbes in 1848, formed part of the collection of Mrs. Smith, of Tunbridge Wells. It is now preserved in the British Museum. It was first figured in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' London, 1850. Pl. I of the present memoir is a faithful drawing of the same beautiful specimen.

*Smith's coll. (London) Sept. 1853.*

2. CALLIDERMA (MOSAICUM, *Forbes*, sp.) Pl. V, figs. 2 *a*—2 *e*; Pl. VI, figs. 1 and 2 *a*, *b*, *c*; Pl. VII, figs. 4 *a*, *b*, *c*; 4 *d*, *e*, *f*

- GONIASTER (ASTROGONIUM) MOSAICUS, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 475.
- — MOSAICUS, *Forbes*, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to., p. 334, pl. xxiv, fig. 26.
- — MOSAICUS, *Morris*, 1854. Catalogue of British Fossils, 2nd ed., p. 80.
- ASTROGONIUM MOSAICUM, *Dujardin and Hupé*, 1862. Hist. Nat. Zooph. Échin. (Suites à Buffon), p. 399.
- GONIASTER (ASTROGONIUM) MOSAICUS, *Forbes*, 1878. In Dixon's Geology of Sussex, (new edition, Jones), p. 367, pl. xxvii, fig. 26.
- GONIASTER MOSAICUS, *Etheridge*, 1885. In Phillips's Manual of Geology (new edition), part ii, by R. Etheridge, p. 560.

Body of large size. Disk large. Rays narrow at the base and well produced. General form depressed and thin. Abactinal area probably capable of slight inflation, and more or less flexible; some carination present in the radial abactinal regions. Actinal surface flat. Marginal contour stellato-pentagonal, the major radius measuring more than twice and a half the minor radius. Rays narrow, the supero-marginal plates being united in the median radial line. Interbrachial arcs wide and with their curvature more or less flattened, which gives a distinctly pentagonal character to the disk. Margin rather thin, and with the lateral wall perpendicular.

The supero-marginal plates are about twenty-eight in number, counting from the median interradial line to the extremity. (This number is taken from the fragment figured on Pl. VII, fig. 4 *a*; in the larger example drawn on Pl. V fig. 2 *a*, twenty-two may be counted up to the place where the ray is broken.) They form a well-defined, conspicuous border, but the breadth of this is distinctly less in proportion to the size of the disk when compared with the breadth of the marginal plates in *Calliderma Smithiæ*. The largest supero-marginal plates in the specimen figured on Pl. V, fig. 2 *a*, near the median interradial line, measure 5.25 mm. in breadth and 3.25 mm. in length. The breadth diminishes very slightly as the plates approach the base of the ray, but from that part outward the length of the plates becomes much reduced—the breadth remaining the greater dimension throughout the ray.

The supero-marginal plates are comparatively flat on the abactinal surface and only slightly depressed along their margins of juncture. The general surface of the whole series has the character of sloping at a small angle to the margin of the disk, to which it gives a slightly bevelled appearance. The marginal surface of the plate is almost vertical, the junction of the abactinal and marginal surfaces is well rounded but not tumid, and there is very slight, if any, convexity on the marginal surface, at least along the disk. The height of the plates as seen in the margin is only a little greater than the length, and the diminution in height is only very trifling as the plates proceed along the ray. The whole superficies of the plates is covered with small hexagonal punctations upon which granules were previously borne. Small foraminate pedicellariæ are occasionally present here and there upon the plates; the foramen is small and oval, and is surrounded by a definite margin or lip. Sometimes more than one are present on one plate. The example figured on Pl. VII, fig. 4 *a*, is remarkable for the presence of the prominent teat-like eminences, in the centre of which the pedicellarian foramen is situated. These eminences at first sight look like tubercles for the articulation of spines (see Pl. VII, figs. 4 *a*, 4 *c*). A similar character is also seen in the example drawn on Pl. V, fig. 2 *a*, but is less strongly marked (see fig. 2 *d*).

The abactinal area of the disk is covered with small, regular, hexagonal and tetragonal plates or paxillar tabula; those in the radial areas being regularly hexagonal and larger than those in the intermediate regions, which are rhomboid, and all diminish in size as they approach the margin. The abactinal plates or paxillæ do not appear to extend beyond the twelfth supero-marginal plate, counting from the median interradial line; the supero-marginal plates of the two sides of the ray meeting in the median radial line beyond this point. The plates or paxillæ of the median radial series are larger and broader than any of the others; they are succeeded on each side by five or six longitudinal series of hexagonal plates, those of the second or third series from the median series measuring about 1.5 mm.



in diameter. The remaining plates which occupy the intermediate areas are tetragonal or rhomboid. All the plates have their surface marked with rather widely-spaced punctations—the impressions of the granules previously present. Small foraminate pedicellariæ are also frequently present here and there, usually near the margin of the plate.

The madreporiform body is flat, distinct, and polygonal in outline; it is situated near the centre of the disk. Its surface is marked by fine straight striæ, which radiate regularly centrifugally from the centre to the margin (see Pl. V, fig. 2 *e*).

Other specimens show that the infero-marginal plates in this species are more nearly subequal to the supero-marginal series than in *Calliderma Smithiæ*, that the actinal intermediate plates are relatively larger than in that species and a good deal larger than the abactinal paxillar plates or tabula. The actinal intermediate plates originally bore granules only, judging from the character of the punctations with which their surface is ornamented. A fragment belonging to the British Museum Collection (which bears the register number “E 373”), in which the spines that formed the armature of the adambulacral plates are preserved, indicates that these spines are smaller, shorter, and perhaps more numerous than in *Calliderma Smithiæ*.

In the example drawn on Pl. VI, fig. 2 *a*, the supero-marginal plates are preserved, but the whole of the abactinal plating has been removed, leaving exposed the inner surface of some of the actinal intermediate plates and the adambulacral plates. Magnified details of these plates are given, and they represent the characters of the structures preserved better than any verbal description.

*Dimensions.*—The large example figured on Pl. V, fig. 2 *a*, has the following measurements:—Major radius 82 + mm. (all the rays are broken and imperfect, and the full dimensions cannot therefore be given); minor radius 36 mm.; thickness of the margin about 8 mm. Breadth of a ray between the eighth and ninth supero-marginal plates about 15 mm., or a trifle more.

*Locality and Stratigraphical Position.*—The example figured on Pl. V, fig. 2 *a*, is labelled from the Lower Chalk, but the locality is not recorded. It formed part of one of the old collections preserved in the British Museum. Other examples in the British Museum are from the Grey Chalk or Chalk Marl of Dover, from the Lower Chalk of Glynde in Sussex, and from the Lower Chalk of Amberley Pit, Arundel. There is also a magnificent specimen in the Museum of Practical Geology, Jermyn Street, from the Lower Chalk of Dover.

3. *CALLIDERMA LATUM*, *Forbes*, sp. Pl. II, figs. 1 *a*—1 *e*, 2 *a*—2 *d*; Pl. III, figs. 1 *a*—1 *e*, 2 *a*, 2 *b*, 3 *a*, 3 *b*.

- GONIASTER (ASTROGONIUM) LATUS*, *Forbes*, 1848. *Memoirs of the Geological Survey of Great Britain*, vol. ii, p. 474.
- — — — 1850. In *Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 4to., p. 333, pl. xxiii, figs. 4, 5.
- — — — *Morris*, 1854. *Catalogue of British Fossils*, 2nd ed., p. 80.
- ASTROGONIUM LATUM*, *Dujardin and Hupé*, 1862. *Hist. Nat. Zooph. Échin. (Suites à Buffon)*, p. 399.
- GONIASTER (ASTROGONIUM) LATUS*, *Forbes*, 1878. In *Dixon's Geology of Sussex (new edition, Jones)*, p. 367, pl. xxvi, figs. 4, 5.

Body of large or moderate size. General form depressed. Abactinal surface probably capable of some degree of inflation. Actinal surface flat. Marginal contour stellato-pentagonal, the major radius probably not exceeding the minor radius by more than one half. Rays narrow at the base, short, not greatly produced, and probably tapered to a pointed extremity. Interbrachial arcs very wide and flattened, which gives a strongly marked pentagonal outline to the disk. Margin of uniform thickness.

The infero-marginal plates are more than sixteen in number, counting from the median interradiial line to the extremity (the tip of the ray being broken in all the specimens examined). They form a remarkably broad margin to the actinal area of the disk, which diminishes rather rapidly in width at the base of the rays, and then slightly to the extremity. The largest infero-marginal plates near the median interradiial line measure about 13 mm. in breadth and 4.5 mm. in length. The length is nearly uniform throughout, or at any rate till well out on the free part of the ray; but the breadth diminishes until the plates at the base of the ray are 6.5 mm., and the diminution proceeds to a certain extent along the ray. The infero-marginal plates are slightly convex along their line of breadth, by which means the separate plates are distinctly marked. They are well rounded at the junction of the actinal and lateral surfaces, and are slightly tumid in the margin. The outline of their inner or adcentral edge is also rounded. The height of the

infero-marginal plates as seen in the margin is a little greater than their length. The height of the supero-marginal plates is, however, somewhat greater.

The whole superficies of the plates is covered with circular punctations of irregular size rather than hexagons, as in the other forms, and the irregularity caused by the presence of larger punctations here and there is remarkable. This character seems to indicate the former presence of an irregular-sized granulation.

The supero-marginal plates are similar in character to the infero-marginal series, but the large irregular punctations are larger and more numerous.

The adambulacral plates are broader than long, and they bear upon their surface five or six ridges parallel or subparallel to the ambulacral furrow, each with prominent well-defined granulations or elevations, all uniform and closely placed, upon which the adambulacral armature of spines was previously borne (see Pl. II, fig. 1 *d*; Pl. III, fig. 2 *b*).

The actinal interradial areas are large, and are covered with comparatively large polygonal and rhomboid intermediate plates, which are arranged in series parallel to the ambulacral furrow, and originally formed a compact tessellated pavement. In a number of the fossils of this species, however, these plates are often separated and displaced, which leads to the inference that in life the plates were not so intimately connected as in other species, and that membrane or connective tissue was more largely developed. The one or more series of plates adjacent to the adambulacral plates are much larger than the others, and none of the intermediate plates extend beyond the base of the ray. The surface of the plates is covered with large, irregular, and rather deeply sunken pits, the character of which leads to the inference that the granulation originally present was also somewhat irregular in size and coarse in character (see Pl. II, fig. 1 *c*; Pl. III, fig. 1 *e*).

In some examples (notably in that figured on Pl. III, fig. 2 *a*) small oval foraminate pedicellariæ, distinctly lipped at the margin of the foramen, are present on the actinal intermediate plates.

The mouth-plates are elongate, about three times as long as broad, triangular in shape, with the two outer sides subequal. Their surface is covered with large, coarse, irregular, tuberculose elevations (see Pl. II, fig. 1 *e*), which suggest the inference that the armature of the mouth-plates consisted of large, irregular, papilliform granules.

In some examples a portion of the actinal floor has been removed, exposing the inner surface of the abactinal floor. In these cases the stellate base of the abactinal plates or paxillæ are seen (see Pl. II, figs. 2 *a*, 2 *d*; Pl. III, figs. 3 *a*, 3 *b*). It will be noticed that there is a difference in the form of the stellate bases in these examples, which may indicate a specific or varietal difference, but I do not feel justified from this character alone in recognising either of these fragments as the

type of a distinct species. More material is needed before such a step would be warranted.

*Dimensions.*—The large example figured on Pl. II, fig. 1 *a*, has a major radial measurement of from 80 to 95 mm. or more, with a minor radius of about 52 mm. The breadth of the ray between the sixth and seventh infero-marginal plates, counting from the median interradial line, is about 17 or 18 mm.

*Locality and Stratigraphical Position.*—This species appears to be confined to the Lower Chalk. Examples have been collected from Washington, Amberley, Southerham, and Glynde, in Sussex. Also from the Lower Chalk of Folkestone, and the Chalk Marl of Dover.

*History.*—Two examples of this species were first figured by Forbes in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' London, 1850, pl. xxiii, figs. 4 and 5. Both these specimens are now preserved in the British Museum. One example, which is from Amberley, is drawn on Pl. III, fig. 1 *a*. The other, which is from Washington, is accurately represented by fig. 3 *a* of the same plate.

*Variations.*—In addition to the difference noted above in the form of the stellate bases of the abactinal plates or paxillæ, other minor differences may be observed. In some examples the breadth of the border formed by the marginal plates on the disk area is not relatively so great as in other examples, and the proportions of length to breadth, as well as the amount of tumidity of the component plates, are subject to variation. In some examples, again, the irregularity in the granulation of the marginal plates, arising from the former presence of coarser granules interspersed amongst the average granulation, is more marked than in others. These differences will be more readily noticed by turning to the figures given on Pl. II and Pl. III than by a lengthy verbal description. Some of the examples come from different beds and different localities—circumstances which I consider to be sufficient to account for the variation.

*Genus*—NYMPHASTER, *Sladen*, 1885.

NYMPHASTER, *Sladen*. In Narr. Chall. Exp., 1885, vol. i, p. 612; Zool. Chall. Exped., part li, Report on the Asteroidea, 1889, p. 294.

Disk large and flat. Rays elongate, slender, tapering, and almost square in section. Marginal plates forming a broad border to the disk, and either united

along the median abactinal line of the ray throughout, or separated only by a single series of medio-radial plates. The marginal plates of both series are granulated, and bear no spines (normally, but occasional incipient spinelets may be present). Abactinal area of the disk covered with large and regularly arranged plates, those in the radial areas well separated, usually hexagonal, more or less tabulate and paxilliform, and frequently bearing an excavate or entrenched pedicellaria. Actinal interradial areas large, confined to the disk. Actinal intermediate plates well defined, covered with uniform granules, and occasionally bearing pedicellariæ. Armature of the adambulacral plates arranged in longitudinal series. Madreporiform body exposed and situated within one third of the distance from the centre to the margin. Large entrenched pedicellariæ are frequently present on the marginal plates in some species.

This genus includes a number of recent species brought to light by the deep-sea explorations of late years. It has been found in the Atlantic, the Pacific, and the Eastern Archipelago. The Atlantic species pass into the abyssal zone, but those inhabiting the Pacific and Eastern Archipelago do not, so far as at present known, extend beyond the continental zone, or in other words they live in depths of less than 500 fathoms.

The structure and character of the Cretaceous species described in the following pages, so far as they can be made out from the fragmentary condition of the fossils, appear to me to warrant their inclusion in the genus *Nymphaster*.

1. [NYMPHASTER] COOMBII, *Forbes*, sp. Pl. VII, figs. 1—3; Pl. VIII, figs. 1 a, 1 b; *Ophryaster* — *Nymphaster* *Forbes* 1848. *Memoirs of the Geological Survey of Great Britain*, vol. ii, p. 474. 2, 4, 33 (1112).  
[1] 10  
[2] 12  
= 30th

— — — — 1850. In *Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 4to., p. 334, pl. xxiii, fig. 6.

— — — — *Morris*, 1854. *Catalogue of British Fossils*, 2nd ed., p. 80.

ASTROGONIUM COOMBII, *Dujardin and Hupé*, 1862. *Hist. Nat. Zooph. Échin. (Suites à Buffon)*, p. 399.

GONIASTER (ASTROGONIUM) COOMBII, *Forbes*, 1878. In *Dixon's Geology of Sussex (new edition, Jones)*, p. 367, pl. xxvi, fig. 6.

Body of medium size. Disk moderately large. Rays well produced, rather broad at the base and tapering to the extremity. General form depressed and thin. Marginal contour stellato-pentagonal, the major radius measuring more than twice and a half the minor radius. Marginal plates broad, the supero-marginal series of the two sides of the ray meeting in the median radial line. Interbrachial arcs deeply indented and well rounded. Margin rather thin.

The infero-marginal plates are more than fifteen in number, counting from the interradial line to the extremity. They form a broad conspicuous border to the actinal area, which is relatively broad in proportion to the size of the disk. The largest infero-marginal plates near the median interradial line measure about 5.5 mm. in breadth, and about 2.5 to 2.75 mm. in length. The breadth decreases slightly from this point as the plates approach the base of the ray, and then much more rapidly, the plates on the outer part of the ray having the length considerably in excess of the breadth. The plates are tumid and roundly bevelled at the lateral edges, but are flatly rounded at the margin of the disk, and without tumidity there. The whole superficies of the plate is covered with large, rather deeply depressed, hexagonal punctations, closely placed, which give somewhat of a honeycomb appearance to the plate (see Pl. VIII, fig. 1 *b*). These are the marks left by the granules previously borne upon the plate. Upon a number of the plates in the example figured on Pl. VIII, fig. 1 *a*, the granules are still preserved *in situ*. They are large and closely placed. The punctations, and consequently the granules, in this species are coarser than in any of the other Cretaceous forms known to me. I have not been able to assure myself of the presence in this example of any pedicellariæ on the infero-marginal plates.

The adambulacral plates are broader than long, except on the outer part of the ray, and their armature appears to have consisted of five or six regular series of spinelets. This is indicated by the presence upon the surface of the plate of that number of ridges, running parallel or subparallel to the ambulacral furrow, each having four or five articular elevations and intervening pits upon which spinelets had previously been borne. The spinelets were probably short, and similar to those described in *Calliderma Smithiæ* and *Calliderma mosaicum*, but I have not found any preserved in specimens which I consider to be undoubted examples of *Nymphaster Coombii*.

*Dimensions.*—In the type specimen, figured on Pl. VIII, fig. 1 *a*, the major radius is more than 56 mm., and the minor radius 23 mm. The breadth of the ray between the fourth and fifth infero-marginal plates measures about 15 mm.

*Locality and Stratigraphical Position.*—The specimen figured is from the Lower Chalk of Balcombe Pit, Amberley. The species has also been obtained from the

Lower Chalk of Glynde, Sussex; as well as from the Lower Chalk of Dover and the Isle of Wight. Other specimens of *Nymphaster*, as to the reference of which to *N. Coombii* I am more or less doubtful, which show certain differences in structural details, are from the Grey Chalk of Folkestone and Dover, and from the Lower Chalk of Betchworth. Several examples in the Museum of Practical Geology, Jermyn Street, are labelled from the "Upper Chalk," but I am inclined to think that their reference to that horizon is more or less doubtful.

*History.*—The type of this species was found by Mr. G. Coombe at Balcombe Pit, Amberley, and formed part of Mr. Dixon's collection. It is now preserved in the British Museum. It was first figured by Edward Forbes in Dixon's *Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 1850, pl. xxiii, fig. 6. The same specimen is carefully represented on Pl. VIII, figs. 1 *a*, 1 *b* of this memoir.

*Doubtful Examples of this Species.*—Three specimens are figured on Pl. VII, which I only place provisionally and with very great doubt under this species. I do not, therefore, at present propose to describe them in detail, or to definitely assign the characters they present as supplementary to those already given as belonging to *Nymphaster Coombii*.

1. An example from the Lower Chalk of Betchworth, in which a portion of the actinal surface is preserved (Pl. VII, figs. 1 *a*—1 *e*). This specimen shows large infero-marginal plates somewhat longer in proportion to their breadth than in the type specimen, and their surface is covered with an extremely fine uniform punctation. The latter character is altogether unlike that of examples which I consider to be true forms of *Nymphaster Coombii*. But from this character alone, which recent forms show to be one subject to considerable variation, I shrink from taking any more definite step, at least until further material is available for study. This example has some of the adambulacral plates and actinal intermediate plates well preserved. The adambulacral plates (see Pl. VII, fig. 1 *c*) conform to the description given above. The actinal intermediate plates are rhomboid in form, and their surface is covered with deep, large, well-spaced pits, which indicate the former presence of a coarse uniform granulation. These plates are shown on Pl. VII, fig. 1 *e*. The margin of this example is quite characteristic of *Nymphaster Coombii*. The infero-marginal plates are seen to be low and more or less bevelled or sloping towards the margin; whilst the supero-marginal plates are relatively rather higher and more abruptly bent at the junction of the actinal and lateral surfaces (see Pl. VII, fig. 1 *b*).

2. This is a badly preserved specimen from the Grey Chalk of Folkestone, in which nothing but the supero-marginal plates and the general outline are available

for determination (see Pl. VII, figs. 2 *a*, 2 *b*). The marginal plates resemble in character those of the specimen just mentioned, and they are like them covered with a very fine punctation, unlike that of the typical *Nymphaster Coombii*. There are also fewer plates in that portion of the interbrachial arc which may be said to belong to the disk than in *Nymphaster Coombii*, but as the example is smaller, this may probably be only a question of age; or it may, like the punctation of this and the preceding example, be attributed to variation, which I am disposed to consider a not improbable reason for the differences, when regard is had to the horizon from which the fossils were obtained, and consequently the changed conditions of existence in which those Asterids probably lived.

3. This specimen (figured on Pl. VII, figs. 3 *a*, 3 *b*) is from the Lower Chalk of Glynde, Sussex, and I consider that its reference to *Nymphaster Coombii* is less doubtful than that of either of the two preceding examples. The fragment represents a portion of the abactinal surface. The supero-marginal plates are large, and are covered with the characteristic coarse punctation of *Nymphaster Coombii* (see Pl. VII, fig. 3 *b*). The supero-marginal plates of the two sides of a ray meet in the median radial line from the very base of the ray, distinctly characteristic of the genus *Nymphaster*. Comparing this example with the typical form of the species, there appear to be a much smaller number of supero-marginal plates in the interbrachial arc belonging to the true disk, and on these grounds I hesitate from accepting it positively as an undoubted example of this species until further material is forthcoming to throw light upon the amount of plasticity which may be accredited to this species.

2. [NYMPHASTER] MARGINATUS, *Sladen*. Pl. VIII, figs. 4 *a*, 4 *b*.  
*Nymphaster marginatus* Sladen, 1830.

Body of medium size. General form depressed. Marginal contour stellato-pentagonal. Rays well produced, rather broad at the base, and tapering gradually to a pointed extremity. Interbrachial arcs deep and rounded, the sweep of the curve from the tip of one ray to the tip of the neighbouring ray being of a paraboloid character. Margin rather thin.

The supero-marginal plates form a broad and massive border to the abactinal area of the disk. There are six plates on each side of the disk counting from the base of one ray to the base of the neighbouring ray. All the succeeding plates along the ray meet the corresponding plate of the opposite side of the ray in the median radial line. The abactinal surface of the ray is thus occupied entirely by the supero-marginal plates throughout its length.



All the supero-marginal plates are of uniform height, excepting the normal diminution towards the extremity of the ray; and all have the breadth greater than the length. The plates on each side of the median interradial line measure about 4 mm. in breadth and about 2 mm. in length; and this length is maintained with very slight diminution until about midway between the base and the extremity of the ray, where the length is 1.75 mm., and the breadth is between 2.75 and 3 mm. Sixteen supero-marginal plates are preserved in the longest ray of the specimen under description, counting from the median interradial line to the broken extremity. A few plates are apparently missing. Measured in the margin, the height of the plates is about 2.5 mm.

All the supero-marginal plates are distinctly convex in the direction of their median line of breadth, by which each plate is very clearly marked out, and a highly ornate character is given to the species. The plates are also tumid and well rounded on their marginal surface. The whole surface of the plates is covered with rather large, widely spaced punctations or pits, which have a peculiarly isolated appearance, unlike that of any other species (see Pl. VIII, fig. 4 *b*). I have not detected the presence of any pedicellariæ upon this example.

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.

*Dimensions.*—The specimen figured on Pl. VIII, fig. 4 *a*, has a minor radius of about 12 mm.; and the longest fragment of a ray preserved measures about 35 mm. The extremity is wanting. The thickness of the margin is 4.5 mm. The breadth of the ray at the base between the third and fourth supero-marginal plates counting from the median interradial line is from 8 to 8.5 mm.

*Locality and Stratigraphical Position.*—The example described is from the Upper Chalk near Bromley. It is preserved in the British Museum, and bears the registration number 35,484.

3. [NYMPHASTER] OLIGOPLAX, *Sladen*. Pl. VIII, figs. 3*a*, 3*b*. *Cytherea* 1. 1872

Body of medium size. General form depressed and thin. Marginal contour stellato-pentagonal. Rays narrow at the base and produced. Interbrachial arcs wide and rounded. Margin thin.

The supero-marginal plates form a broad border to the abactinal area of the

disk. There are only three (or possibly four) supero-marginal plates between the median interradial line and the base of the ray—that is to say, about six plates on each side of the disk. The fourth (or perhaps the fifth) plate counting from the median interradial line, and all the succeeding plates along the ray, appear normally to meet the corresponding plate of the opposite side of the ray in the median radial line. The abactinal surface of the ray is thus occupied entirely by the supero-marginal plates throughout its length. In one of the rays preserved there appear, however, to be traces of a few abactinal plates which interfere with the union of the supero-marginal plates in the median radial line near the base of the ray. As to how far this is normal I am unable to say.

All the supero-marginal plates are comparatively low and flat. The plates on each side of the median interradial line are 3·5 mm. in breadth, and from 3 to 3·5 mm. in length, and are thus practically square. Their abactinal surface is slightly convex; and their height as seen in the margin is less than the length, and the abactinal surface is gradually bevelled to the inferior margin which abuts upon the infero-marginal plates. The other plates which form the border of the disk-area are of the same size and character as those adjacent to the median interradial line. The supero-marginal plates along the ray have the breadth greater than the length, the fifth plate counting from the median interradial line measuring about 3·75 mm. in breadth and 2·5 mm. in length. Their character is similar to that of the plates above described. The surface of the plates is covered with small well-spaced punctations, and there is a distinct smooth border on the inner and two lateral margins of each plate on which no punctations or pits are present.

Large trench-like pedicellariæ, which are nearly the length of the plate, are present in this species; they occur more frequently on the infero-marginal plates than on those of the superior series; in fact, only one or two are present on the latter series of plates in the example under description.

No other portions of this fragment are available for description.

*Dimensions.*—The fragment figured in Pl. VIII, fig. 3 *a*, has a minor radius of about 15 mm. The longest portion of the major radius preserved is about 33 mm., and the ray is broken off abruptly. The thickness of the margin is between 4 and 5 mm. The breadth of the ray at the base is about 8 mm.

*Locality and Stratigraphical Position.*—The fragment described, which is, unfortunately, all that I have seen, is from the Upper Chalk of Bromley. It is preserved in the British Museum, and bears the registration number 40,178.

*Remarks.*—The character of the marginal plates, as regards both their form

and their ornamentation, as well as the presence of the peculiar pedicellariæ, and indeed the whole facies of this fossil, lend strong support to the presumption that this species may ultimately need to be placed in a distinct genus, but I do not feel warranted in taking that step on the basis of such scanty material.

*Genus*--PYCNASTER, *Sladen*.

Disk relatively small and pentagonal. Abactinal surface more or less convex, and was probably somewhat inflated during life. Margin thick, and highest in the region of the disk. Rays elongate, narrow, and robust. Marginal plates forming a broad border to the disk, and united along the median abactinal line of the ray throughout. The marginal plates are high and very robust, those of the superior series being prominently convex abactinally in the median line of breadth and height, which imparts a well-rounded character to the ray. The marginal plates of both series are finely granulated, and probably bore no spines. Actinal intermediate plates large, covered with uniform granules. Armature of the adambulacral plates arranged in longitudinal series. Foraminate pedicellariæ with radiating channels may be present on the marginal plates.

The fragmentary state of the fossils which I have referred to this type unfortunately does not permit of a complete diagnosis of the genus being drawn up. The characters above given appear, however, to me to be sufficient to warrant the recognition of the possessors of them as the representatives of a distinct genus. The small high disk, the massive convex marginal plates, and the large actinal intermediate plates, together with the form of the rays, produce a facies alone sufficient to stamp its individuality, irrespective of other details of structure.

1. PYCNASTER ANGUSTATUS, *Forbes*, sp. Pl. IX, figs. 1 a, 1 b.  
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GONIASTER (ASTROGONIUM) ANGUSTATUS, *Forbes*, 1848. *Memoirs of the Geological Survey of Great Britain*, vol. ii, p. 474.

— — — — — 1850. In *Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 4to., p. 335, pl. xxiii, fig. 10.

- GONIASTER (ASTROGONIUM) ANGUSTATUS, *Morris*, 1854 Catalogue of British Fossils, 2nd ed., p. 80.
- ASTROGONIUM ANGUSTATUM, *Dujardin and Hupé*, 1862. Hist. Nat. Zooph. Échin. (Suites à Buffon), p. 399.
- GONIASTER (ASTROGONIUM) ANGUSTATUS, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 368, pl. xxvi, fig. 10.

Disk of medium size or relatively small and pentagonal. Rays elongate, narrow, robust, and, though tapering, nearly uniform in breadth throughout. Marginal contour stellate. Interbrachial arcs more or less flattened, which emphasises the pentagonal outline of the disk. Margin thick and robust, much highest in the region of the disk. Abactinal surface more or less convex, and was probably somewhat inflated during life. Actinal intermediate plates very large, covered with uniform granules.

The supero-marginal plates are thick and massive, and they form a high and broad border to the disk. There are only three supero-marginal plates between the median interradial line and the base of the ray—that is to say, six plates on each side of the disk. The fourth plate counting from the median interradial line, and all the succeeding plates along the ray, meet the corresponding plate of the opposite side of the ray in the median radial line. The abactinal surface of the ray is thus occupied entirely by the supero-marginal plates throughout its length.

The supero-marginal plates which form the border of the disk are much larger in the direction of height than any of the others. The plates on each side of the median interradial line are about 4.75 mm. in breadth as seen on the abactinal surface, and about the same measurement in length. They are convex abactinally, and well rounded at the junction of the abactinal and lateral surfaces. Measured in the margin their height is 8 mm., and their lateral surface (which forms the vertical wall of the margin) is distinctly convex or pulvinate, but to a less degree than their abactinal surface.

The supero-marginal plates of the ray are not so high as those of the disk, although their height is greater than their length. The height of the sixth plate from the median interradial line is about 5 mm. Their abactinal and lateral surfaces form together a true segment of a circle, and this imparts a well-rounded character to the ray. The plates are deeply bevelled at their junction with the adjacent plates, and consequently distinctly pulvinate in the median line of breadth and height. The surface of the plates is covered with minute punctations, but

these are so extremely faint that they are seen with difficulty. They are probably weather-worn in the example under notice.

The infero-marginal plates, as seen in the direct lateral view of the margin, are much smaller in height than the supero-marginal series in the type specimen. The plates which form the margin of the disk are higher than long, the height being about 5 mm. and the length about 3.25 mm. in those adjacent to the median interradial line; the succeeding plates on the margin of the disk are each less in height than the preceding plate, the third or fourth plate, counting from the median interradial line, having the height and length about equal. The infero-marginal plates along the ray have the length greater than the height. The surface of the infero-marginal plates resembles that of the superior series in the character of its punctation.

Traces of small excavate pedicellariæ are present on occasional plates, but these appear to have been very few in the example under description.

On the abactinal surface of the disk a few isolated and displaced plates are present. Some of these seem rather thick and tuberculous in character, but the state of the preservation of this part of the fossil is unfortunately quite unfitted for description.

There is a fine fragment of this species preserved in the Museum of Practical Geology, Jermyn Street, from the Upper Chalk of Bromley, which shows part of the actinal surface. The infero-marginal plates in the disk are very high in this example, and five of them in an interbrachial arc bear a small foraminate pedicellaria. This is situated near the upper margin of the plate, about equidistant from that margin and the lateral margins of the plate, and consists of a small round foramen situated in the middle of a very shallow concavity, and with five or six faint channels radiating from the foramen to the margin of the concavity, gradually thinning and dying out there. The channels radiate like the spokes of a wheel, or a five-rayed star, and produce a facies unlike that of any other pedicellarian apparatus with which I am acquainted. The actinal intermediate plates are very large, and not more than three series are present. The plates of the series next to the adambulacral plates are much larger than the others, and are broader than long. The adambulacral plates are broader than long, and their surface is marked with three or four ridges parallel to the furrow, upon which spinelets were previously borne. The furrow series consists of about five spinelets. A few of these spinelets are preserved, and they are rather short, cylindrical, and slightly tapering. The mouth-plates are very small and narrow.

*Dimensions.*—The specimen figured on Pl. IX, fig. 1 *a*, has a minor radius of about 23 mm. The longest portion of a major radius preserved is 53 mm.; the ray is broken abruptly, and there is very slight diminution in the breadth at the

broken extremity as compared with the breadth at the base; there would appear to be every indication that only a small part of the ray is preserved.

The thickness of the margin at the median interradial line is 13 mm., and at the base of the ray 8.5 mm. The breadth of the ray at the base is about 12 mm.

*Locality and Stratigraphical Position.*—The example above described, which has been drawn on Pl. IX, fig. 1 *a*, was obtained from the Upper Chalk in Kent, but unfortunately the exact locality is unknown. It is preserved in the British Museum. A fine fragment preserved in the Museum of Practical Geology, Jermyn Street, was obtained from the Upper Chalk of Bromley. The species has also been found in the Upper Chalk of Sussex.

*History.*—The type of this species was first described by Forbes under the name of *Goniaster* (*Astrogonium*) *angustatus*, and was afterwards figured by him in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' London, 1850, pl. xxiii, fig. 10. That illustration does not, however, give a good idea of the facies of the species.

*Genus*—PENTAGONASTER, *Linck*, 1733.

PENTAGONASTER,	<i>Linck.</i>	De Stellis marinis, 1733, p. 20.
—	<i>Schülze.</i>	Betrachtung der versteinerten Seesterne und ihrer Theile, Warschau u. Dresden, 1760, p. 50.
GONIASTER (pars),	<i>L. Agassiz.</i>	Prod. Mon. Radiaires, Mém. Soc. Sci. Nat. Neuchatel, 1835, t. i, p. 191.
ASTROGONIUM (pars),	<i>Müller and Troschel.</i>	System der Asteriden, 1842, p. 52.
GONIODISCUS (pars),	<i>Müller and Troschel.</i>	Ibid., 1842, p. 57.
HOSIA (pars),	<i>Gray.</i>	Ann. and Mag. Nat. Hist., 1840, vol. vi, p. 279.
TOSIA,	<i>Gray.</i>	Ibid., 1840, vol. vi, p. 281.

Body depressed and pentagonal in contour, or with the rays slightly produced. Marginal plates smooth or granular, ordinarily few in number. Supero-marginal plates form a broad border to the disk, and, when the ray is produced, are separated throughout by abactinal plates. Abactinal area covered with rounded or polygonal plates, which may either be smooth or bear co-ordinated granules. Actinal intermediate plates and infero-marginal plates smooth or granulose, devoid of prominent spinelets.

Much diversity of opinion has existed, unnecessarily it seems to me, as to the

and limits of this genus. Two species were originally referred to *aster* by its founder. The type of one of these is now lost, and its identity rests only on surmise. The second species, however, *Pentagonaster semis*, is a well-known and widely distributed recent form, about which there is no doubt. I therefore consider that this form has every claim to be regarded as the type of the genus. The existing species of *Pentagonaster* are found in the Atlantic, the Pacific, the Indian and the Southern Oceans, and in the Eastern Archipelago; and the bathymetrical range of the genus extends from 20 to 1500 fathoms or more.

*Ophiaster*

1. [PENTAGONASTER] LUNATUS, *Woodward*, sp. Pl. IV, figs. 1 a—1 c. 1833

ASTERIAS LUNATUS, *Woodward*, 1833. An Outline of the Geology of Norfolk, p. 52, pl. v, fig. 1.

TOSIA LUNATA, *Morris*, 1843. Catalogue of British Fossils, p. 60.

— — *Bronn*, 1848. Index Palæontologicus, Nomenclator, p. 1274.

Body of medium size. General form depressed. Abactinal and actinal areas flat. Marginal contour stellato-pentagonal, the major radius measuring nearly twice the minor radius. Rays short and moderately produced, rather narrow at the base and tapering to the extremity. Interbranchial arcs deeply indented and well rounded.

The infero-marginal plates are twelve (or more) in number, counting from the median interradial line to the extremity. They form a broad border to the actinal area of the disk, the breadth of which diminishes rather rapidly plate by plate as they recede from the median interradial line. The largest infero-marginal plates adjacent to the median interradial line measure about 5.25 mm. in breadth and about 3 mm. or a little more in length. The length and breadth decrease as each plate proceeds outward until about midway on the ray, where these dimensions are subequal. On the outer part of the ray the length is greater than the breadth. The infero-marginal plates are distinctly convex on their actinal surface in the direction of the median line of breadth, and are slightly tumid at the margin. Their surface is covered with small, uniform, closely placed, and deeply sunken moniliform punctations, upon which small granules were previously borne, probably uniform in size and closely placed (see Pl. IV, fig. 1 c). I am not aware that traces of any pedicellariæ have been detected on these plates.

The adambulacral plates are small and oblong, and bear on their surface ridges

of alternating granuliform eminences and depressions, upon which the spinelets constituting the armature of the adambulacral plates were originally borne.

The actinal interradial areas are small, and are covered with regular pentagonal or rhomboid intermediate plates, which are arranged in series parallel to the ambulacral furrow, and form a compact, mosaic-like pavement. The actinal intermediate plates are moderately large in relation to the size of the disk. The plates of the series adjacent to the adambulacral plates are sensibly larger than any of the others, and the plates of the next series are also larger than those which form the rest of the pavement. Near the infero-marginal plates the actinal intermediate plates become small and more or less irregular. The intermediate plates extend at the base of the ray to about the fifth infero-marginal plate, counting from the median interradial line. The surface of the plates is covered with rather large, widely spaced, and deeply sunken punctations, upon which granules were previously borne, and these would appear to have been comparatively large in size and uniform (see Pl. IV, fig. 1 *b*).

From what is visible of the margin of this example it is seen that the supero-marginal series of plates are nearly of the same height as the infero-marginal series, and are similar in structure.

Unfortunately no other portions of this fragment are available for description.

*Locality and Stratigraphical Position.*—The specimen upon which this species was founded was collected by Mr. Samuel Woodward, from the Upper White Chalk, near Norwich.

*Dimensions.*—In the type specimen (figured on Pl. IV, fig. 1 *a*) the major radius is about 35 mm., and the minor radius about 18 mm. Breadth of the ray between the fifth and sixth infero-marginal plates about 10 mm.

*History.*—The type specimen was figured by Woodward in his ‘Outline of the Geology of Norfolk,’ pl. v, fig. 1, and is now preserved in the collection of the Norfolk and Norwich Museum. It was kindly lent by the committee of that institution to Dr. Wright for the purpose of this monograph. It has been carefully drawn on Pl. IV, figs. 1 *a*—1 *c*. An admirably executed cast of this specimen is in the British Museum. I am not at present aware of the existence of any other examples of this rare form.

*Remarks.*—The example referred by Forbes to this species, and figured by him in Dixon’s ‘Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,’ London, 1850, pl. xxiii, fig. 9, belongs to a distinct species, which I have named *Pentagonaster megaloplaea*. A number of other specimens in other



collections have, following Forbes, been erroneously referred to *Pentagonaster lunatus*, which are in reality examples of *Pentagonaster megaloplax*. This is unfortunate, for the latter form has thus become comparatively well known under the name of *Pentagonaster lunatus*, a name which they must now cease to bear, as the real *Pentagonaster lunatus* is quite a different form, and there is no doubt whatever either as to the type (which is preserved in Norwich) or the priority. The differences between the two species will be further noticed under the description of *Pentagonaster megaloplax*.

*Ceratopaster quinqueloba* Giff.

2. PENTAGONASTER MEGALOPLAX, *Sladen*. Pl. IV, figs. 2—4.  $\Sigma 1 + 1$   
 18 *Asterias quinqueloba* Giff. *Pol. of I. 200* (par.), p. 63, fig. 5 a-u. (non 5 a -  
 1841 GONIASTER (ASTROGONIUM) LUNATUS, *Forbes*, 1850. In *Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex*, London, 4to., p. 353, pl. xxiii, fig. 9 (non *Asterias lunatus*, Woodward, 1833).  
 1907 *Pentagonaster quinqueloba* *Spencer* K. 108, p. 114, fig. 74  
 1913 *Ceratopaster* — — *Evolut.* 7, 127, p. 12, figs. 7-10, 12, 13.

Body of medium size. General form depressed. Abactinal and actinal areas flat. Marginal contour stellato-pentagonal, the major radius measuring a little more than once and a half the minor radius. Rays short and not greatly produced, tapering gradually to the extremity. Interbranchial arcs regularly rounded, curving gradually from the tip of one ray to that of the adjacent ray, which gives a distinctly lunate character to the disk. Margin of uniform thickness.

The infero-marginal plates are only five or rarely six in number, counting from the median interradial line to the extremity. They form a very broad border to the actinal area of the disk in relation to its size, and the breadth is maintained until near the extremity. The largest infero-marginal plates adjacent to the median interradial line measure 7 mm. in breadth, and about 6.5 mm. or nearly 7 mm. in length; they are consequently almost square. The proportion of breadth diminishes in the succeeding plates as they recede from the median interradial line. The infero-marginal plates have a more or less pulvinate appearance actinally, consequent on being rounded or bevelled at the edges; and they are slightly tumid in the margin. Their whole actinal surface is covered with large, well-spaced, deeply sunken pits, in the centre of which is a slight eminence—a structure which has almost the character of a granule surrounded by a scrobicule (see Pl. IV, fig. 2 b). On the surface which stands in the margin the punctations are fewer and more widely spaced on the upper half of the surface—that is to say,

the half adjacent to the supero-marginal series (see Pl. IV, fig. 4 *c*). I have not found any pedicellariæ on these plates.

The adambulacral plates are broader than long, except on the outer part of the ray, and bear on the surface four or five ridges with granuliform eminences, upon which the spinelets constituting the adambulacral armature were originally borne. In one well-preserved specimen these small artulatory tubercles are seen to have each a small microscopic central puncture (see Pl. IV, fig. 3 *c*), but I am not certain whether this is always present.

The actinal interradial areas are small, and are covered with a comparatively small number of large pentagonal or tetragonal intermediate plates, which are arranged in series parallel to the ambulacral furrow, and form a compact tessellated pavement. The actinal intermediate plates are larger in relation to the size of the disk than in the species above described. The plates of the series adjacent to the adambulacral plates, and a few of the plates of the succeeding series within the angle towards the mouth, are larger than the others. The intermediate plates do not extend beyond the second, or at most a short distance along the margin of the third infero-marginal plate, counting from the median interradial line. The surface of the intermediate plates, excepting a border round the margin of the plate, is covered with large punctations, which are nearly confluent, and in some cases almost give the appearance of a coarse reticulate superficial ornamentation; the border round the margin of the plate above mentioned is marked with a concentric crenulation (see Pl. IV, fig. 3 *b*). Within the pits are more or less definite elevations. In other examples the reticulate character is less marked, and the margin of the pit is then prominently lipped, and the marginal crenulation is not so strongly shown (see Pl. IV, fig. 4 *e*).

In the marginal view of the type specimen the supero-marginal plates are seen to be higher than the infero-marginal plates, and that their height is greater than their length, whereas in the infero-marginal series of plates the height is less than the length (see Pl. IV, fig. 2 *c*).

In other examples the mouth-plates are preserved. These are rather small, triangular, and covered with rather large, irregular, tuberculose eminences for the attachment of the mouth-plate armature.

*Variations.*—Three examples of this species are figured on Plate IV. These present a number of minor differences, which will be readily noticed on referring to the figures.

The example which is shown in fig. 3 *a* has the marginal border of the infero-marginal plates rather less broad than in the type form, and it is especially remarkable for the peculiar retiform and crenulated ornamentation of the actinal intermediate plates already noticed. The disposition of the armature of the



PLATE I.

CALLIDERMA SMITHIÆ, *Forbes*, sp. (P. 6.)

*From the Lower Chalk.*

FIG.

- 1 *a.* Actinal aspect ; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin ; natural size.
- c.* Infero-marginal plates ; magnified 2 diameters.
- d.* Lateral view of the marginal plates ; magnified.
- e.* Adambulacral plates ; magnified.
- f.* Actinal intermediate plates ; magnified 3 diameters.

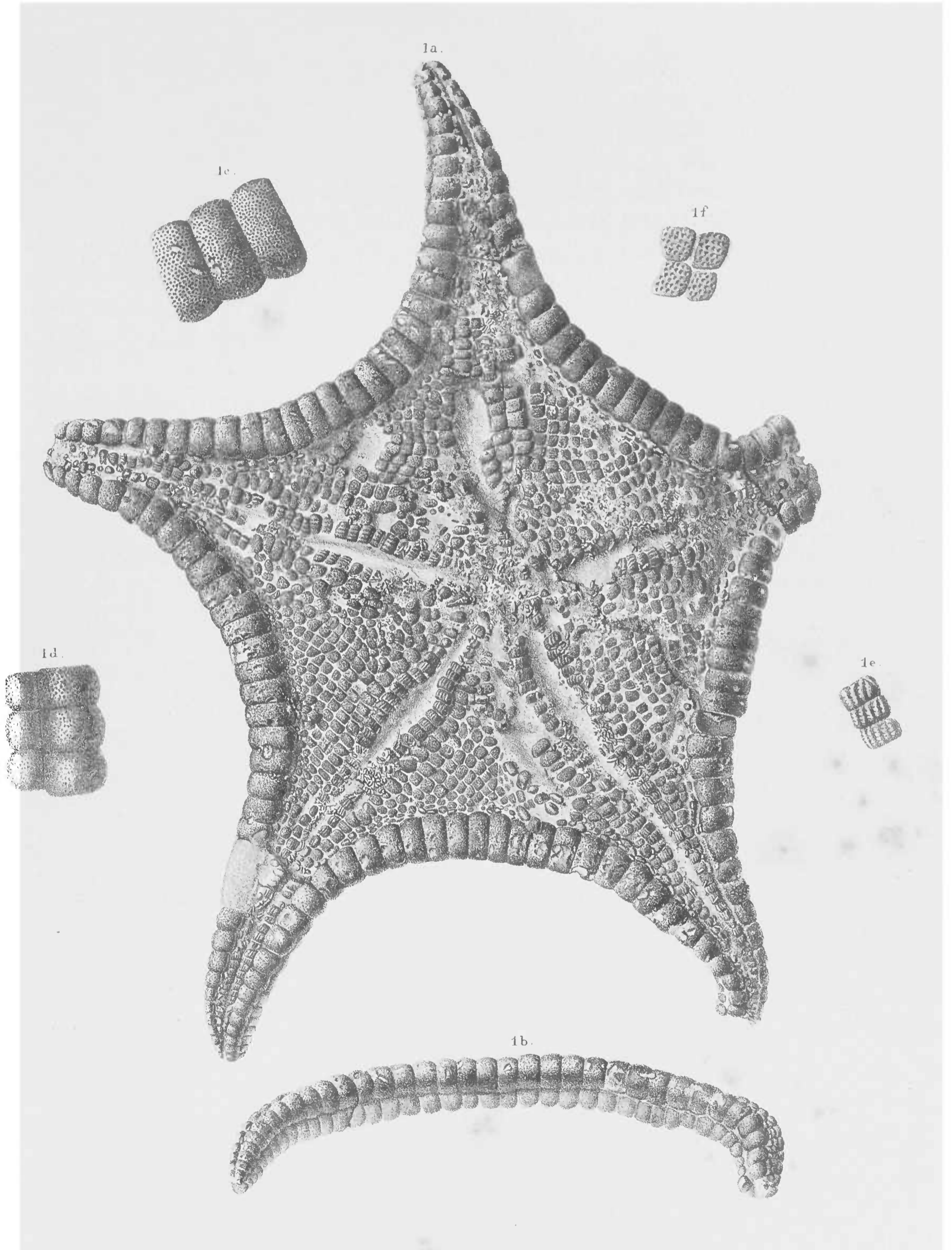






PLATE II.

CALLIDERMA LATUM, *Forbes*, sp. (P. 12.)

*From the Lower Chalk.*

FIG.

- 1 *a.* Actinal aspect; natural size. (Coll. Brit. Mus.)
- b.* Infero-marginal plates; magnified 2 diameters.
- c.* Actinal intermediate plates; magnified 3 diameters.
- d.* Adambulacral plates; magnified.
- e.* A mouth-plate; magnified.
- 2 *a.* Actinal aspect of another example, with a portion of the actinal floor removed, showing the stellate bases of the abactinal plates or paxillæ; natural size. (Coll. Brit. Mus.)
- b.* Actinal surface of part of the ray; magnified  $1\frac{1}{2}$  diameters.
- c.* Infero-marginal plates; magnified 3 diameters.
- d.* Stellate bases of the abactinal plates or paxillæ; magnified 4 diameters.



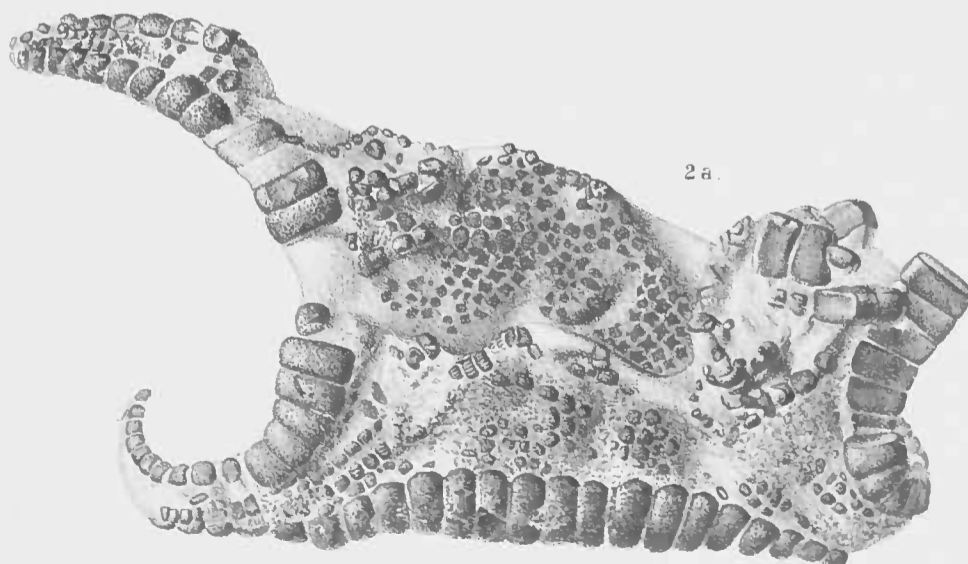
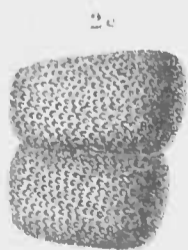
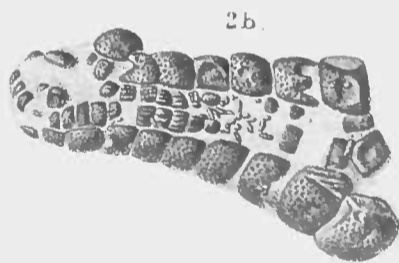
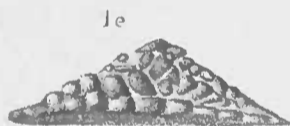
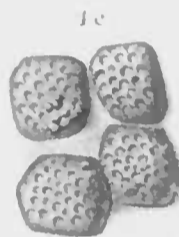
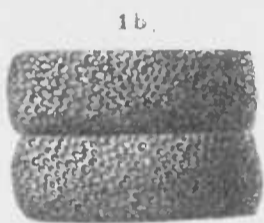
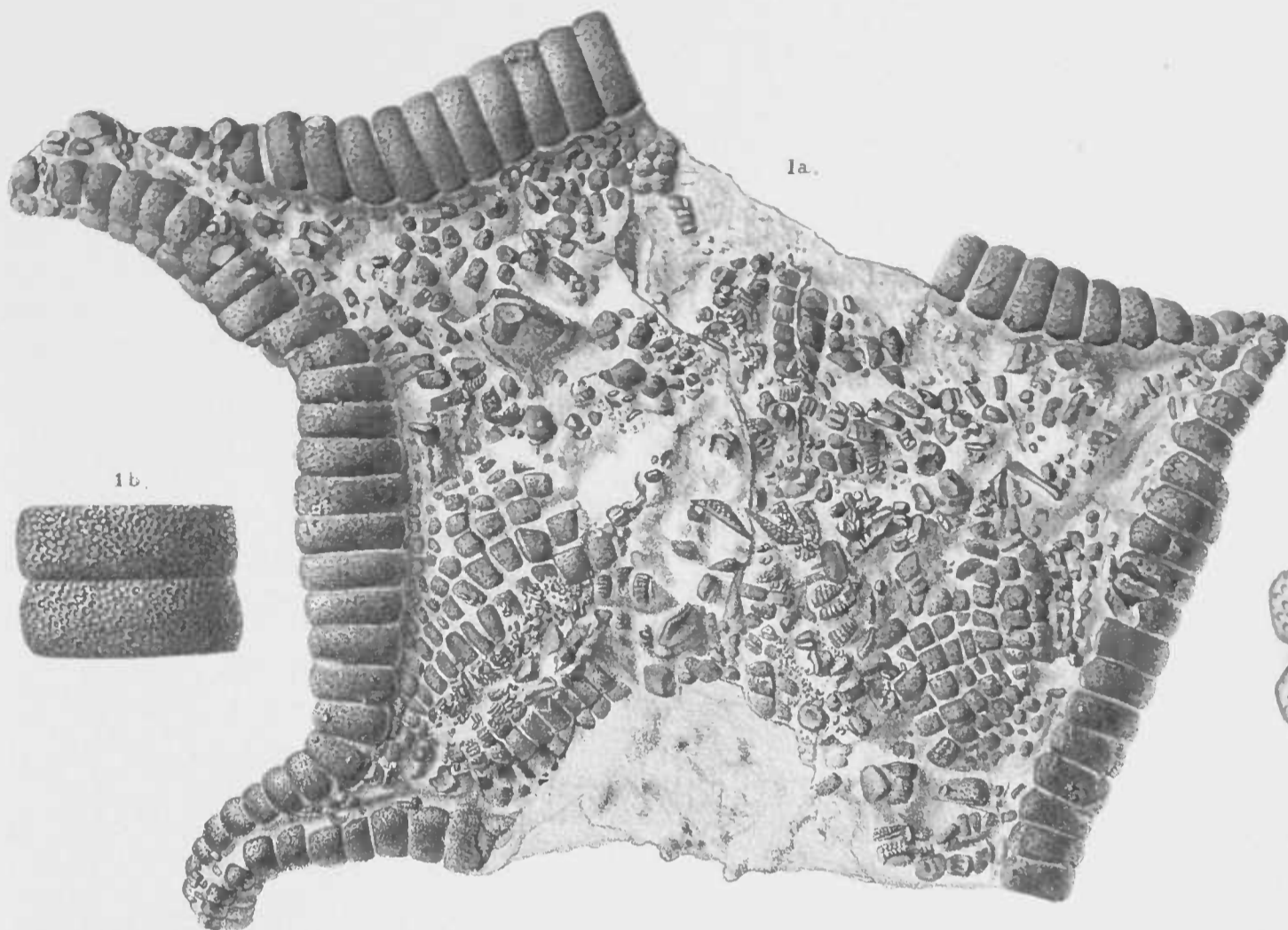






PLATE III.

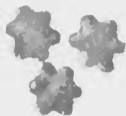
CALLIDERMA LATUM, *Forbes*, sp. (P. 12.)

*From the Lower Chalk.*

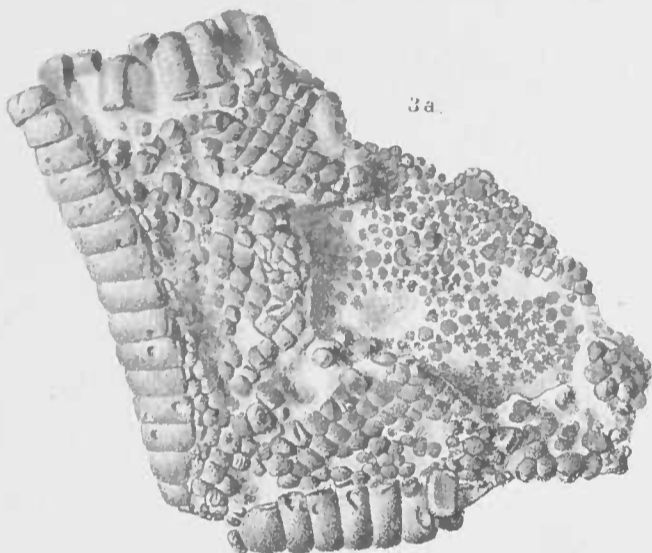
FIG.

- 1 *a.* Actinal aspect of an example from Amberley; natural size. (Coll. Brit. Mus.)
  - b.* Lateral view of the margin; natural size.
  - c.* Lateral surfaces of the marginal plates; magnified.
  - d.* An infero-marginal plate; magnified.
  - e.* An actinal intermediate plate; magnified.
- 2 *a.* Actinal aspect of an example from the Chalk Marl of Dover; natural size. (Coll. Brit. Mus.)
  - b.* An adambulacral plate; magnified.
- 3 *a.* Actinal aspect of an example from Washington, with a portion of the actinal floor removed, showing the stellate bases of the abactinal plates or paxillæ; natural size. (Coll. Brit. Mus.)
  - b.* Stellate bases of the abactinal plates or paxillæ; magnified.

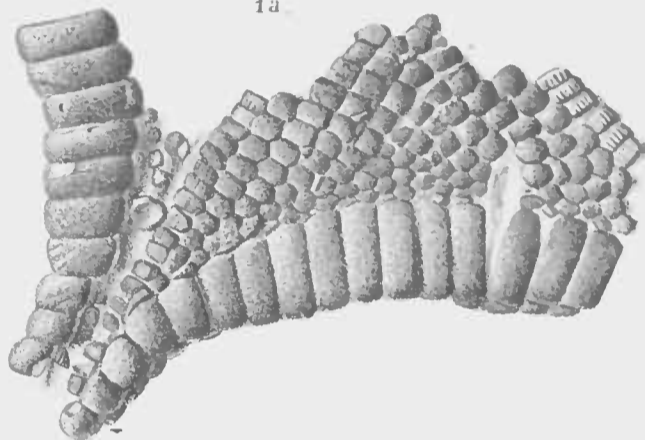
3b



3a



1a



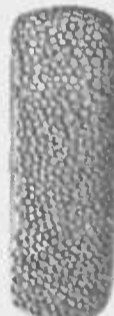
1c



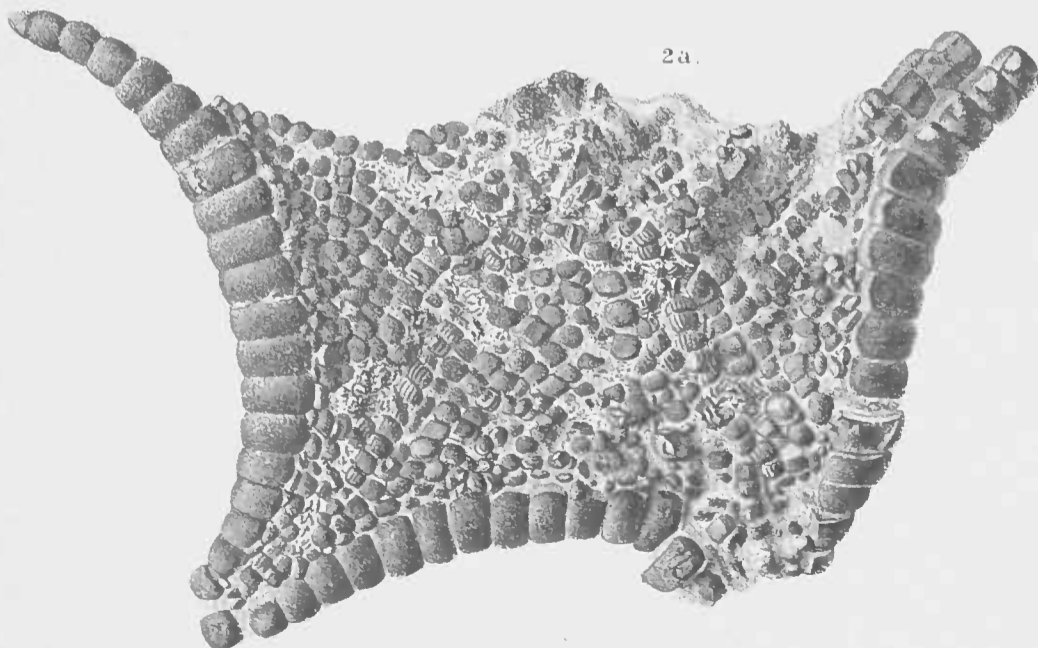
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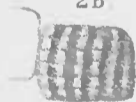
1d



2a



2b



1e

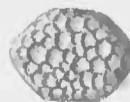






PLATE IV

PENTAGONASTER LUNATUS, *Woodward*, sp. (P 25.)

*From the Upper Chalk.*

FIG.

- 1 *a.* Actinal aspect of the type specimen; natural size. (Coll. Norfolk and Norwich Mus.)  
*b.* An actinal intermediate plate; magnified.  
*c.* An infero-marginal plate; magnified.

[PENTAGONASTER MEGALOPLEX, *Sladen*.] (P. 27.)

*Crateraster quinquelobatus* *Forbes*

*From the Lower Chalk.*

- 2 *a.* Actinal aspect of the example figured by Forbes, under the name of *Goniaster* (*Astrogonium*) *lunatus*; natural size. (Coll. Brit. Mus.)  
*b.* An infero-marginal plate; magnified 3 diameters.  
*c.* Lateral view of the margin; natural size.
- 3 *a.* Actinal aspect of another example; natural size. (Coll. Brit. Mus.)  
*b.* An actinal intermediate plate; magnified 6 diameters.  
*c.* Adambulacral plates; magnified 6 diameters.
- 4 *a.* Actinal aspect of an example from the Upper Chalk of Bromley; natural size. (Coll. Brit. Mus.)  
*b.* Lateral view of the margin; natural size.  
*c.* Lateral surface of an infero-marginal plate; magnified.  
*d.* An infero-marginal plate; magnified.  
*e.* An actinal intermediate plate; magnified 6 diameters.



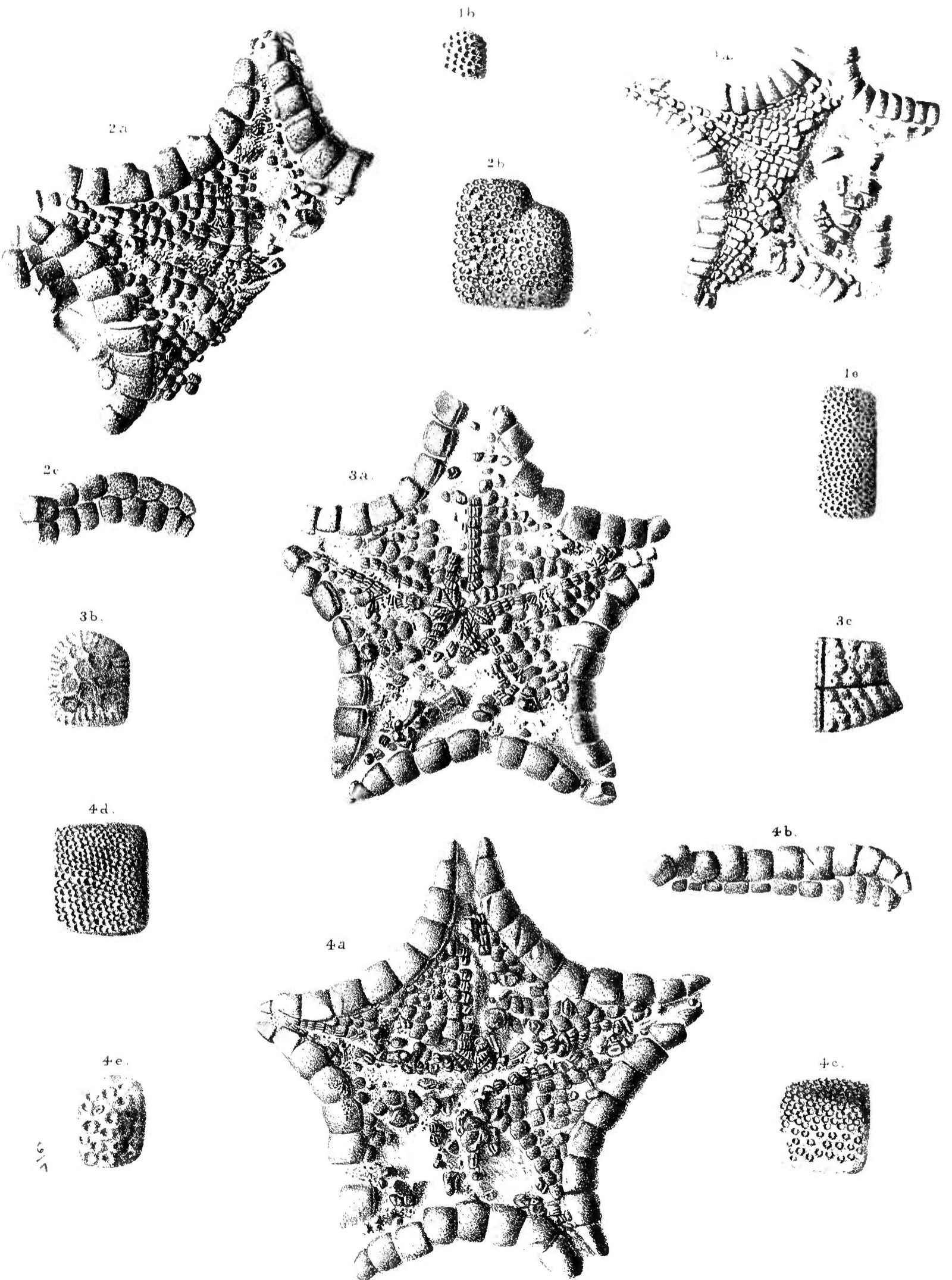






PLATE V  
*Calliderma Smithiae*  
[TOMIDASTER SULCATUS, *Sladen.*]

*From the Grey Chalk.*

FIG.

- 1 *a.* Actinal aspect ; natural size. (Coll. Brit. Mus.)
- b.* Actinal intermediate plates ; magnified.
- c.* Adambulacral plates ; magnified 3 diameters.

*do.*  
[CALLIDERMA MOSAICUM, *Forbes, sp. (P. 9.)*]

*From the Lower Chalk.*

- 2 *a.* Abactinal aspect ; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin ; natural size.
- c.* Abactinal plates ; magnified.
- d.* Supero-marginal plates ; magnified.
- e.* Madreporiform body and surrounding plates ; magnified.

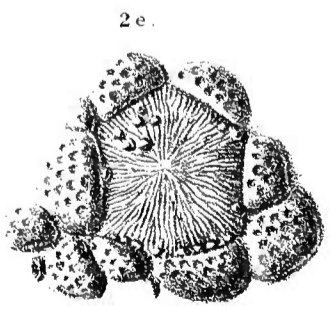
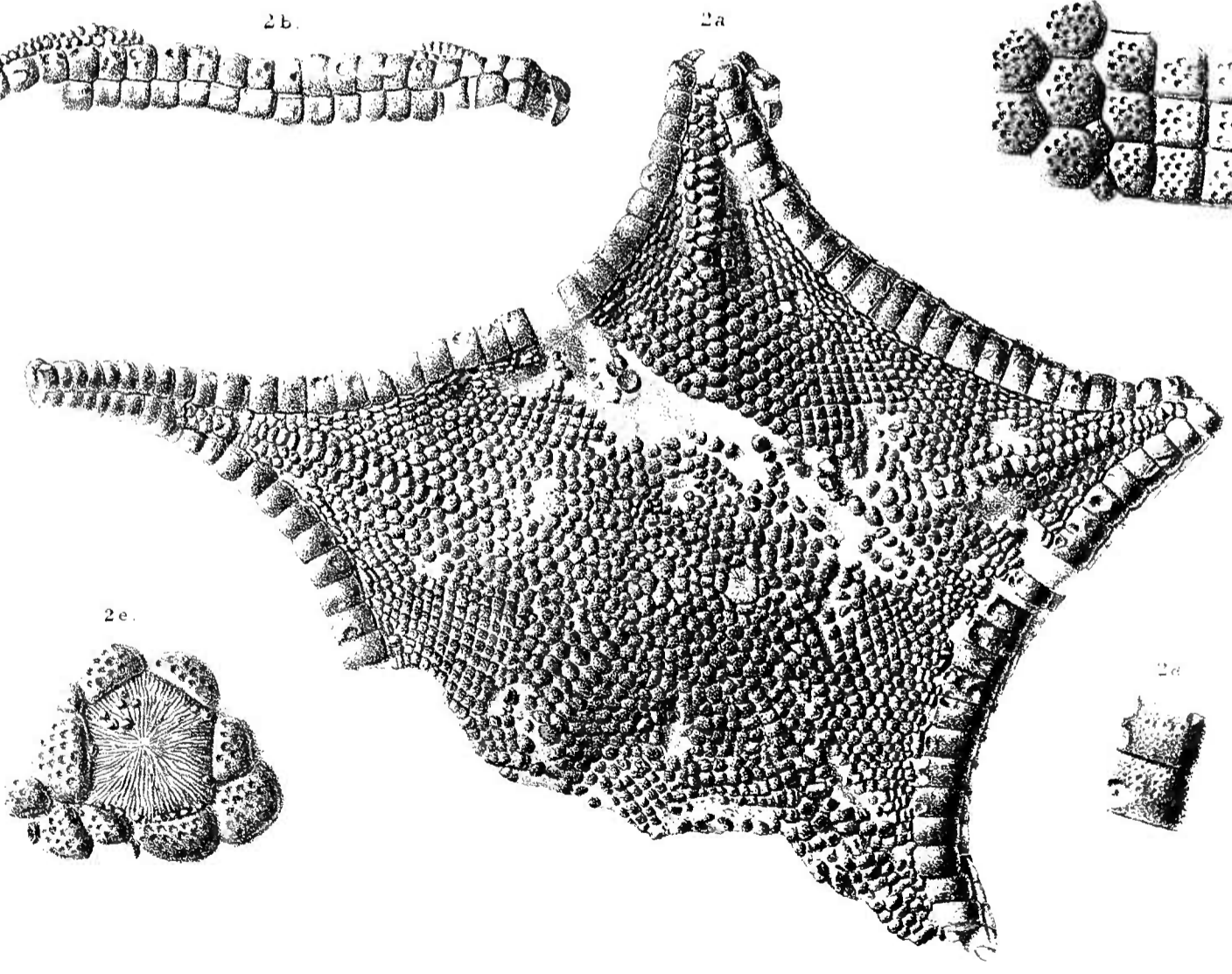
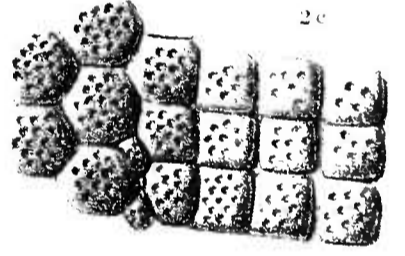
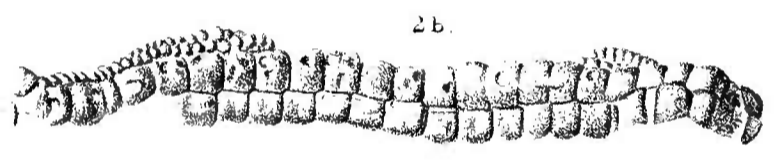
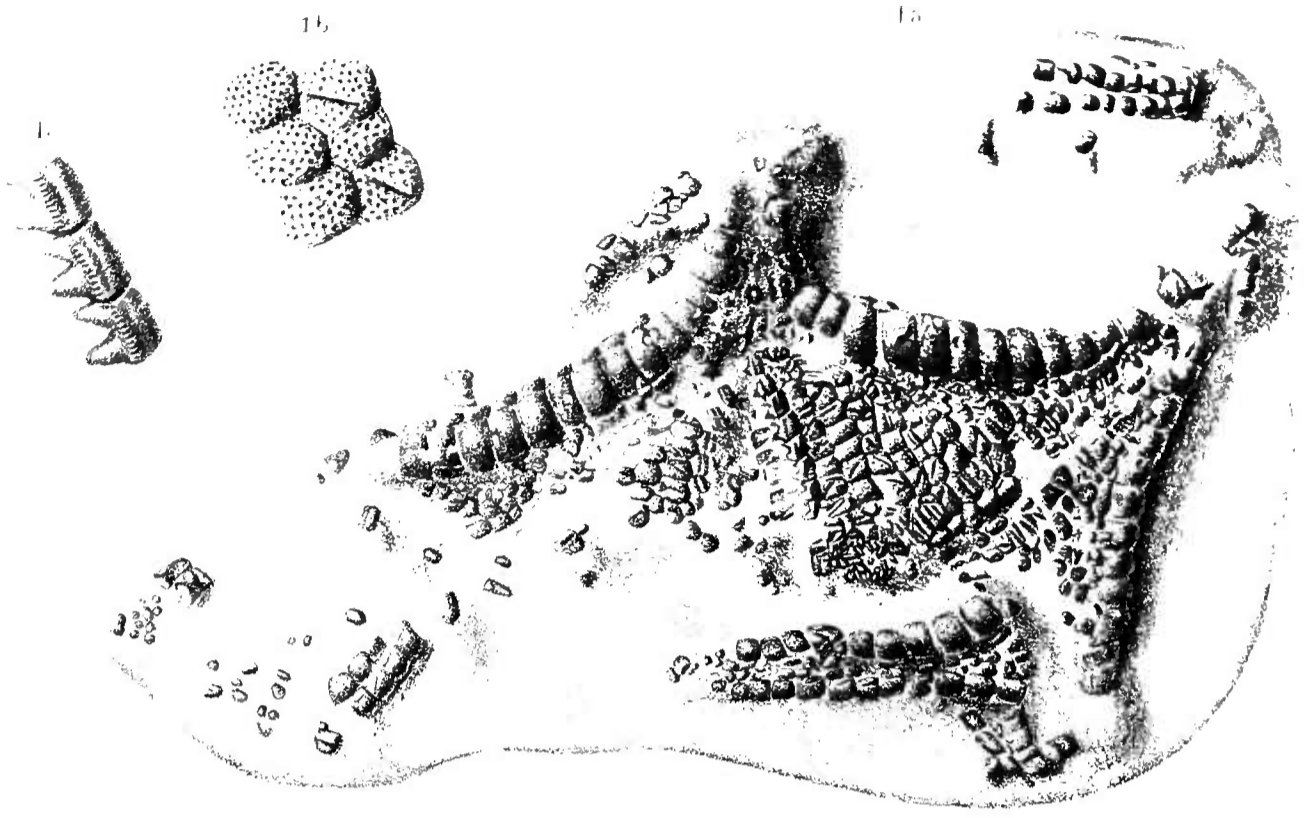






PLATE VI.

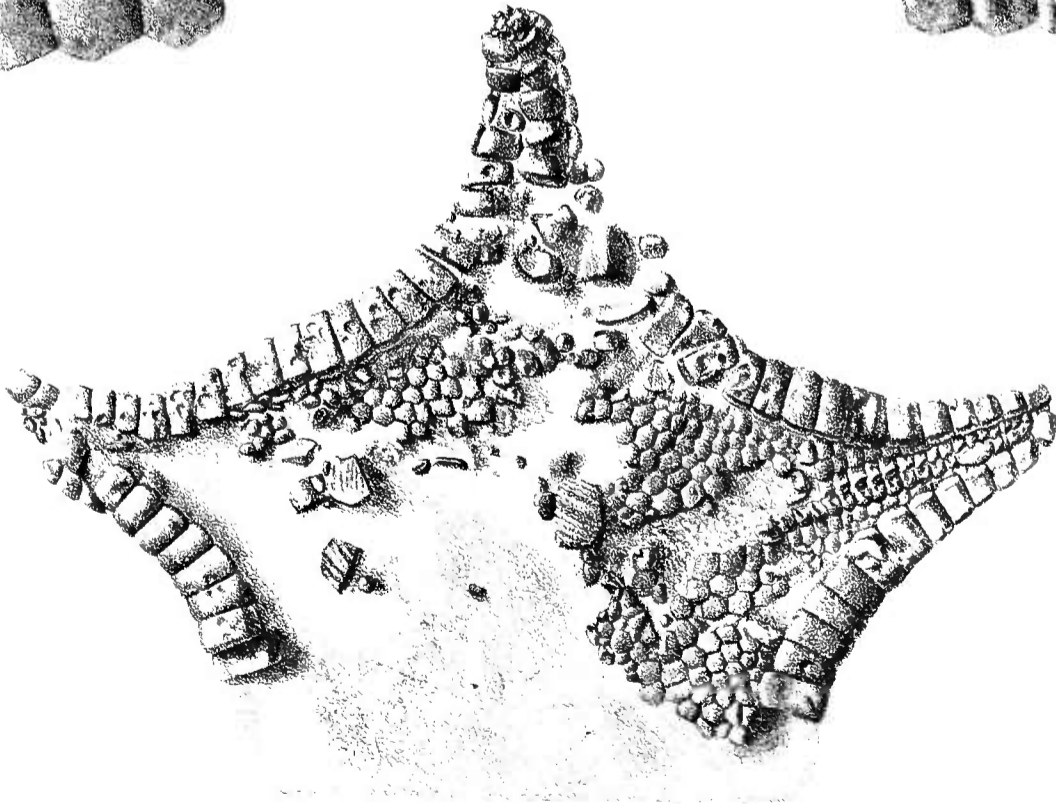
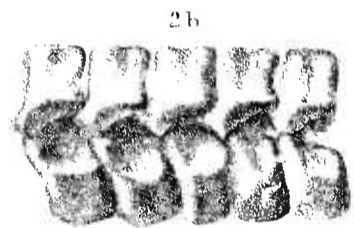
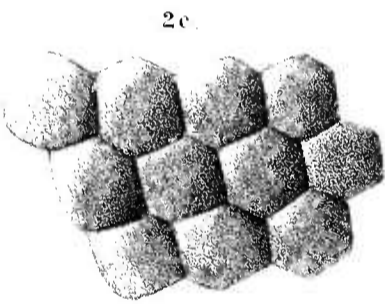
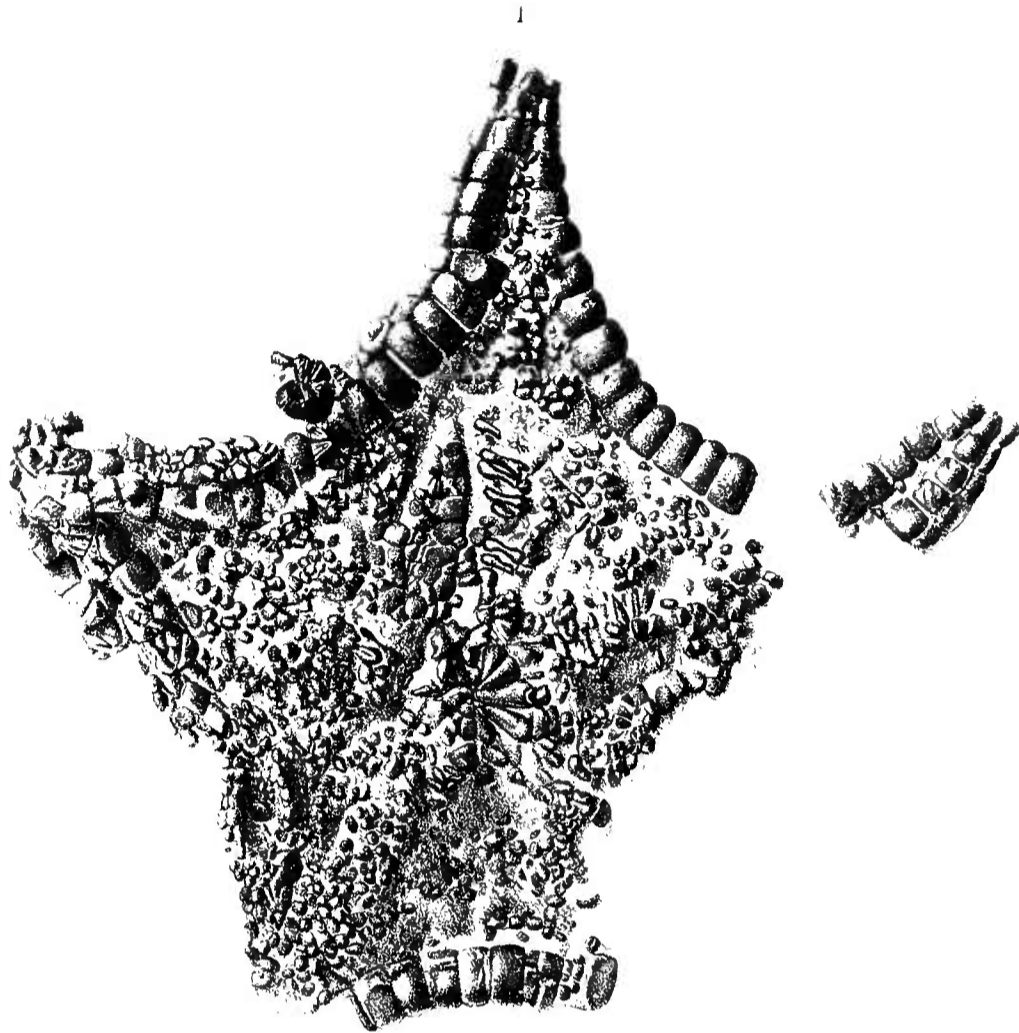
*Smithsonian Institution* 1878 (P. 123)  
CALLIDERMA [MOSAICUM, *Forbes*, sp. (P. 9.)]

*From the Grey Chalk.*

FIG.

1. Abactinal aspect of an example from which the abactinal plates have been removed; natural size. (Coll. Brit. Mus.)
- 2 *a.* Abactinal aspect of another example from which the abactinal plates have been removed, showing the inner surface of some of the actinal intermediate plates and adambulacral plates; natural size. (Coll. Brit. Mus.)
- b.* Adambulacral plates, seen from within; magnified.
- c.* Actinal intermediate plates, inner surface; magnified.





2a





PLATE VII.

[ (?) NYMPHASTER COOMBII, *Forbes*, sp. (P. 15.) ]

*From the Lower Chalk.*

FIG.

1 *a.* Actinal aspect; natural size. (Coll. Brit. Mus.)

*Call.* } *b.* Lateral view of the margin; natural size.

*derma* } *c.* Adambulacral plates; magnified.

*7 in the sc* } *d.* An infero-marginal plate; magnified.

*sept 1* } *e.* Actinal intermediate plates; magnified.

723 } 2 *a.* Abactinal aspect of an example from the Grey Chalk at Folkestone; natural size. (Coll. Brit. Mus.)

*b.* A supero-marginal plate; magnified.

3 *a.* Abactinal aspect of an example from the Lower Chalk of Glynde; natural size. (Coll. Brit. Mus.)

*b.* A supero-marginal plate; magnified.

*Call. derma* } *7 in the sc* }  
CALLIDERMA MOSAICUM, *Forbes*, sp. (P. 9.)

*From the Lower Chalk.*

4 *a.* Abactinal aspect; natural size. (Coll. Brit. Mus.)

*b.* Lateral view of the margin; natural size.

*c.* A supero-marginal plate; magnified.

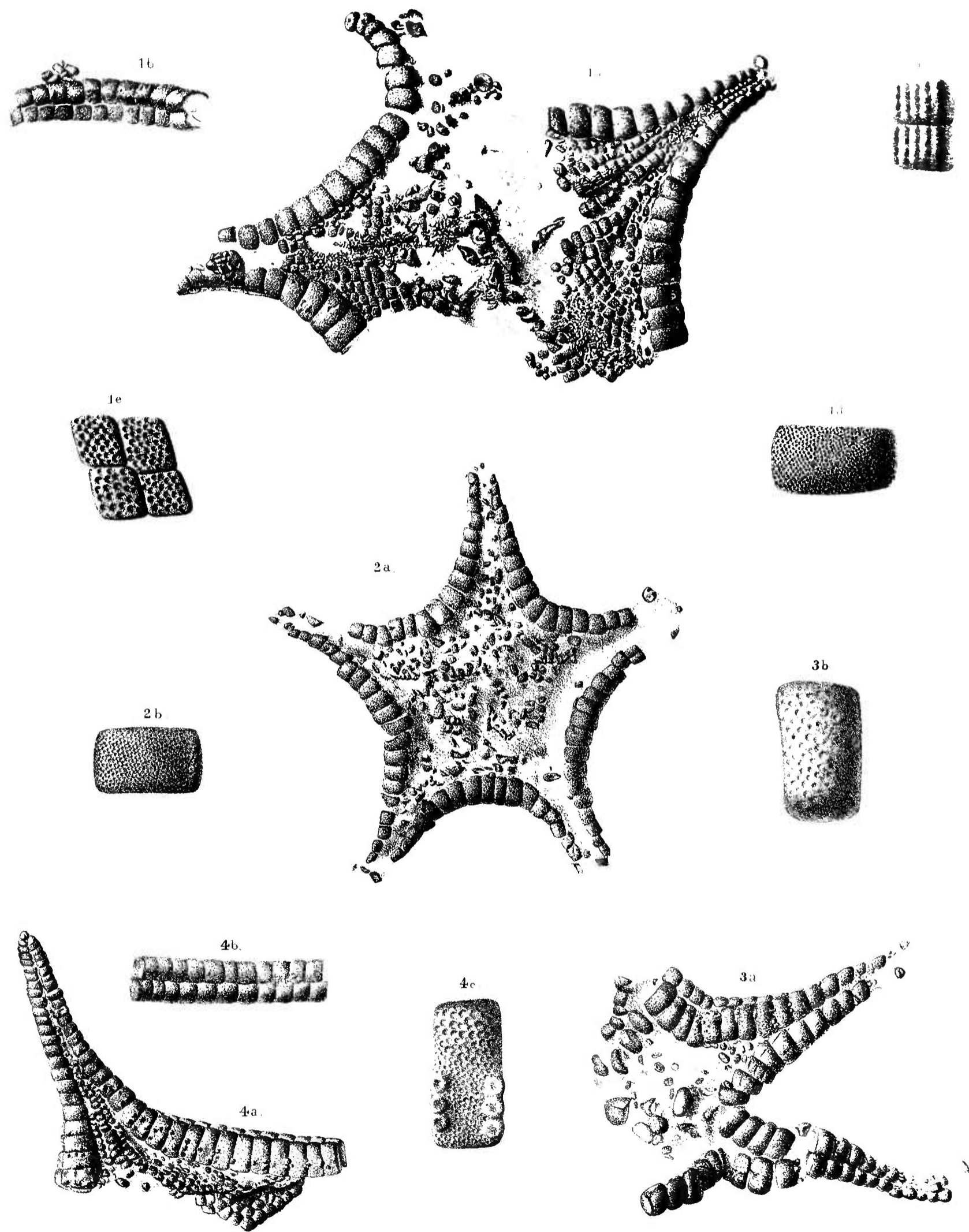






PLATE VIII.

NYMPHASTER COOMBII, *Forbes*, sp. (P. 15.)

*From the Lower Chalk.*

FIG.

- 1 *a.* Actinal aspect of the type specimen ; natural size. (Coll. Brit. Mus.)
- b.* An infero-marginal plate ; magnified 3 diameters.

CALLIDERMA SMITHIÆ, *Forbes*, sp. (P. 6.)

*From the Lower Chalk.*

- 2 *a.* Profile view of a fragment of a ray ; natural size. (Coll. Brit. Mus.)
- b.* Actinal view of the same ; natural size.
- c.* An adambulacral plate ; magnified 6 diameters.

NYMPHASTER OLIGOPLAX, *Sladen*. (P. 19.)

*From the Upper Chalk.*

- 3 *a.* Abactinal aspect ; natural size. (Coll. Brit. Mus.)
- b.* A supero-marginal plate ; magnified.

NYMPHASTER MARGINATUS, *Sladen*. (P. 18.)

*From the Upper Chalk.*

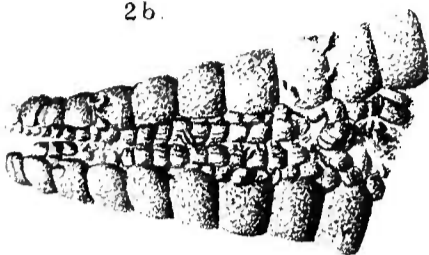
- 4 *a.* Abactinal aspect ; natural size. (Coll. Brit. Mus.)
- b.* A supero-marginal plate ; magnified 4 diameters.



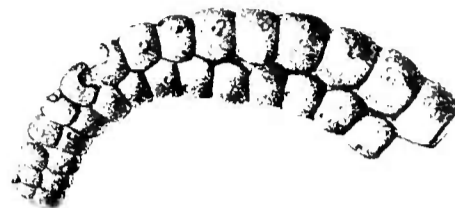
2c



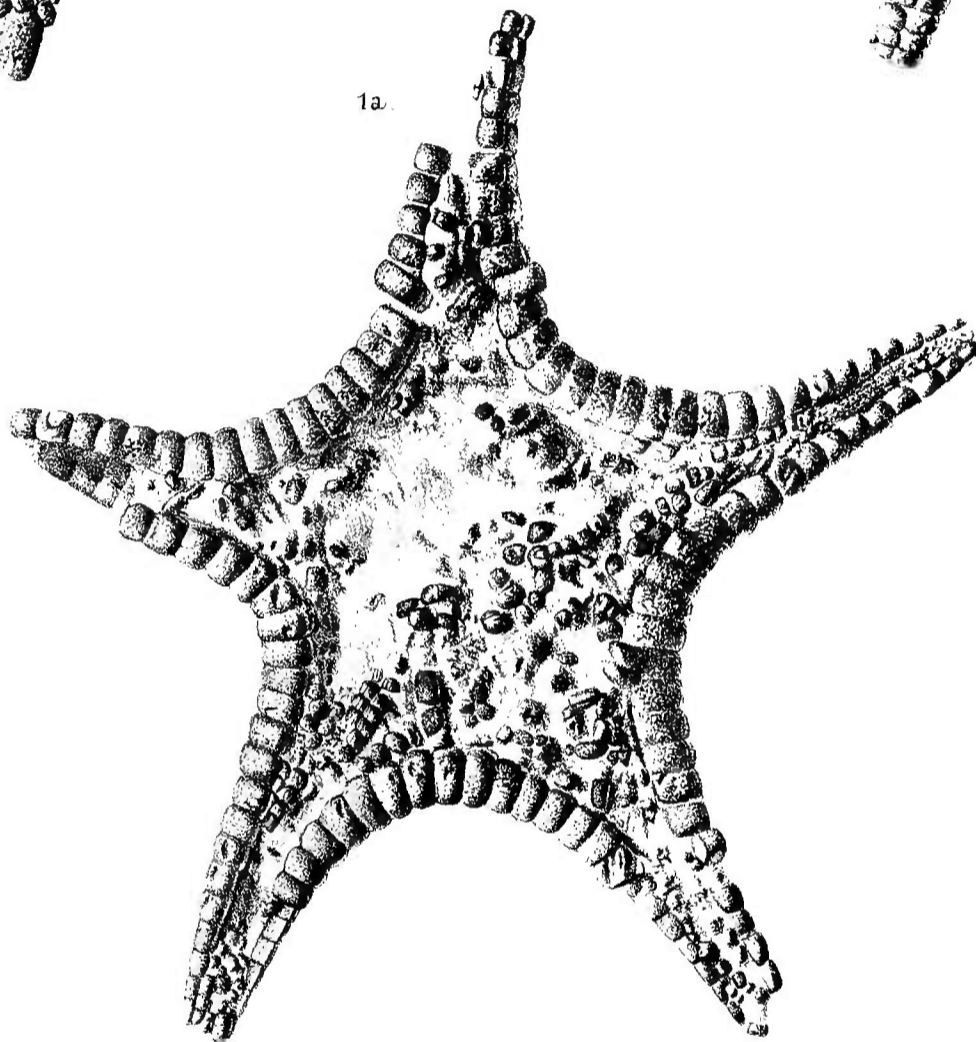
2b



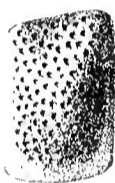
2a



1a



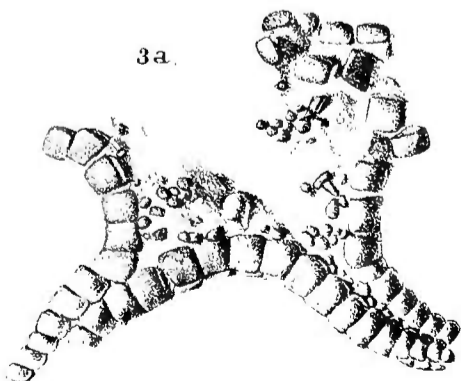
3b



1b



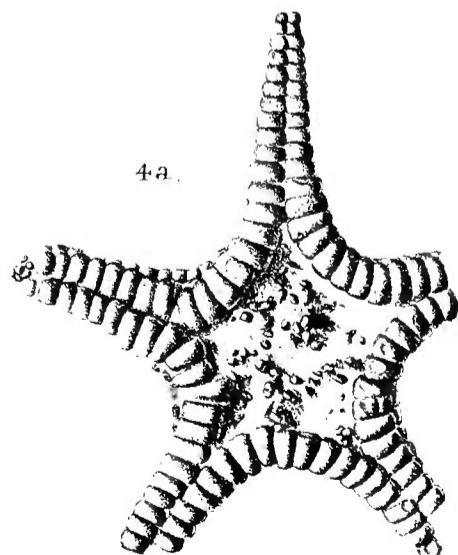
3a



4b



4a

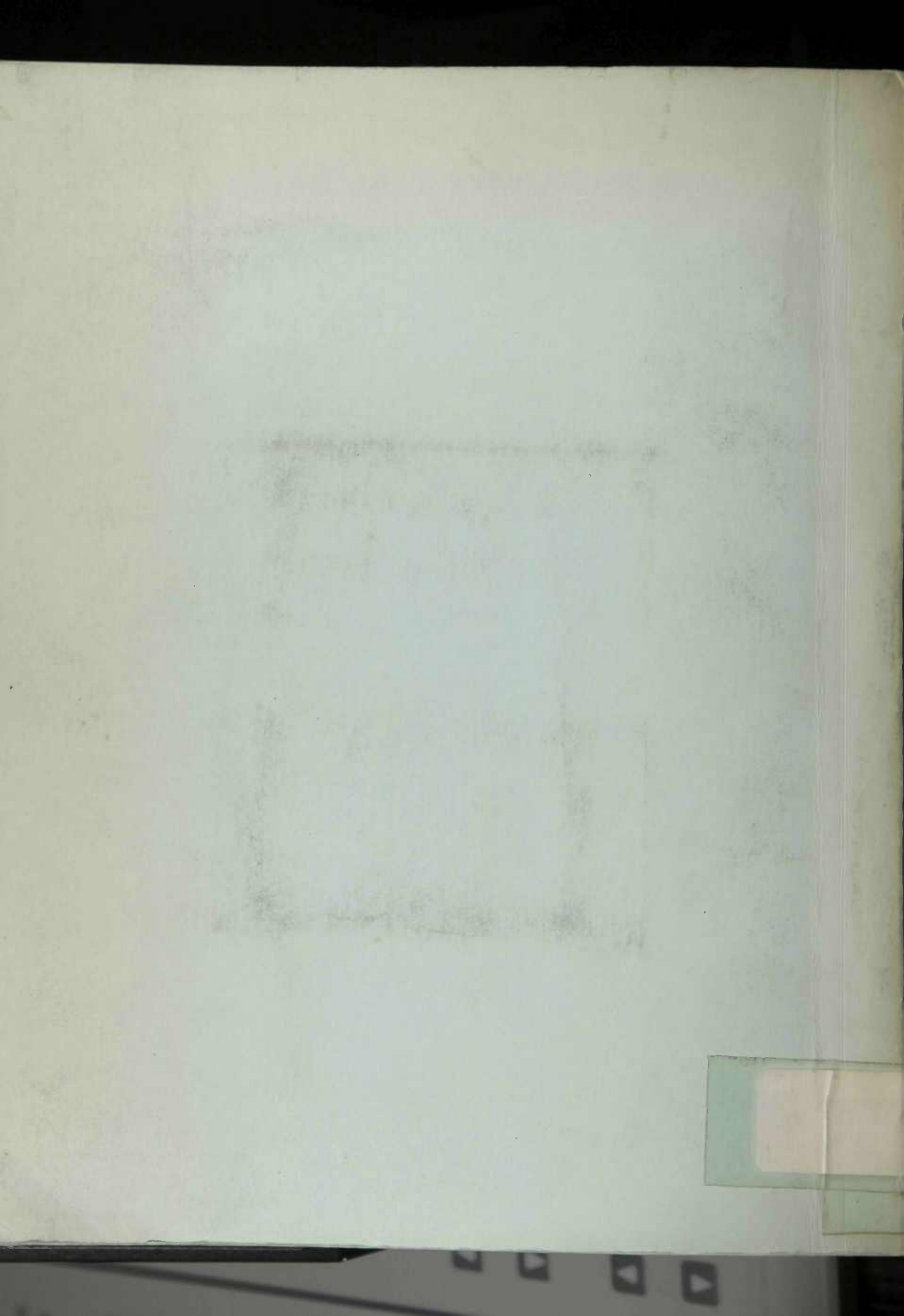












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