

Cretaceous Echinodermata.

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A MONOGRAPH
ON THE
BRITISH FOSSIL
ECHINODERMATA

FROM
THE CRETACEOUS FORMATIONS.

VOLUME SECOND.

THE ASTEROIDEA.

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PART SECOND.

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adambulacral plates is also noteworthy. This seems to indicate the former presence of a distinct furrow series of spinelets or granules much smaller than usual, followed by granules or spinelets borne on the outer part of the plate, more irregularly placed than in the other forms described, and articulated on punctured eminences.

The example which is represented in fig. 4 *a* also has a narrower marginal border of infero-marginal plates than the type. The punctuation of the infero-marginal plates is smaller than in the type, and does not present the striking scrobiculate character noticed in that example. The markings are rather to be described as lipped pits, and some granules are still *in situ*. The actinal intermediate plates do not have the retiform and crenulate ornamentation shown in the plates belonging to the specimen figured in 3 *a*, but the margins of the punctations are strongly lipped. The supero-marginal plates are less regular and much less high than in the type specimen, but they are not perfectly preserved.

Dimensions.—In the type specimen (figured on Pl. IV, fig. 2 *a*) the major radius is about 41 mm., and the minor radius 26 mm. Breadth of a ray between the third and fourth infero-marginal plates, counting from the median interradial line, about 12 mm. or rather more. Thickness of the margin about 8.5 mm.

The specimen given in fig. 3 *a* has a major radius of about 39 mm. and a minor radius of 24 mm.

The specimen given in fig. 4 *a* has a major radius of about 41 mm. and a minor radius of 25.5 mm. Breadth of the ray between the third and fourth infero-marginal plates about 11 to 12 mm., or rather more.

Locality and Stratigraphical Position.—The type specimen, which is now preserved in the British Museum, is labelled from the "Lower Chalk" of "Sussex," but is stated by Forbes to have been obtained from the Upper Chalk. Other examples of the species have been collected from the Upper Chalk of Bromley, Sittingbourne, Purfleet, Gravesend, Sussex, and Wiltshire. Fine series are preserved in the British Museum and in the Museum of Practical Geology, Jermyn Street.

History.—The specimen which I have taken as the type of this species was originally referred by Forbes to the *Asterias lunatus* of Woodward, and was figured by him as that species in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex' (pl. xxiii, fig. 9). The same example is carefully represented on Pl. IV, fig. 2 *a*, of this memoir.

Remarks.—It will be at once seen on referring to the figures that Woodward's *Pentagonaster lunatus*, which is drawn on Pl. IV, fig. 1 *a*, of this Monograph, is a distinct species. The rays are more produced, and are narrower at the base. The infero-marginal plates are twice as numerous, the marginal border is less broad, and the plates are much shorter in proportion to their breadth. Their punctuation is also different. The actinal intermediate plates are smaller in relation to the size of the actinal interradial areas, and their punctuation is different from that which characterises *Pentagonaster megaloplax*. The armature of the adambulacral plates also appears to be more regular in its arrangement.

Under these circumstances I have no hesitation in considering the form under description a distinct species. I much regret having to impose a new name, as this form has for a long time been known under the specific name of *lunatus*; the course, however, seems unavoidable, as the actual type of the real *Pentagonaster lunatus* described by Woodward is in existence, and there can, in my opinion, be no question as to its being a different species.

Since the preceding sheet was printed off I have found several specimens in the British Museum which show the abactinal aspect of the disk. I have little hesitation in referring these examples to *Pentagonaster megaloplax*, and a drawing of one of them is given on Pl. XIII, fig. 1 *a*. The infero-marginal plates all show more or less distinctly the characteristic "scrobiculate" or areolated pits already described. A similar ornamentation also extends upon the supero-marginal plates, but is confined to the lateral wall which falls in the margin of the disk. The curvature which unites the abactinal and lateral areas of the plate is more or less abrupt, and the lateral wall of the disk is consequently vertical and not rounded, as a rule. The abactinal area of the supero-marginal plates is covered with small, uniform, granular eminences (see Pl. XIII, fig. 1 *b*). Two or three supero-marginal plates at the extremity of the ray meet the corresponding plates of the opposite side of the ray in the median radial line, and a rapid diminution in breadth occurs as they approach the extremity.

Genus—METOPASTER, Sladen.

[*Μέτωπον* = a cheek-piece.]

Body depressed and pentagonal or stellato-pentagonal in contour, the rays being produced to a very slight degree. Marginal plates covered with well-spaced uniform punctations, upon which granules were originally borne, and surrounded by a narrow depressed border with very minute and crowded puncta-

tions for the articulation of setæ. Supero-marginal plates ordinarily few in number, and form a broad border to the disk. Ultimate paired supero-marginal plates the largest of the series. Abactinal area covered with polygonal, and usually hexagonal, plates (some of which may have stellate bases), and upon the tabulæ 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 of the ray. Their ornamentation similar to that of the superior series. Actinal intermediate plates small, polygonal, covered with uniform granules. Armature of the adambulacral plates arranged in longitudinal lines. Small entrenched pedicellariæ may be present occasionally on the plates.

Metopaster differs from *Pentagonaster* by the large ultimate paired supero-marginal plates, by the comparatively small number of the 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.

The forms ranked under this genus were all classed by the late Professor Edward Forbes under *Goniodiscus*, which he considered to be a sub-genus of *Goniaster*. There is, however, no justification whatever in my opinion for regarding any of the Cretaceous starfishes hitherto described as belonging to either the genus *Goniaster* or *Goniodiscus*. The species which may be considered as the types of each of these genera are existing forms, and no Cretaceous forms agreeing in structural detail have, so far as I am aware, been discovered. It is also erroneous to rank *Goniodiscus* as a sub-genus of *Goniaster*. The two genera belong to different families; and I am in perfect accord with Professor Edmond Perrier as to the limitation of the two genera. His view appears to me to be perfectly logical, and to be the result of careful and impartial judgment. I also consider that the fossil forms under consideration are quite distinct from the recent genus *Astrogonium*, as limited by me elsewhere.¹

(Pl. XIX, fig. 2)

1. METOPASTER PARKINSONI, *Forbes*, sp. Pl. IX, figs. 2 a—2 c; Pl. X, figs. 1 a—4

[non 5 &]; Pl. XI, figs. 1 a—2 c; Pl. XII,

figs. 1 a—1 d; Pl. XVI, figs. 2 a, 2 b.

(Pl. X, fig. 5 = *Metopaster* *Sp. nov.* 1913.)

PENTAGONASTER REGULARIS, *Parkinson*, 1811. Organic Remains, vol. iii, p. 3, pl. i, fig. 3 (non Linck).

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

¹ 'Zool. Chall. Exped.,' part li, "Report on the Asteroidea," 1889, p. 285.

FOSSIL ASTEROIDEA.

- GONIASTER (GONIODISCUS) PARKINSONI, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 472.
- — RECTILINEUS, *McCoy*, 1848. Ann. and Mag. Nat. Hist., ser. 2, vol. ii, p. 408.
- — PARKINSONI, *Forbes*, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 332, pl. xxi, figs. 10, 11; pl. xxii, figs. 5—7.
- — — Morris, 1854. Catalogue of British Fossils, 2nd ed., p. 81.
- — — RECTILINEUS, *McCoy*, 1854. Contrib. Brit. Pal., p. 55.
- — — — Morris, 1854. Catalogue of British Fossils, 2nd ed., p. 81.
- Astrogonium PARKINSONI, Dujardin and Hupé, 1862. Hist. Nat. Zooph. Échin. (Suites à Buffon), p. 399.
- — — RECTILINEUM, Dujardin and Hupé, 1862. Ibid., p. 400.
- GONIASTER (GONIODISCUS) PARKINSONI, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 365, pl. xxiv, figs. 10, 11; pl. xxv, figs. 5—7.
- PENTAGONASTER RECTILINEUS, Woods, 1891. Catalogue of the Type Fossils in the Woodwardian Museum, Cambridge, p. 36.

Body of medium size. General form depressed. Abactinal surface flat, with a tendency, however, for the extremity of the rays to be slightly upturned; as found in the fossil state the area occupied by the abactinal plates is usually at a lower level than the marginal plates, which leads to the assumption that the abactinal floor had collapsed or fallen to a certain extent on the death of the animal. Actinal surface slightly convex. Marginal contour pentagonal, with slightly lunate sides, the curvature being often flattened at right angles to the median interradial line. The major radius measures about one-third more than the minor radius, and frequently less than one-third; the rays are consequently very feebly produced. Margin thick and well rounded.

The supero-marginal plates are four in number, counting from the median interradial line to the extremity, or eight from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk of uniform breadth throughout, which measures about 9 mm. at the median interradial line in an example whose minor radius measures 30 mm. Excepting the ultimate paired plates all the supero-marginal plates are of equal size, the breadth being about

twice the length, the actual measurements in the specimen under notice being, length 4·75 mm. and breadth 9·5 mm. respectively, *i.e.* as 1 : 2. The abactinal surface of these plates is distinctly convex, with a slight depression along their margins of juncture, formed by a well-defined bevel along the sides and adcentral end. The general surface of the whole series is well rounded, the curvature being regular and uninterrupted between the adcentral margin of the plate and the margin in the lateral wall adjacent to the infero-marginal plates. The height of the plates as seen in the margin is a little greater than their length, and there is no diminution in height as the plates approach the extremity of the ray—in fact, the ultimate paired plate is not unfrequently higher than the other plates in consequence of a tendency to become gibbous on its abactinal surface. The whole superficies of the plates is covered with small, widely spaced, equidistant, uniform punctations, and there is a depressed border along the margin of the plate, varying slightly in breadth in different examples, covered with much smaller and closely crowded punctations, upon which much smaller granules than those upon the median area of the plate were originally borne. Traces of these granules may occasionally be found *in situ*.

The ultimate paired plate is larger than any of the other supero-marginal plates, and is of a different shape. It is subtriangular in form as seen from above, and one margin touches the corresponding plate of the adjacent side of the disk throughout, the junction coinciding with the median radial line of the disk. The length of this margin of the plate is subequal to or only slightly greater than the breadth of the preceding marginal plates. In small specimens the subequal measures are the rule, whilst in larger examples the plate becomes more elongate and produced in the direction of the prolongation of the ray. When viewed in the margin of the test the form of the ultimate plate strikingly resembles that of the carapace of some Coleoptera. The length of the plate in this aspect, measured from its outer extremity to the margin adjacent to the penultimate plate, is in small and medium sized specimens about once and a half the length of the other marginal plates, but in large examples it may be as much as, or even exceed, twice their length. The surface of the ultimate plate bears a similar ornamentation to that on the other supero-marginal plates.

The odd terminal plate is very small, appearing externally when denuded of granules like a truncate cylinder, having a fanciful resemblance to a cannon projecting from a porthole. This plate seems to be very rarely preserved *in situ* in the fossil state. In a remarkably good specimen belonging to the British Museum Collection (marked “E 2034”) (see Pl. XVI, figs. 2 *a*, 2 *b*) each of the terminal plates preserved bears at its outer truncate extremity a single horizontally placed entrenched pedicellaria. Whether this regularly placed pedicellaria is always present on the odd terminal plate in this species I am unable to say.

The abactinal area of the disk within the boundary of the marginal plates is covered with small sub-regular plates or paxillar tabulæ, an hexagonal form predominating especially in the radial regions; and a small but distinct diminution in size takes place as the plates approach the margin of the disk. All the plates have their surface marked with minute, shallow, and closely placed punctations—the impressions of the attachment of the granules previously present. The primary basal plates are larger than any of the other abactinal plates, and they are well shown in several of the drawings illustrative of this species (see Pl. X, figs. 1, 2 *a*). Occasional plates bear small entrenched pedicellariæ, the normal form consisting of a small, central, lipped foramen with a lateral trench on each side. It frequently happens, however, that the organ exhibits a more complex development, and assumes a stellate form in consequence of the presence of additional trenches—five or six being not an unusual number—which radiate from the central foramen; the whole being placed on a small hemispherical elevation, and producing an appearance shown on Pl. X, fig. 2 *d*.

The madreporiform body is large and subtriangular in outline; and its surface is sculptured by very fine striations which radiate from the centre to the margin, with more or less wavy lines here and there (see Pl. X, fig. 2 *c*). The margin of the plate is surrounded by three large plates, one on the adcentral side of the madreporite towards which it presents a straight suture; the other two plates are on the remaining sides of the triangular body, and they have a concave curve directed towards the madreporite to correspond with the convexity of its sides. The position of the madreporite is nearer the centre of the disk than the margin.

The infero-marginal plates are seven in number, counting from the median interradial line to the extremity—that is to say, there are fourteen for the whole side of the disk, as against eight in the supero-marginal series. The length of the three innermost plates on each side of the median interradial line is equal to that of the superior series, but there are four infero-marginal plates corresponding to the large ultimate supero-marginal. As seen in the lateral wall of the disk the height of the infero-marginal plates is less than that of the supero-marginal series. The breadth of these plates adjacent to the median interradial line on the actinal surface is 7·5 mm. in an example whose major radius measures 36·5 mm. and the minor radius 27·5 mm. The breadth of the marginal border rapidly diminishes towards the extremity of the ray. The surface of the plates is ornamented in a precisely similar manner to that of the supero-marginal plates. A narrow border of smaller granulation is also present round the whole margin of the plate, similar in all respects to that already described in the case of the superior series of plates.

The adambulacral plates are small, about or nearly twice as broad as long, and

their surface is traversed by four or five ridges running parallel to the ambulacral furrow, with punctures upon which the spinelets composing the armature were articulated. There were four or five spinelets in each lineal series. The spinelets are short, their length being about equal to the length of the plate, stumpy compressed, slightly tapering and rounded at the extremity; and all appear to have been uniform.

The actinal intermediate plates are rather large for the genus; those adjacent to the adambulacral plates are pentagonal in form, but elsewhere they are subhexagonal, or perhaps more correctly polygonal. The plates are very large on the inner portion of the area, but diminish greatly in size at the outer margin of the disk adjacent to the marginal plates. The surface of the intermediate plates is entirely covered with small, equidistant punctations, upon which a uniform close granulation was previously attached. Remains of this granulation are still occasionally to be seen *in situ* on plates here and there in the example under notice. Entrenched pedicellariæ similar to those above described on the plates of the abactinal surface occur on a number of the plates in the series adjacent to the adambulacral plates, but the organ does not appear to diverge, or only very rarely, from the normal form of a central foramen and two lateral trenches.

Dimensions.—In the specimen figured on Pl. X, fig. 2*a*, the major radius is 38 mm., and the minor radius 30 mm. Other examples have the following approximate measurements: $R = 35$ mm., $r = 27$ mm.; $R = 43$ mm., $r = 34$ mm. The diameter of the disk ($R + r$) in well-grown tests ranges, therefore, from 60 mm. to 80 mm. The thickness of the margin is about 11·75 mm.

Locality and Stratigraphical Position.—All the examples figured in this Monograph were obtained from the Upper Chalk, near Bromley. The species is a characteristic Upper Chalk fossil in the south of England, and has been found in beds of that age at Brighton, Charlton, Gravesend, Kent, and other localities. It is stated by Forbes to occur in the Lower Chalk of Sussex, but I have not seen any examples from that horizon.

History.—A fossil starfish which has been generally considered to be this species was figured by Parkinson in his ‘Organic Remains of a Former World,’ vol. iii, pl. i, fig. 3, but it was referred by that author to the *Pentagonaster regularis* of Linck. The last named has, however, been supposed to be a recent species, but the type has unfortunately been lost, and the form has not subsequently been recognised definitely. Apart from this the fossil starfishes now under notice are certainly distinct from the form indicated by Linck’s figure, and this view was taken by Forbes, who named the species after Parkinson in his memoir ‘On the Asteriadæ found fossil in British Strata,’ and figures of the

fossils so named by him were given in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' London, 1850. One, if not more, of the specimens delineated in that work is now preserved in the British Museum.

Variations.—In some examples the breadth of the border formed by the supero-marginal plates on the abactinal surface is greater in relation to the disk-area than in others, and this variety was noted by Forbes ('Mem. Geol. Surv.', vol. ii, p. 472). I have not been able to establish the relation of this modification with any other permanent morphological character, nor to associate it with any special locality or stratum, and I am therefore led to consider, for the present at least, that the variation in question is one affecting individual examples of the species independently of other structural modifications which would warrant recognition by name.

Two other variations are to be noted in this species which are superficially much more striking, and either of them would, if only isolated examples were known, lend a strong temptation to the separation of their possessor from the normal form of the species. One of the variations in question affects the large ultimate paired supero-marginal plates. On comparing the examples drawn on Pl. X, fig. 1 and fig. 2 *a*, with fig. 1 *a*, Pl. XII, and fig. 1 *a*, Pl. XI, it will be seen that the ultimate plates are relatively much larger than the adjacent supero-marginal plates and are more produced at the extremity; whilst in the specimen delineated in fig. 2 *a*, Pl. XI, this modification is carried to such an extent that at first sight it would appear scarcely possible to believe that this fossil belongs to the same species as, for example, fig. 2 *a*, Pl. X. I have, however, been unable to find any other constant variation from what has been considered the typical form of *Metopaster Parkinsoni* associated with this modification in the size and shape of the ultimate plates; and as the most complete gradation between the two extremes may be traced in the splendid series of specimens now preserved in the British Museum, all obtained from the same locality and the same horizon, no reasonable doubt can be entertained that the variation in question is of a comparatively trivial character, affecting the individual independently, and that it is not stamped by correlation with other structural modification with sufficient importance to justify the forms being separated from the species, or even a name being given to the variety. All the examples referred to in the foregoing remarks and figured in the plates accompanying this Memoir are from the Upper Chalk, and were obtained from the same locality near Bromley.

The fine specimen with large and greatly produced ultimate plates drawn on Pl. XI, fig. 2 *a*, is also an example of the second variation in the structure of this species, to which I have alluded. This manifests itself in the presence of an

additional supero-marginal plate. It will be seen that there are nine supero-marginal plates, exclusive of the terminals (or so-called oculars) on each side of the pentagonal disk. At first sight the presence of this odd intermediate marginal plate in association with the strikingly modified ultimate plates found in this example would appear sufficient to indicate a well-marked variety, if not actually a distinct species. A careful examination of the collection in the British Museum shows, however, that this assumption is untenable, for in another example (which bears the Museum number "46,765"), which also possesses an odd intermediate marginal plate on two of its sides, the ultimate plates are in no way specially abnormal in their form or size. The presence of the additional supero-marginal plate would in this case, therefore, appear to be only an occasional variation, and, so far as I am able to detect, occurring independently of other structural modifications. I have observed no differences either in the proportions or the ornamentation of the intermediate marginal plates worthy of remark. This view is strengthened, if not absolutely confirmed, by the presence in another specimen (British Museum number "46,796"), drawn on Pl. XII, fig. 1 *a*, of nine supero-marginal plates on two sides only of the disk, the remaining three sides having the normal number of eight marginal plates. In this example the ultimate plates are distinctly larger and more produced than in the truly normal forms of the species, but it will be noticed that their development is unequal, as is also the case in No. "46,765;" in other words, in three of the rays one of the ultimate plates is smaller than the corresponding ultimate plate to which it is adjacent. The two sides which have an additional marginal plate are also the sides which have one of the smaller ultimate plates, and the inference naturally follows that the additional plate is to balance or compensate for the smaller size of the ultimate plate; and I am inclined to think that the additional plate is not in this case a true *odd interradial* marginal plate at all, such as occurs in *Gnathaster*, Sladen, but that it is only a supplementary plate formed because its primitive or embryonic rudiment has not been included in the series merged together during development to form the structurally compound ultimate plate. That these ultimate plates are compound, or formed by the union of several embryonic plates, there is in my opinion little doubt when regard is had to the embryonic history of the ultimate plate and the associated infero-marginal plates.

2. METOPASTER MANTELLI, *Forbes*, sp. Pl. XIII, figs. 2a—4b; *op. cit.* p. 87, t. 1.

PENTAGONASTER SEMILUNATUS.

Parkinson, 1811. Organic Remains of a
Former World, vol. iii, p. 3,
pl. i, fig. 1 (*non Linck*).

? GONIASTER SEMILUNATA.

Mantell, 1844. The Medals of Creation,
London, vol. i, p. 338, lign. 75
(*non Linck*, ? *nec Parkinson*)

GONIASTER (*GONIODISCUS*) MANTELLI, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 472.

Forbes, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 332, pl. xxiii, figs. 11, 12.

? — MANTELLI

Morris, 1854. Catalogue of British Fossils, 2nd ed., p. 81.

Astrogonium Mantelli

Dujardin and Hupé, 1862. Hist. Nat.
Zooph. Echin. (Suites à Buffon), p. 399.

GONIASTER (*GONIODISCUS*) MANTELLI, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 366, pl. xxvi, figs. 11, 12.

Body of medium or rather small size. General form depressed. Abactinal surface flat, with the area circumscribed by the supero-marginal plates plain and rather sunken below the level of the median convexity of the border formed by these plates. Actinal surface plain, or may be a little convex in consequence of a tendency to a slight upturning of the rays in some examples. Marginal contour pentagonal, with sides faintly lunate, or in small examples they may be almost straight. The major radius measures scarcely one-third more than the minor radius. Margin rather thin, but well rounded.

The supero-marginal plates are four in number, counting from the median interradial line to the extremity, or eight from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. In one example, which is figured by Forbes in Dixon's 'Geology of Sussex',

there would appear to be only seven plates on the entire side, but only one radial angle is preserved intact, and much displacement of plates has occurred. The circumstance is in any case of comparatively trifling importance. The supero-marginal plates form a conspicuous and moderately broad border to the abactinal area of the disk, of uniform breadth throughout, and measuring about 6 mm. at the median interradial line in an example whose minor radius measures about 25 mm.

Excepting the ultimate paired plate all the supero-marginal plates are nearly subequal in size; the plates, however, adjacent to the median interradial line are slightly longer in relation to their breadth than those adjacent to the ultimate paired plate. The plates adjacent to the median interradial line have the appearance of being nearly square in outline as seen from above, the actual dimensions in the specimen under notice, whose side measures 38 mm., being length 5 mm., and breadth 6 mm. In a smaller example, with a side measurement of 29·5 mm., the corresponding plate is 3·5 mm. long and 4·5 mm. broad. In Forbes's type the measurements are, length 3·75 mm., and breadth 5 mm.

The abactinal surface of the supero-marginal plates is slightly tumid, and the general surface of the whole series forms a well-rounded regular curve from the adcentral margin to the margin in the lateral wall adjacent to the infero-marginal plates. The height of the plates as seen in the margin is less than their length, the actual measurement being about 3 mm. Their abactinal contour is distinctly convex, but not gibbous. The whole superficies of the plates is covered with small, widely spaced, equidistant, uniform punctations. In some examples which have been subjected to much weathering the punctations are almost obliterated, as in the case of the fine specimen shown on Pl. XIII, fig. 2 *a*. A narrow depressed border surrounds the margin of the plate, bearing very small, closely crowded punctations, those adjacent to the main or median area being in serial arrangement. Occasionally a small entrenched pedicellaria may be detected on the median area of the plate (see Pl. XIII, fig. 2 *b*).

The ultimate paired plate is small and triangular in outline as seen from above, and one margin touches the corresponding plate of the adjacent side of the disk throughout, the junction coinciding with the median radial line of the disk. The length of the plate—that is to say, of the side of the plate which falls in the margin of the disk—is a trifle greater than the length of the largest supero-marginal plate, measuring in the example under notice nearly 5·5 mm., whereas the breadth of the plate, or measurement of the side adjacent to the penultimate supero-marginal plate, is not more than 5 mm. Near the outer or apical extremity of this plate when seen from above there is frequently a more or less strongly developed tendency to gibbosity present.

The abactinal area of the disk within the boundary of the marginal plates is

covered with small subregular hexagonal plates or paxillar tabulae, which are, however, comparatively large for the size of the species. The primary apical plates are large and conspicuous, and all the plates in the central area of the disk and in the interradial areas are considerably larger than elsewhere; all diminish in size as they approach the margin of the disk. All the plates have their surface covered with a small, uniform, closely placed granulation, in which an indefinite subcircular arrangement in relation to the centre of the plate is discernible (see Pl. XIII, fig. 2 d).

The madreporiform body is small and subtriangular in outline; its surface is sculptured by fine striations which radiate from the centre to the margin. The madreporite is usually enclosed by three plates, but four may be present in consequence of the division or retarded development of one of them, as is the case in the example figured on Pl. XIII, fig. 2 c. The position of the madreporite is rather nearer the centre of the disk than the margin.

The infero-marginal plates are at least six in number, counting from the median interradial line to the extremity,—that is to say, there are twelve (or perhaps more) for the whole side of the disk, as against eight in the supero-marginal series. The length of the three innermost plates on each side of the median interradial line is equal to that of the superior series, but there are three infero-marginal plates corresponding to the ultimate paired supero-marginal. As seen in the lateral wall of the disk, the height of the infero-marginal plates is greater than that of the supero-marginal series. The breadth of these plates, adjacent to the median interradial line on the actinal surface, is 5 mm. in an example whose minor radius measures about 15 mm. The breadth of the marginal border appears to be well maintained till near the extremity. The surface of the plates is ornamented in a similar manner to that of the supero-marginal plates, excepting that the punctations on the main area are rather more numerous, and that the finely punctate depressed border round the margin of the plate is much broader than in the plates of the superior series; the border is broader on the adcentral margin of the plate than elsewhere. (Compare figs. 3 b and 4 b on Pl. XIII.)

The adambulacral plates appear to be comparatively small, but their preservation in the examples examined is not sufficiently good to permit of description.

The actinal intermediate plates, which are small and hexagonal, are covered with small, closely crowded, uniform granules. All are much displaced in the specimens under notice.

Dimensions.—In the example figured on Pl. XIII, fig. 2 a, the major radius is about 32 mm., and the minor radius about 25 mm. The length of the side is 38 mm. The thickness of the margin is about 8 mm. In Forbes's type (Pl. XIII, fig. 3 a) the major radius is about 20 mm., and the minor radius about 15.5 mm.;

the length of the side about 25·5 mm. In a very finely preserved cast from the Upper Cretaceous beds of Haldon the length of the side is 29·5 mm.

Locality and Stratigraphical Position.—All the examples of this form with which I am acquainted are from the Upper Chalk. One of Forbes's type is from Gravesend, but the locality of the other is not recorded. The large example figured on Pl. XIII, fig. 2 *a*, is from the Upper Chalk near Bromley.

An extremely well-preserved cast in flint from the Upper Cretaceous beds of Haldon (Devonshire) is in the collection of the Albert Museum, Exeter; and a cast of this example may be seen in the Museum of the Geological Survey, Jermyn Street.

History.—This form appears to have been first recognised by Parkinson, who erroneously referred it to the *Pentagonaster semilunatus* of Linck. The latter is a well-known recent species, and quite distinct from the fossil under consideration. Mantell, following Parkinson's determination, referred to the form under the name of *Goniaster semilunata*. Forbes was the first to indicate that these views of his predecessors were incorrect, and diagnosed the species in his memoir 'On the Asteriadæ found fossil in British Strata' under the name of *Goniaster (Gonio-discus) Mantelli*; and figures of two examples were subsequently given in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' London, 1850. Both these specimens are now preserved in the British Museum. Careful drawings of each fossil are given on Pl. XIII, figs. 3 *a* and 4 *a*.

Remarks.—It is not without hesitation that I maintain this species of Forbes's as independent from *Metopaster Parkinsoni*. For the present, however, I consider it to be distinguished by the smaller size, the comparative squareness of the supero-marginal plates, the small size of the ultimate paired plates, as well as by the character of the ornamentation of the supero-marginal plates and of the abactinal plates. Whether a more extensive series of specimens will break down or uphold these distinctions I do not feel prepared to say. It is undoubtedly that the two forms are very nearly allied.

I feel considerable doubt as to whether one of Forbes's types—that shown in Pl. XIII, fig. 4 *a*—really belongs to the same species as the examples illustrated in figs. 2 *a* and 3 *a* on the same plate.

3. METOPASTER BOWERBANKII, *Forbes*, sp. Pl. XV, figs. 2a—2d; Pl. XVI, figs. 1a—1d.

GONIASTER (GONIODISCUS) BOWERBANKII, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 473.

— — — *Forbes*, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 333, pl. xxii, fig. 4.

— — — *Morris*, 1854. Catalogue of British Fossils, 2nd ed., p. 81.

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

GONIASTER (GONIODISCUS) BOWERBANKII, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 366, pl. xxv, fig. 4.

Body of medium or rather large size. General form depressed. Abactinal surface flat; actinal surface also flat, or with a slight tendency to become convex. Marginal contour pentagonal, with a very small amount of lunation in the sides. Margin thick and well rounded.

The supero-marginal plates are five in number counting from the median interradial line to the extremity, or ten from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk of uniform breadth throughout, which measures about 8.5 mm. at the median interradial line in the type-specimen described by Forbes from the collection of the late Dr. Bowerbank. Excepting the ultimate paired plate all the supero-marginal plates are of equal size. They are short and broad, the breadth being nearly twice and a half the length, the actual measurements in the type being length 3.5 mm. or a trifle more, and breadth 8.5 mm., in which case the dimensions are in the proportion of 7 : 17. The abactinal surface of the plates is slightly convex along the direction of the breadth, sufficient to define each plate distinctly. The general surface of the whole series is gently arched towards the margin adjacent to the infero-marginal plates. The height of the plates as seen in the margin is about 6 mm., and there is scarcely any or only the slightest diminution in height as the plates approach

the extremity of the ray, and the ultimate paired plate is not prominent or gibbous abactinally. The whole superficies of the supero-marginal plates is covered with small, widely spaced, equidistant, uniform punctations, and along the entire margin of the plate is a very narrow and deeply depressed border of fairly uniform breadth, covered with much smaller and closely crowded punctations, upon which much smaller granules than those which occupied the central area of the plate were originally borne. One or two or even three small entrenched pedicellariæ may be present on the central area of a plate, irregularly disposed.

The ultimate paired plate is triangular in form as seen from above. The margin or side which represents its length and coincides with the margin of the disk measures a little more than once and a half or nearly twice the length of the adjacent supero-marginal plates; and the margin representing the breadth of the plate which abuts on the penultimate supero-marginal plate is shorter than the margin of the latter plate. The remaining side of the plate which touches the corresponding ultimate plate of the adjacent side of the disk, and falls in the median radial line of the disk, is subequal to or even slightly shorter than the breadth of the preceding marginal plates. The ultimate plate in this species is not elongated, and no prolongation beyond the normal pentagonal contour of the disk occurs in the extension of the median radial line. The surface of the ultimate plate is covered with punctations and margined with a finer and closely crowded series precisely similar to those on the other supero-marginal plates.

The abactinal area of the disk within the boundary of the marginal plates is covered with small, subregular, hexagonal plates or paxillar tabulæ, which have their surface marked with minute, low, subhemispherical, and closely placed miliary granulations, which do not, however, extend quite to the margins of the plates. A number of the plates bear in the centre a rather large entrenched pedicellaria, consisting of a central foramen and normally two lateral fossæ, and there is usually a circular series of coalesced granules in which the fossæ are included, which imparts a very characteristic appearance to the organ in this species (see Pl. XVI, fig. 1 d).

The following description of the characters of the actinal area of the disk of this species is taken from an example preserved in the Museum of Practical Geology, Jermyn Street, and figures of which are given on Pl. XV, figs. 2 a—2 d.

The infero-marginal plates are eight in number counting from the median interradial line to the extremity,—that is to say, there are sixteen for the whole side of the disk, as against ten in the supero-marginal series. The length of the four innermost plates on each side of the median interradial line is slightly greater than that of the corresponding plates of the supero-marginal series; and there are four infero-marginal plates much smaller than those preceding, corresponding

to the ultimate supero-marginal plate. As seen in the lateral wall of the disk the height of the infero-marginal plates is slightly greater than that of the supero-marginal series. The breadth of these plates adjacent to the median interradial line on the actinal surface is 6 mm., or even a little more in an example whose major radius measures 37 mm. and the minor radius 27 mm. The breadth of the marginal border rapidly diminishes towards the extremity of the ray. The surface of the infero-marginal plates is ornamented with extremely small and closely crowded punctations, upon which traces of a minute, closely crowded, and uniform granulation are preserved here and there.

The adambulacral plates are small, about twice as broad as long, and their surface is traversed by about three ridges, bearing punctures, running parallel to the ambulacral furrow, upon which the spinelets composing the adambulacral armature were articulated. There were about five or six spinelets in each lineal series.

The mouth-plates are regularly triangular, about twice and a half as long as broad, and the two adjacent plates which constitute a pair form together a regular rhomboid or lozenge-shaped figure. Their surface is covered with small, crowded, rather coarse, irregularly disposed tubercles or granules (see Pl. XV, fig. 2 d).

The actinal intermediate plates are fairly large, and there is a distinct diminution in size towards the outer margin of the disk adjacent to the marginal plates. The plates adjacent to the adambulacral plates are pentagonal, but a subhexagonal or polygonal form elsewhere is the rule, with comparatively little irregularity. The surface of the actinal intermediate plates is entirely covered with very small equidistant punctations, upon which a uniform close granulation was previously borne. Occasional small excavate pedicellariæ are present here and there, the lateral fossæ being slightly curved.

Dimensions.—The type specimen is unfortunately fragmentary, and the radial dimensions cannot be given. The length of one side of the disk, measured from the tip of one ray to the tip of the adjacent ray, is about 41 mm.; the breadth of the supero-marginal plates adjacent to the median interradial line is 9 mm.; and the thickness of the margin is about 12 mm.

In the fine example preserved in the Museum of Practical Geology, Jermyn Street, figured on Pl. XV, fig. 2 a, the major radius measures 37 mm., and the minor radius 27 mm.; the length of one side of the disk measured about 42 mm., or probably rather more when complete; the breadth of the infero-marginal plates adjacent to the median interradial line is 6 mm.; and the thickness of the margin is 8.5 mm.

Locality and Stratigraphical Position.—The type specimen is stated by Forbes

to have been obtained from the Upper Chalk of Kent, but no indication of locality is now preserved on the label. The example belonging to the Museum of Practical Geology is from the Upper Chalk of Gravesend.

History.—The type of this species, which was described by Forbes in his memoir ‘On the Asteriadæ found fossil in British Strata’ (‘Mem. Geol. Surv.,’ vol. ii, p. 473, 1848), originally formed part of Dr. Bowerbank’s Collection, and was first figured by Forbes in Dixon’s ‘Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,’ London, 1850, pl. xxii, fig. 4. That specimen is now preserved in the British Museum, where it bears the register number “E 2578.” An accurate drawing of the type is given on Pl. XVI, fig. 1 *a*, of the present work.

4. METOPASTER ZONATUS, *Sladen.* Pl. XII, figs. 2 *a*—2 *c*.

Body of small or medium size. General form depressed. Abactinal surface in the fossil condition, as at present known, essentially concave in consequence of the conspicuously upturned extremities of the rays. Actinal surface conformably convex. Marginal contour pentagonal, with the radial angles slightly produced and obtusely rounded, and the sides distinctly lunate. The major radius measures nearly one-half more than the minor radius, or in the proportion of 3 : 2 approximately; the actual dimensions in the example under notice being $R = 27$ mm., $r = 19$ mm. approximately. Margin very thick in relation to the size of the disk, and regularly rounded.

The supero-marginal plates are four in number, counting from the median interradial line to the extremity, or eight from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or “ocular” plate in each case. They form a broad border to the abactinal surface of the disk, of uniform breadth throughout, which measures about 8 mm. at the median interradial line, in an example whose minor radius measures 19 mm. Excepting the ultimate paired plate all the supero-marginal plates are subequal, the breadth being nearly three times the length, the actual measurements in the example under notice being length 2·75—3 mm., and breadth about 8 mm. The abactinal surface of the plates is distinctly convex along the median line of breadth, by which means each plate is conspicuously defined. The general surface of the whole supero-marginal series between the two ultimate plates is regularly rounded, and forms an uninter-

rupted regular curve between the adcentral margin of the plate and the margin in the lateral wall adjacent to the infero-marginal plates. The height of the plates as seen in the lateral view of the disk is greater than their length, and there is an apparent increase in height as the plates approach the extremity of the ray, the ultimate plate being still higher and distinctly tumid (see Pl. XII, fig. 2 b). The whole superficies of the plates is covered with small, widely spaced, equidistant, uniform punctations; and there is a narrow depressed border surrounding the margin of the plate with much smaller and closely crowded punctations, upon which minute miliary granules were previously borne.

The ultimate paired plate is much larger than any of the other supero-marginal plates, its length as measured on the outer margin being more than twice the length of the other supero-marginal plates. Its breadth is about equal to that of the adjacent supero-marginal plate. It is subtriangular in form as seen from above, and the line of junction with the corresponding companion plate of the adjacent side of the disk is complete throughout, and coincides with the median radial line. The convexity of the plate falls in a line parallel and adjacent to this margin of the plate, and its height is greatest there. From this convexity the surface slopes gradually and regularly in conformity to the curve of the superficies of the other supero-marginal plates. The actual dimensions of the ultimate plate in the example under notice are, length 7 mm., breadth 7 mm.; greatest height as seen in the marginal view, about 8.5 mm. The surface of the ultimate plate is marked with a precisely similar ornamentation to that on the other supero-marginal plates.

The odd terminal plate is very small, and though only traces are present in the type it is well preserved in other examples. It is prominent, cylindrical, and abruptly truncate, resembling in all respects the form described in *Metopaster Parkinsoni*.

The madreporiform body, which is only partially exposed in the example under notice, is apparently subtriangular in outline, and is marked with very fine centrifugally radiating striations (see Pl. XII, fig. 2 c).

The infero-marginal plates are seven in number, counting from the median interradial line to the extremity,—that is to say, there are fourteen for the whole side of the disk, as against eight in the supero-marginal series. The length of the three innermost plates on each side of the median interradial line is subequal to that of the superior series, but their height as seen in the marginal view of the disk is much greater, the thickness of the whole margin, i. e. both series of plates together, being 10 mm. in an example whose minor radius is 19 mm. Four plates underlie the superior ultimate plate, the last two being very small and triangular in form. All the four are adjacent to the adambulacral series of plates. The ornamentation or surface-marking of the infero-marginal plates is precisely similar to that of the supero-marginal series.

Dimensions.—In the example figured on Pl. XII, fig. 2a, the major radius is 27 mm. and the minor radius about 19 mm., the thickness of the margin 10 mm.

Locality and Stratigraphical Position.—The figured example is from the Upper Chalk near Bromley. A number of other examples of this species are in the collection of the British Museum, all from the Upper Chalk, and most of them from the same locality, the locality of the remainder being not recorded.

Remarks.—I was at first somewhat in doubt as to whether to rank this form as a variety of *Metopaster Parkinsoni*, or as a distinct species. I have taken the latter course. Although there are many points of resemblance in general structure, as well as in various details when considered independently, the facies of this form is so distinct from that of *Metopaster Parkinsoni*, and is so readily recognisable, that there seems to me full justification for considering *Metopaster zonatus* specifically distinct. The great breadth of the supero-marginal plates as compared with their length, the form and character of the ultimate plates, the great thickness of the margin, and the relative proportions of the marginal plates, as well as the general habit of the abactinal surface, apart either from the individual characteristics of the plates independently or from other special details, are amply sufficient to distinguish the form from its nearest ally, *Metopaster Parkinsoni*.

5. METOPASTER UNCATUS, *Forbes*, sp. Pl. XI, figs. 3a, 3b; Pl. XIV, figs. 1a—3; Pl. XV, figs. 1a, 1b.

GONIASTER (GONIODISCUS) UNCATUS, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 472.

— — — *Forbes*, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 331, pl. xxi, figs. 4, 5, 8.

— — — *Morris*, 1854. Catalogue of British Fossils, 2nd ed., p. 81.

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

GONIASTER (GONIODISCUS) UNCATUS, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 365, pl. xxiv, figs. 4, 5, 8.

Body rather small, or at most only of medium size. General form depressed. Abactinal surface flat, or with a tendency for the rays to be slightly directed upward at the extremities. Actinal surface slightly convex. Marginal contour pentagonal, with the sides slightly lunate, though the curvature is often more or less flattened; the extremity of the rays is only slightly produced. The major radius measures about one-third more than the minor radius, the major dimension being proportionately rather greater in large tests than in small ones. The margin is thick, and the lateral wall has more of a precipitous than a rounded character, although the infero-marginal plates are well rounded on the actinal surface.

The supero-marginal plates are three in number, counting from the median interradial line to the extremity, or six from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk, of uniform breadth throughout, which measures about 7 mm. at the median interradial line in an example whose major radius measures 36·5 mm. and minor radius 27 mm. (Pl. XIV, fig. 2 *a*). Excepting the ultimate paired plates, the four intermediate supero-marginal plates on each side of the disk are of equal size, the breadth being about once and a half the length, the actual measurements in the specimen under notice being length 5 mm., and breadth 7 mm. The abactinal surface of these plates is tumidly convex, while the lateral wall is plane and vertical, and the abactinal tumidity commences abruptly at a little distance from the adcentral margin of the plate, which leaves a small level area at the rounded end of the plate abutting on the abactinal plates or paxillar tabulæ. On the surface of this level band near the adcentral margin, and forming a more or less definite series running parallel to it, are three or four irregular tubercular eminences or granules, but very indistinct and more or less weatherworn (see Pl. XIV, fig. 2 *c*). The entire margin of the plate is surrounded by a very narrow depressed border, with very fine, closely crowded, uniserially disposed punctations, upon which a small miliary granulation was previously borne. The whole general superficies of the plate is smooth and weatherworn in every example I have seen. The height of the plates as seen in the margin is as great as or even slightly greater than their length, and the prominently tumid character of the plates abactinally causes them to appear in the lateral view somewhat like truncate cones abruptly rounded (see Pl. XIV, fig. 2 *b*).

The ultimate paired plate is larger and longer than any of the other plates, and is of a different and very peculiar shape. It is subtriangular in form as seen from above, produced and pointed at the extremity, and to a certain extent recalls the form of a ploughshare or coulter in consequence of a peculiar nipped-in appearance caused by the extension of a tumid region which runs parallel to the

outer margin and rises abruptly from a level area which occupies the inner half of the plate along the margin touching the corresponding plate of the adjacent ray, —the line of junction of the two plates coinciding with the median radial line. The length of the ultimate plate is nearly twice that of the other marginal plates, measuring 9·25 mm. in an example whose major radius is 36·5 mm. and minor radius 27 mm. As seen in the marginal view of the test, the ultimate is not higher or more tumid than the other marginal plates (see Pl. XIV, fig. 2 b). The outer margin of the ultimate plate has a slight concave curvature, and the inner margin adjacent to the corresponding plate is curved convexly towards the proximal end of the plate. In consequence of this rounding the two ultimate plates in a pair do not unite throughout their entire length, but are separated by a small notch at the end of the suture adjacent to the abactinal paxillar area of the disk. On the small level area of the ultimate plate are a number of small irregular tubercular eminences ; four or five larger than the others form a sort of series parallel to the rounded margin, and a longitudinal series of eight or nine much smaller miliary granules run along the flank of the longitudinal tumidity of the plate ; and several additional granules of intermediate size may be present in the space between the two series just described. Excepting these granules, the surface of the ultimate plate is smooth like that of the other supero-marginal plates.

The abactinal area of the disk within the boundary of the marginal plates is covered with small subregular plates or paxillar tabulæ, an hexagonal form predominating. The plates in the median interradial areas are much larger than the other plates on the disk, and a marked diminution in size in all the plates takes place as they approach the margin. All the plates have their surface marked with a very fine granulation. Small entrenched pedicellariæ are occasionally present, but there appear to have been very few.

The primary basal plates are larger than any of the other abactinal plates. They are well seen in an example from the Upper Chalk of Kent, in which the inner side of the abactinal wall is exposed by the removal of the actinal floor and ambulacral plates. This specimen, which is preserved in the British Museum, and bears the registration number "35,496," is drawn on Pl. XI, fig. 3 a. The example in question is further interesting in showing that the plates of the radial regions have stellate bases, whereas the larger plates of the interradial regions are sharply hexagonal, and fit closely to their adjacent plates (see fig. 3 b).

The madreporiform body is very small, and is subsagittiform or irregularly lozenge-shaped in outline ; in the example under notice it is embedded, all except two straight sides, in one large adcentrally placed basal plate (see Pl. XIV, fig. 2 d) ; the two straight sides are bounded each by one large plate. The surface of the madreporite is sculptured by very fine striations, which though more or less wavy are directed subparallel to the adcentral sides of the body.

The position of the madreporite is nearer the centre of the disk than the margin.

The infero-marginal plates are six in number, counting from the median interradial line to the extremity,—that is to say, there are twelve for the whole side of the disk, as against six in the supero-marginal series. The length of the two innermost plates on each side of the median interradial line is subequal to that of the superior series, but the four succeeding infero-marginal plates are much shorter, and together correspond to the large ultimate supero-marginal plate. As seen in the lateral wall of the disk the height of the infero-marginal plates is very little more than one-half that of the superior series, the actual proportion in the specimen under notice being less than three-fifths. The breadth of the plates adjacent to the median interradial line on the actinal surface is 7·5 mm. in an example whose major radius measures 25 mm. and the minor radius 20 mm. The breadth of the marginal border diminishes so rapidly on each side of the median interradial line towards the extremities of the rays that the inner margin of the series of infero-marginal plates of each side of the disk is practically a sector of a circle. The surface of the plates is marked with small widely spaced punctations, and there is a narrow depressed border round the entire margin of the plate which is very finely punctate; the border is broader at the adcentral end of the plate and the adjacent corners than elsewhere.

The adambulacral plates are small, broader than long, and their surface is marked with about three oblique series, and an outer irregular group of fine punctations upon which the spinelets composing the armature of the plates were articulated. There are about six punctations in the innermost ridge or series adjacent to the ambulacral furrow. A few spinelets are still preserved in an example from the Upper Chalk near Bromley, from which this description is taken, which is in the British Museum collection, and bears the registration number, "E 2613." The spinelets are cylindrical, truncated, and do not appear to taper; and their length is about equal to the length of the plates.

The actinal intermediate plates are rhomboid and hexagonal or polygonal in form, and their surface is entirely covered with small equidistant punctations, upon which small uniform granules were previously attached. Remains of this granulation are occasionally to be found preserved *in situ*, and may be seen in the example referred to in the preceding paragraph. Small entrenched pedicellariæ are occasionally present on the actinal intermediate plates.

Dimensions.—The example figured on Pl. XIV, fig. 2 *a*, has a major radius of 36·5 mm. and a minor radius of 27 mm. The length of the side is about 40 mm. Another specimen, shown in fig. 1 *a* on the same plate, is rather larger, the length of the side being about 45 mm. Much displacement of the plates has occurred in

this fossil, and the radial dimensions can only be calculated approximately. The specimen figured by Forbes, which I have unfortunately not been able to trace, is smaller than either of the above. The drawing represents a test with the major radius measuring about 25 mm., the minor radius 20 mm., and the length of the side about 28 mm. The figure of the actinal aspect of this example is reproduced on Pl. XIV, fig. 3, of this memoir.

Locality and Stratigraphical Position.—This is a well-known Upper-Chalk form. It is recorded by Forbes from Kent, Sussex, and Wiltshire. Specimens in the British Museum bear the localities of Charlton, Gravesend, Bromley, and “Kent.”

History.—This species, primarily described by Forbes in his memoir ‘On the Asteriadæ found fossil in British Strata,’ was first figured in Dixon’s ‘Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,’ London, 1850. The example which I consider must undoubtedly have been the type (Dixon, pl. xxi, figs. 4 and 5) I have hitherto unfortunately not been able to find. It is stated by Forbes to have formed part of the late Mr. Pearce’s collection, and to have been obtained from the Wiltshire Chalk. A badly drawn fragment (Dixon, pl. xxi, fig. 8) is preserved in the British Museum, but I do not consider it to be correctly referred to this species. In my opinion it belongs to a distinct species, *Metopaster cingulatus*, of which a description is given at p. 53.

The examples of this species which have been drawn on Pl. XIV are preserved in the British Museum.

6. METOPASTER SUBLUNATUS, *Forbes*, sp.

GONIASTER (GONIODISCUS) SUBLUNATUS, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 472.

— — — — — *Forbes*, 1850. In Dixon’s Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 331.

— — — — — *Morris*, 1854. Catalogue of British Fossils, 2nd ed., p. 81.

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

ASTROGONIUM SUBLUNATUM,

GONIASTER (GONIODISCUS) SUBLUNATUS, *Forbes*, 1878. In Dixon’s Geology of Sussex (new edition, Jones), p. 365.

This species was described by the late Professor Edward Forbes in Dixon's 'Geology of Sussex' in 1850 in the following words :

" Body pentagonal, with gently lunated sides. Superior intermediate marginal plates four, nearly equal, plain, smooth, or minutely punctate. Inferiors similar. Superior oculars mitrate, large, triangular, acuminated. Ossicula of disc punctate.

" Easily distinguished from the last species [*uncatus*] by its flattened marginals and from the next [*Hunteri*] by its lunated sides.

" Mus. Bowerbank, from the white chalk; also in the collection of the Geological Survey" (op. cit., p. 331).

No figure of the species has ever been published, and no record exists as to the specimen or specimens seen or used by Forbes as type. I have been unable to find any example from the Bowerbank Collection to which this name has been or can be applied; and the only examples which I have seen referred to this species at all are four fragmentary specimens now preserved in the Museum of the Geological Survey in Jermyn Street, and not more than two of these could have been in that collection in 1850.

After a careful study of these specimens I am bound to confess that I find no character by which they can be separated from *Metopaster uncatus*; and if the diagnosis is correct I am led to consider that I have certainly not seen Forbes's type. The *supero-marginal* plates in the specimens in question are *not* flattened, and cannot be said to differ in character from those of *Metopaster uncatus*.

A possible explanation suggests itself in the supposition that Forbes inadvertently mistook the actinal for the abactinal surface of the disk, a mistake which might easily be made by a less careful observer than the author of this species when dealing with a badly preserved fragment. If, however, what is really the actinal surface has been described as the abactinal surface the difficulty is practically solved, for the *infero-marginal* plates in the fragments under notice are "plain, smooth, or minutely punctate." That this is not an improbable explanation I would submit the following facts:—(1) that in the original diagnosis of 1848¹ Forbes states that the *infero-marginal* plates are unknown; (2) that in the diagnosis of 1850, given above, the *infero-marginal* plates are stated to be "similar" (to the *supero-marginals*); and (3) that notwithstanding these statements all the examples in the Geological Survey Collection are essentially actinal presentations of the disk, and therefore the *infero-marginal* plates are the plates

¹ The following is the diagnosis in full:—"G. corpore pentagonali, lateribus lunatis; *ossiculis lateralibus superioribus* 4, subæqualibus, planis, minutissime punctatis; *inferioribus?* *Ossiculis ocularibus superioribus* magnis, triangularibus, mitratis, tumidis, acuminatis." ('Mem. Geological Survey of Great Britain,' vol. ii, p. 472.)

conspicuously available for description. To my mind it follows with little doubt either that Forbes has described the infero-marginal plates as supero-marginals, or else that I have not seen his type specimens.

With my reverence for all that Forbes has written I prefer to leave the species as described by him, together with the record of these remarks, rather than strike a ruthless pen through any species created by so careful and accurate a worker. Time will pronounce the verdict.

I consider it quite unnecessary to figure any of the fragments, here referred to, as being in the Jermyn Street Collection. The differences they present as compared with a series of *Metopaster uncatus* do not in my opinion amount to even varietal rank, and are confined to the slightly less developed tumidity of the abactinal surface of the supero-marginal plates, and to the external contour of the mitrate ultimate paired supero-marginal plates, which is slightly convex marginally rather than incurved to produce the characteristically claw-shaped form of *Metopaster uncatus*. These are, in my opinion, merely individual differences.

7 METOPASTER CINGULATUS, Sladen. Pl. XIV, figs. 4 a—4 d.

Body of small size. General form depressed. Abactinal surface slightly concave, actinal surface flat. Marginal contour pentagonal, with the sides slightly lunate. The rays are not produced beyond the contour of a true pentagon, and the radial angles are not rounded. The major radius is proportional to the minor radius as 100 : 77·5, the actual dimensions in the example described being, major radius 20 mm., minor radius 15·5 mm., approximately. The margin is thick, and though well rounded has more or less of a precipitous character.

The supero-marginal plates are three in number, counting from the median interradial line to the extremity, or six from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk of uniform breadth throughout, which measures about 6·5 mm. at the median interradial line in an example whose diameter ($R + r$) measures from about 36 mm. to 37 mm.

Excepting the ultimate paired plates, the four intermediate supero-marginal plates on each side of the disk are approximately equal in size, the breadth being more than twice and a half the length, the actual dimensions in the example under notice being length 2·25 mm., and breadth 6·5 mm., in the plate adjacent to the median interradial line. The abactinal surface of these plates is distinctly tumid, a subtubercular eminence rising in the median third of the abactinal area of the plate. The slope of the tumidity descends gradually on the outer side, and

merges in the rounding of the high lateral wall of the plate. On the level area of the plate, which is consequently the inner or adcentral part of the surface, are several low tubercular eminences of irregular shape and disposition, but which appear to assume a more or less distinct biserial arrangement at right angles to the adcentral margin of the plate. They appear to be enlarged irregular granules, and in all the examples I have examined they have become to a certain extent ill-defined, owing either to growth or to weather-wearing. The general character of the ornamentation is shown in Pl. XIV, fig. 4c. The entire margin of the plate is surrounded by a very narrow depressed border, which is very minutely punctate, probably only in a single lineal series. The general superficies of the plate beyond the ornamentation mentioned is smooth, as if weatherworn, in all the examples I have seen, but in some specimens there appear to be traces of a more or less granulous character, and in some instances suggest the impression that an ornamentation similar to that noticed in *Mitraster rugatus* was probably present on at least a part of the surface of the plate. The height of the supero-marginal plates as seen in the margin is greater than their length, and their prominent abactinal tumidity has a distinctly conical character from this point of view.

The ultimate paired plate is fully twice as long as the other supero-marginal plates measured on the outer margin, and its breadth is equal to that of the adjacent supero-marginal. It is triangular in form, and the line of junction with the companion ultimate plate of the adjacent side coincides with the median radial line. The actual dimensions in the example under description are, length 6·2 mm., breadth about 6 mm. As seen in the lateral view of the disk the ultimate plates are distinctly tumid abactinally (see Pl. XIV, fig. 4b). The abactinal surface of the plate is ornamented by a number of miliary tubercles or granules, more or less serially disposed parallel to the margin adjacent to the companion plate, and more numerous at the adcentral end of that margin. Beyond this the surface of the ultimate plate is smooth, like that of the other supero-marginal plates.

The abactinal area of the disk within the boundary of the marginal plates is covered with hexagonal or polygonal plates or paxillar tabulæ, which are small in size generally, excepting the primary apical plates, which are comparatively very large. All the plates have their surface covered with a fine, uniform granulation. The primary apical plates have a small central area of low elevation, not higher than if a number of granules had become coalesced—the structure being suggestive of a tubercle in process of disappearance,—in other words, the scar left by a tubercle which had existed in an earlier stage of growth (see Pl. XIV, fig. 4d).

Dimensions.—The example figured on Pl. XIV, fig. 4a, has the following

measurements:—major radius, 20 mm.; minor radius, 15.5 mm.; length of the side, about 22 mm. The thickness of the margin is 7 mm. in a specimen whose side is 23.5 mm.

Locality and Stratigraphical Position.—The specimen described above and figured on Pl. XIV, fig. 4a, is from the Upper Chalk, near Bromley. It is preserved in the British Museum, and bears the register-number “46,776.” Other examples which I refer to the same species are also in the National Collection, and one, if not more, was obtained from the same locality.

Remarks.—A fragmentary example which was figured in Dixon’s ‘Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,’ pl. xxi, fig. 8, and was referred by Forbes to *Goniaster (Gonioidiscus) uncatus*, now forms part of the collection in the British Museum, and bears the registered number “E 2577” This specimen appears to me to belong to the present species, and not to the true *Metopaster uncatus*. I can scarcely think that Forbes would have intentionally ranked the two forms as belonging to one species, and I have not thought it needful on the sole grounds of this fragment having been figured to regard *Metopaster cingulatus* as a dismemberment of Forbes’ *Metopaster uncatus*.

Metopaster cingulatus is readily distinguished from *Metopaster uncatus* by its very short broad supero-marginal 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 uncatus*. In many respects *Metopaster cingulatus* appears to hold an intermediate position between *Mitraster rugatus* and *Metopaster uncatus*.

Thoracifer [in

8. METOPASTER [CORNUTUS, Sladen.] Pl. XIV, figs. 5a—5d.

Body of small size. General form depressed. Abactinal surface slightly concave, the extremity of the rays being directed slightly upward. Actinal surface slightly convex. Marginal contour pentagonal, with the sides slightly lunate and the extremity of the rays slightly produced. The major radius is proportional to the minor radius as 100 : 74, the actual dimensions in the example described being, major radius about 19 mm., minor radius about 14 mm. approximately. The length of the side is 22.5 mm. The margin is moderately thick and apparently well rounded.

The supero-marginal plates are only two in number, counting from the median interradial line to the extremity, or four from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk. The supero-marginal plate adjacent to the median interradial line is broader than long, the dimensions in the example described being length about 3·25 mm., and breadth about 5·75 mm. The abactinal surface of this plate is slightly convex in the median line of breadth. The entire margin of the plate is surrounded by a very narrow depressed border with very minute punctations, closely crowded and uniserially disposed near the inner edge of the border, upon which a small miliary granulation was previously borne. The general superficies of the plate is covered with minute punctations irregularly disposed. The height of the two intermediate supero-marginal plates as seen in the lateral view of the margin (Pl. XIV, fig. 5 *b*) is scarcely half their length, and is less than half the height of the underlying infero-marginal plates.

The ultimate paired plate is very much larger than the small intermediate plate just described, being nearly three times as long, the actual measurement being about 9·25 mm. in the example under notice. It is of a peculiar form, being shaped somewhat like an irregularly formed elytron of an insect as seen from above, the proximal margin being truncate where it joins the companion intermediate plate, and the distal extremity obtusely rounded (Pl. XIV, fig. 5 *c*). At a point situated three-fourths of the distance from the proximal to the distal extremity rises an abrupt truncate teat-like eminence. The peculiar form of the plate as seen in the lateral view of the margin and the character of the eminence just described will be better appreciated by reference to Pl. XIV, fig. 5 *d*, than by verbal description. The superficies of the ultimate plate is studded with rather widely spaced punctations disposed in groups, which do not extend over the whole of the area which falls in the lateral wall of the disk. As seen in the marginal view of the test the ultimate is very much higher than the intermediate marginal plates (see Pl. XIV, fig. 5 *b*).

The odd terminal plate is unknown to me, no trace being preserved in the example under notice.

In like manner the whole of the abactinal plating within the boundary of the supero-marginal plates has been removed, excepting only a few isolated fragments of plates out of position.

The infero-marginal plates are large and high. Four are preserved between the median interradial line and the extremity, but the series is incomplete, probably one or more being wanting at the distal end of the series. This would increase the number eight now preserved on the whole side to ten or perhaps twelve. The two infero-marginal plates on each side of the median interradial

line are much larger and higher than the other plates. The plate adjacent to the median interradial line measures about 4 mm. in length and 4 mm. in height; the next plate 5 mm. in length, and from 3·5 mm. to 3·75 mm. in height. The surface of the plates is marked with small widely spaced punctations, and there is a narrow depressed border round the entire margin of the plate, which is very finely punctate.

The actinal area is unknown to me.

History.—The fossil delineated on Pl. XIV, fig. 5 *a*, was drawn by Mr. A. H. Searle under Dr. Wright's instructions, but I regret that I have not been able to find any trace of the specimen. I am therefore led to believe that the type belonged to Dr. Wright's private collection, which has been distributed since his lamented death. Knowing by experience the extreme care and fidelity which characterise all Mr. Searle's work, I have ventured to describe the species from his drawings alone, for it seemed undesirable to leave such an interesting form without notice; and I am hopeful that the publication of the figure and the description of its characteristic features will lead to the detection of the type. I am unable to give any information as to the locality or stratigraphical position from which the fossil was obtained.

Remarks.—The rather small size of this example and the small number of supero-marginal plates—only four for the whole side of the disk—would not unnaturally suggest at first sight that this was possibly an immature form. After careful study, however, I do not consider such to be the case, or at any rate I am unable to regard the fossil under notice as the young of any of the species with which I am acquainted. The large and characteristically developed ultimate supero-marginal plates in conjunction with the presence of a normal number of infero-marginal plates, together with the fact that the size of the test is not less than that of another perfectly characterised species, lead me to rank this as a distinct species with little hesitation. The general proportions as well as the character of the different plates, and the facies of the form as a whole, appear to me to fully warrant this view.

Genus—MITRASTER, *Sladen*.

(*Mitpa* = a broad belt, or girdle.)

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 setæ. 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 tabulæ 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 pedicellariæ may be present occasionally on the actinal intermediate plates.

Mitraster is characterised by its cycloid contour, by the equality in size of the supero-marginal plates, which do not diminish towards the extremity, and by the character of the ornamentation of the marginal plates, especially of the superior series.

The main characters which distinguish this and the two preceding genera are distinctly relative, and may be here conveniently compared. In *Pentagonaster* the rays are more or less produced, the supero-marginal plates are more or less numerous, and decrease in size as they approach the extremity of the ray, and are devoid of a marginal border of setæ. In *Metopaster* the rays are very slightly produced, the contour being pentagonal and only slightly extended. The supero-marginal plates are few in number, and do not decrease in size as they approach the extremity, the ultimate paired plate being larger than the others. All are furnished with a marginal border of setæ. In *Mitraster* the contour is cycloid almost to the obliteration of the pentagonal form. The supero-marginal plates are few in number, but neither decrease nor diminish in size, being subequal throughout; and they are furnished with a marginal border of setæ.

I consider that these differences indicate structural characters of sufficient morphological significance to render the forms presenting them worthy of recognition as distinct genera.

1. MITRASTER HUNTERI, *Forbes*, sp. Pl. IX, figs. 3 *a*—3 *e*; Pl. XII, figs. 3 *a*—3 *e*; Pl. XV, figs. 3 *a*—5 *b*.

GONIASTER REGULARIS,	<i>Mantell</i> , 1844. Medals of Creation, vol. i, p. 335, lign. 73 (<i>non Linck</i>).
GONIASTER (GONIODISCUS) HUNTERI, <i>Forbes</i> , 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 471.	
— — — — —	<i>Forbes</i> , 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 331, pl. xxi, fig. 1.
— — — — —	<i>Morris</i> , 1854. Catalogue of British Fossils, 2nd ed., p. 81.
ASTROGONIUM HUNTERI,	<i>Dujardin and Hupé</i> , 1862. Hist. Nat. Zooph. Echin. (Suites à Buffon), p. 399.
GONIASTER (GONIODISCUS) HUNTERI, <i>Forbes</i> , 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 365, pl. xxiv, fig. 1.	

Body of small size. General form depressed. Abactinal surface flat and apparently depressed within the boundary of the supero-marginal plates, the gibbosity of the latter and their centrally sloping surface giving a concave character to the area generally in fossil examples, which was probably always more or less present. Actinal surface flat or with a tendency to be slightly convex. Marginal contour subcircularly pentagonoid, the sides being slightly convex or bulging outward. The major radius is proportional to the minor radius as 100 : 90·47 approximately; and the rays are not produced, the angles of the pentagon being obtusely rounded. Margin thick and well rounded, the slope being more gradual on the actinal surface.

The supero-marginal plates are three in number counting from the median interradial line to the extremity, or six from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk, of uniform breadth throughout, which measures about 6·3 mm. at the median interradial line in an example whose diameter ($R + r$) measures about 40 mm. Excepting the ultimate plates all the supero-marginal plates are of equal size and uniform, the breadth being a little more than once and a half the length, the actual measurements in the

specimen under notice being length 4 mm. and breadth 6.3 mm., in the plate adjacent to the median interradial line. The length of the plate at the end which falls in the margin of the disk is a shade greater than the adcentral or inner end, and the plates are consequently faintly wedge-shaped, but so slightly that the character is scarcely noticed at first sight. The ultimate plates, however, are distinctly wedge-shaped, the length at the outer margin being a little greater than that of the other marginal plates, while the length of the inner end is rather less—often not more than one-half the length of the same end in the other plates. The breadth of the ultimate plates is the same as that of all the supero-marginal plates; and the corresponding plates of the two adjacent sides touch one another throughout, the line of junction falling in the median line of the ray. The abactinal surface of the plates is distinctly convex, and the character is more conspicuously emphasised by the plate becoming rapidly gibbous on the outer half, the outer side of the eminence forming the rapid bend to the lateral wall of the plate. The height of the plates as seen in the margin is usually equal to, or even rather greater than their length, but may occasionally be less. There is no diminution in height as the plates approach the extremity of the ray, and the ultimate paired plate has a tendency to appear even a trifle higher and more gibbous than the others, but the character is derived probably more from the position in which the plate sometimes is than from an actual increase in size or gibbosity. The abactinal surface of the plates is covered with coarse tuberculiform mammillations which gradually die out before reaching the apex of the gibbosity. In the interspaces between the eminences are small, more or less widely spaced punctations, and these extend over the whole surface of the plate, and are consequently present on the outer portions as well as on the lateral wall. There is a narrow depressed border round the entire margin of the plate, which is very minutely punctate (see Pl. XII, fig. 3 c). In smaller examples there often appears to be only one or two rows of punctations. The ornamentation of the ultimate paired plates is precisely similar to that on the other supero-marginal plates.

The odd terminal or "ocular" plate is very small, and, so far as I can make out, resembles superficially a short truncated cylinder which protrudes somewhat cannon-like from a small triangular space left by the ultimate paired plates similar to what I have already described in *Metopaster*.

The abactinal area of the disk within the boundary of the marginal plates is covered with comparatively large polygonal plates, with closely crowded, rather coarse, uniform granulations, upon which miliary granules or spinelets were previously borne. The primary apical plates are remarkably large, and the plates in the interradial areas are larger than the plates in the radial areas. Of the plates in the radial areas at least the median series and two series on each side have bases of a six-rayed, substellate form. These are admirably seen in an

example preserved in the British Museum bearing the register-number "46,772," in which the inner surface of the abactinal floor is exposed.

The madreporiform body, in the examples in which I have detected its presence, appears to be small and subtriangular, and is marked with very coarse striations.

The infero-marginal plates are five in number, counting from the median interradial line to the extremity,—that is to say, there are ten for the whole side of the disk as against six in the supero-marginal series. The length of the two innermost plates on each side of the median interradial line is a little greater than that of the corresponding superior plates; the breadth of the plate adjacent to the median interradial line is 7 mm. in the specimen bearing the British Museum register-number "46,766," and is a little greater than the breadth of the corresponding superior plate as seen in the example bearing the British Museum register number "E 2583."

The second plate, counting from the median interradial line, is a little less broad, and the third is slightly more diminished in breadth, and its adcentral margin merges with a sweeping curve into the lateral distal margin, which gives the plate a more or less cuneiform shape. A large portion of the distal lateral margin of this plate abuts on the adambulacral plates. The fourth infero-marginal plate is very small and triangular in form, with the apex directed adcentrally, and with one side abutting entirely on the adambulacral plates. The fifth plate is smaller still. In consequence of the triangular shape of the fourth and fifth plates the greatest length of the third plate is opposite the apex of the fourth plate, and the length of the third plate gradually diminishes up to the outer margin. The breadth of the third plate is 5·6 mm., and that of the fourth plate is only 3·2 mm.

The surface of the infero-marginal plates, which is more or less plain, is ornamented with small, widely spaced, and more or less equidistant punctations, and there is no trace of the tubercular mammillation present on the surface of the supero-marginal plates. On the inner third of the plate the punctations are more closely placed, and they have the appearance of falling into a more or less distinct reticulated arrangement (see Pl. XII, fig. 3 d). A narrow depressed border surrounds the entire margin of each plate, which is very minutely punctate.

The adambulacral plates, which are small, are broader than long, and have their surface traversed by several ridges placed slightly obliquely, but I am unable to define the armature.

The actinal intermediate plates, which are somewhat large in relation to the size of the disk, are rhomboid or polygonal in outline. Their surface is covered with small, closely crowded, uniform pits, upon which miliary granules or spinelets

were previously borne (see Pl. XII, fig. 3 e). A small entrenched pedicellaria may be present on an occasional plate here and there.

Dimensions.—The example figured on Pl. XII, fig. 3 a, has a major radius of about 30 mm., and a minor radius of about 28 mm. The length of the side is about 36 mm. The thickness of the margin is about 10 mm. In the specimen given on Pl. XV, fig. 4 a, the major radius measures 21 mm., and the minor radius 19 mm. approximately. The length of the side is about 25 mm.

Locality and Stratigraphical Position.—This species is a characteristic Upper Chalk form. The majority of examples are from Kent and Sussex. A fine series from Bromley is preserved in the British Museum.

History.—This species was referred to by Dr. Mantell under the name of *Goniaster regularis*. The specific name was, however, already preoccupied—at least in literature—for an existing starfish; and although the latter is not now recognisable, no doubt can possibly exist that Mantell's fossil species is certainly a different thing from the starfish to which Linck gave the name of *Pentagonaster regularis*.

Forbes was the first to describe the species under the name of *Goniaster (Gonioidiscus) Hunteri*, and his type-specimen, which is figured in Dixon's 'Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,' pl. xxi, fig. 1, formed part of John Hunter's Collection, now preserved in the Museum of the Royal College of Surgeons. The examples illustrated in the present work are all preserved in the British Museum.

Variation.—There are at least two well-preserved examples in the collection of the British Museum which I consider to be varieties of this species. They are characterised by the presence of only four supero-marginal plates on each side of the disk, exclusive of the odd terminal plates, as against six plates in typical examples. Beyond this difference in number and the relatively greater length of the supero-marginal plates in proportion to their breadth, I can indicate no character worthy of being noted which would distinguish the examples in question from the typical form of *Mitraster Hunteri*. The specimens under notice measure 35 mm. and 30 mm. in diameter ($R + r$) respectively. Both are from the Upper Chalk, one from near Bromley, the other being only labelled "Kent." Figures of the first-mentioned are given on Pl. IX, figs. 3 a—3 e.

2. MITRASTER RUGATUS, *Forbes*, sp. Pl. XVI, figs. 3 a—5 d.

GONIASTER (GONIODISCUS) RUGATUS, *Forbes*, 1848. Memoirs of the Geological Survey of Great Britain, vol. ii, p. 471.

— — — *Forbes*, 1850. In Dixon's Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex, London, 4to, p. 330, pl. xxi, figs. 2, 2*; pl. xxiii, fig. 15.

— — — *Morris*, 1854. Catalogue of British Fossils, 2nd ed., p. 81.

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

GONIASTER (GONIODISCUS) RUGATUS, *Forbes*, 1878. In Dixon's Geology of Sussex (new edition, Jones), p. 364, pl. xxiv, figs. 2, 2*; pl. xxvi, fig. 15.

Body of small size. General form depressed. Abactinal surface flat. Actinal surface also flat. Marginal contour pentagonal with almost straight sides. The major radius is proportional to the minor radius as 100 : 75. The actual measurements in an example from the Upper Chalk of Gravesend, preserved in the British Museum, being, major radius, 17·5 mm.; minor radius, 13·75 mm. The rays are not produced beyond the contour of a true pentagon, and the radial angles are not rounded. Margin moderately thick, the lateral wall being almost vertical in consequence of the rapid bend from the abactinal and actinal surfaces; the bend to the actinal surface is, however, rather more gradual.

The supero-marginal plates are three in number, counting from the median interradial line to the extremity, or six from the tip of one ray to the tip of the adjacent ray, exclusive of the odd terminal or "ocular" plate in each case. They form a broad border to the abactinal area of the disk, of uniform breadth throughout, which measures 6 mm. at the median interradial line in an example whose diameter ($R + r$) measures about 31 mm. Excepting the ultimate plates, the supero-marginal plates are approximately equal in size, the breadth being nearly twice the length, the actual measurements in the above-mentioned specimen of 31 mm. in diameter being, length 3·5 to 3·6 mm., and breadth 6 mm. in the plate adjacent to the median interradial line. The corresponding plate in another example has a breadth of 5 mm. and length 2·75 mm., and in a third, breadth 5·5 mm. and length 2·75 to 2·8 mm. In the plate adjacent to the median inter-

radial line the length at the outer and at the adcentral margin is equal, but in the second plate the length at the adcentral margin is greater than at the outer margin in consequence of a slight extension of the plate to make up for the diminution in size of the ultimate plate, the distal lateral margin of the second plate appearing to be slightly hollowed out for the reception of the ultimate plate, and the corresponding second plates of two adjacent rays consequently touch at their adcentral ends. The ultimate plate is triangular or wedge-shaped in form, and its breadth is less than that of the other supero-marginal plates, and the corresponding plates of the two adjacent sides touch one another throughout, the line of junction falling in the median line of the ray. The ultimate plate is not unfrequently a little longer at the outer margin than the other supero-marginal plates.

The abactinal surface of the plates is regularly convex along the line of breadth, almost resembling the segment of a cylinder, and no special gibbosity is developed. The abactinal area and the lateral area of the plate form a right angle, and the uniting curve is short and abrupt. The height of the supero-marginal plates, as seen in the margin, is less than their length, the height being 2·25 mm. where the length is 2·75 mm. There is no diminution in height as the plates approach the extremity of the ray, and no special prominence is noticeable in the ultimate plate. The abactinal surface of the plates is ornamented with irregular and frequently elongate eminences or ridges, which are usually disposed transversely or in the direction of the length of the plate. Two or three series may be present, as in Pl. XVI, fig. 4, or the linear ridges may be bent at a right angle, or otherwise curved—a character which is probably the result of several eminences being merged together, by which means a peculiar hieroglyphic-like marking is produced, which fancifully resembles Chinese writing to a certain extent (see Pl. XVI, fig. 5 c). This character is emphasised in weathered specimens. The ornamentation covers the whole abactinal area of the plate, but does not extend upon the lateral wall. Sometimes the form of the eminences is more rounded and tuberculiform, as in *Mitraster Hunteri*; this is distinctly the case in one example, and minute punctations are present in the channels which intervene, but it is to be noted that the tubercles and pits cover the *whole* abactinal area of the plate, and that there is no gibbosity, with its outer flank devoid of tubercles, as in *Mitraster Hunteri*. There is a very narrow depressed border round the entire margin of the plate, from which the regular convexity of the plate rapidly rises. The border is very minutely punctate, and there appears to be usually only a single regular lineal series of punctations. The ornamentation of the ultimate paired plates is similar to that on the other supero-marginal plates, but is more rounded and tubercle-like even in an example in which the broad lineal ornamentation occurs on the other plates.

The odd terminal or so-called "ocular" plate must be very small in order to fit the space left by two adjacent ultimate supero-marginal plates; but I am unable to describe the plate, as I have only found a trace of it in one instance, and have not seen a perfect one preserved in any of the examples of the species I have examined.

The abactinal area of the disk within the boundary of the marginal plates is paved with large polygonal plates, whose surface is marked with a very minute, closely crowded uniform granulation, upon which small miliary granules were previously borne. Traces of these granules are still occasionally present in some examples. The abactinal plates in this species are all large in relation to the size of the disk, and the primary apical plates are much larger than any of the others. The primary apical plates and several of the other plates have a central, small, low, irregular eminence, such as might be formed by the merging together and partial grinding down of a number of granules. I am unable to explain this structure, or to consider it as associated with a pedicellarian apparatus, of which I see no trace. It may possibly mark the remains of a tubercle which had existed in an early stage of the animal's life, but had disappeared and been outgrown at a later stage.

The madreporiform body, which is very small, is circularly subtriangular in shape, and is marked with fine regularly radiating striations. In the example under notice two large plates surround two-thirds of the circumference of the madreporite. In this specimen the madreporiform body measures 1·5 mm. in diameter, and the largest primary plate is 3·2 mm. in diameter.

The infero-marginal plates are five in number, counting from the median interradial line to the extremity,—that is to say, there are ten for the whole side of the disk as against six in the supero-marginal series. The length of the two innermost plates on each side of the median interradial line is greater than that of the corresponding supero-marginal plates, consequently the second infero-marginal plate extends a little way beneath the ultimate supero-marginal plate, and the remaining three infero-marginal plates are all under the ultimate supero-marginal plate. In some examples I am inclined to think that probably only four infero-marginal plates were present, counting from the median interradial line to the extremity, in which case the edge of the second and the remaining two plates were under the ultimate supero-marginal plate.

I have unfortunately not seen any example of this species in which the actinal surface of the disk is exposed, I am therefore unable to give the dimensions of the infero-marginal plates on the actinal surface, or to describe their ornamentation. For the same reason I am prevented from offering any remarks on the adambulacral and actinal intermediate plates.

Dimensions.—The example figured on Pl. XVI, fig. 3 *a*, has a major radius of about 17·5 mm., and the minor radius is about 13·75 mm. The length of the side is about 20 mm. The fragmentary type-specimen figured by Forbes, which is drawn on Pl. XVI, fig. 5 *a*, was probably about the same size, judged by computation of the half-side.

Locality and Stratigraphical Position.—One of the type specimens figured by Forbes is stated to have been obtained from the Upper Chalk of Wiltshire, but the second specimen, which is now preserved in the British Museum, bears no record of any locality. Forbes also records the species from Kent and Sussex. Authentic examples from the Upper Chalk from Gravesend and “Kent” are preserved in the British Museum.

History.—This species was described by Forbes in his memoir “On the Asteriadæ found fossil in British Strata” (‘Mem. Geol. Surv.,’ vol. ii, p. 471, 1848), and figures of two examples were given in Dixon’s ‘Geology and Fossils of the Tertiary and Cretaceous Formations of Sussex,’ London, 1850, pl. xxi, figs. 2, 2*; pl. xxiii, fig. 15. The latter specimen is now preserved in the British Museum (register-number “E 2585”), and is illustrated on Pl. XVI, fig. 5 *a*, of the present work. I have not been able to find any trace of the other example figured by Forbes, which originally formed part of the collection belonging to the late Mr. Channing Pearce. Forbes states that it was found in Wiltshire.

Remarks.—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. When the types alone are examined there appears to be no need for any doubt upon this question. But examples occur which are exceedingly difficult to determine on account of presenting features which seem to break down some character which has been regarded as diagnostic of the other species. In illustration of this difficulty I have drawn on Pl. XVI, fig. 3 *a*, an example which I have ranked under *Mitraster rugatus*, but which presents considerable superficial resemblance to *Mitraster Hunteri* in the character of the ornamentation of the supero-marginal plates. I believe, however, that the proportions of the plates, the absence of any abactinal gibbosity, and the extension of the tuberculation over the whole abactinal area constitute, *inter alia*, a justification for regarding the example as *Mitraster rugatus*.

Turning, on the other hand, to a series of *Mitraster Hunteri*, considerable variation is to be noted in the relative length and breadth of the supero-marginal plates, as well as in the amount of gibbosity developed on the abactinal area of the plate. In such an example as that figured on Pl. XV, fig. 3 *a*, the proportions



PLATE IX.

PYCNASTER ANGUSTATUS, *Forbes*, sp. (Page 21.)

From the Upper Chalk.

FIG.

- 1 a. Abactinal aspect; natural size. (Coll. Brit. Mus.)
- b. Lateral view of the margin; natural size.

METOPASTER PARKINSONI, *Forbes*, sp. (Page 31.)

From the Upper Chalk.

- 2 a. Actinal aspect; natural size. (Coll. Brit. Mus.)
- b. Lateral view of the margin; natural size.
- c. An infero-marginal plate; magnified.

MITRASTER HUNTERI, *Forbes*, sp. (Page 59.)

From the Upper Chalk.

- 3 a. Abactinal aspect of a small example with four supero-marginal plates; natural size. (Coll. Brit. Mus.)
- b. Actinal aspect of the same; natural size.
- c. Lateral view of the margin; natural size.
- d. A supero-marginal plate; magnified.
- e. An infero-marginal plate; magnified.

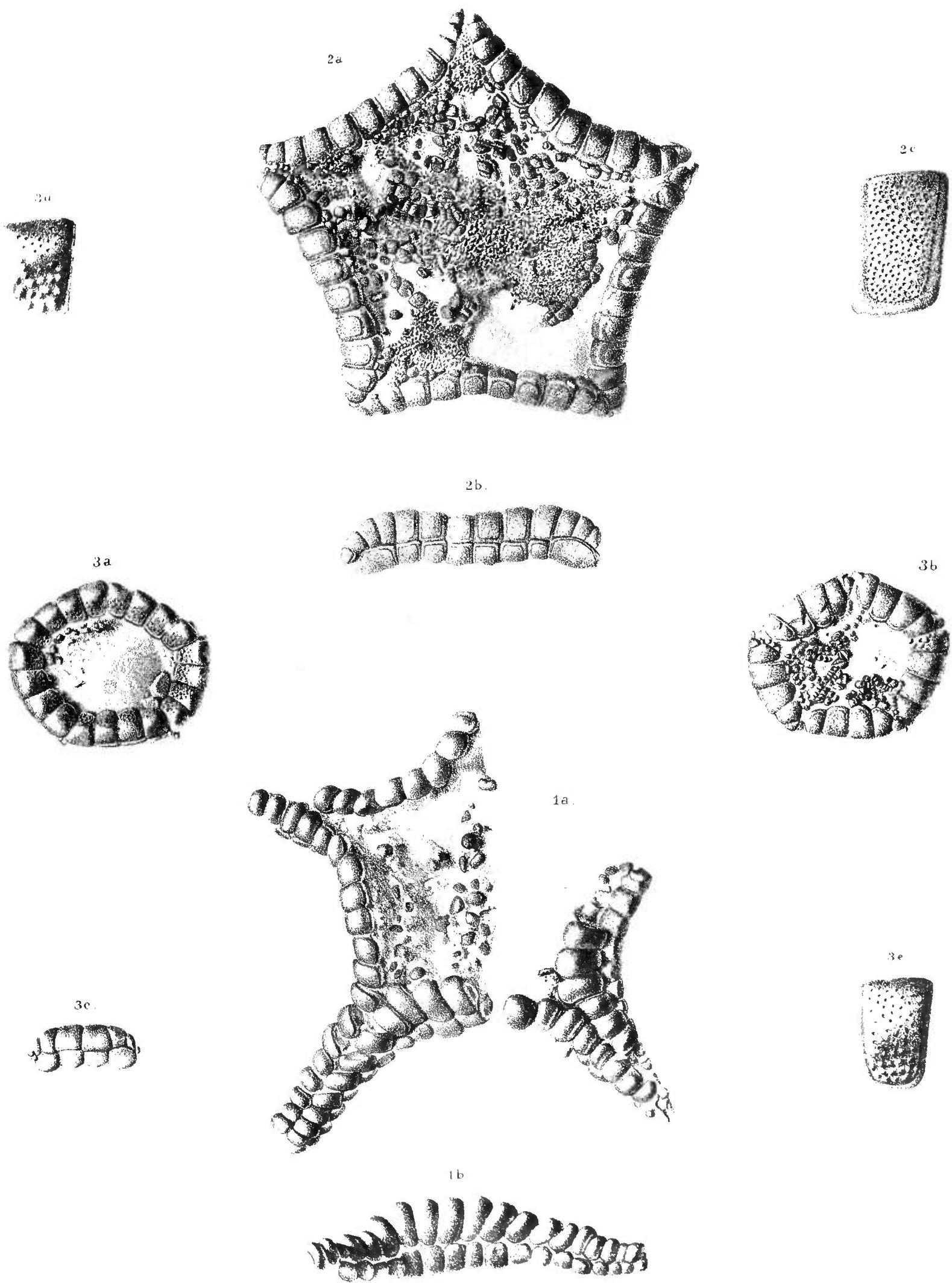


PLATE X.

1-4 METOPASTER PARKINSONI, *Forbes*, sp. (Page 31.)

From the Upper Chalk.

FIG.

1. Abactinal aspect; natural size. (Coll. Brit. Mus.)
- 2 a. Abactinal aspect of another example; natural size. (Coll. Brit. Mus.)
 - b. A supero-marginal plate; magnified 3 diameters.
 - c. The madreporiform body; magnified.
 - d. An abactinal intermediate plate, with pedicellarian apparatus; magnified.
- 3 a. Actinal aspect of another example; natural size. (Coll. Brit. Mus.)
 - b. Lateral view of the margin; natural size.
 - c. Adambulacral plates; magnified.
- 4 a. Actinal aspect of another example; natural size. (Coll. Brit. Mus.)
 - b. An infero-marginal plate; magnified.
 - c. An actinal intermediate plate; magnified.
- 5 a. Abactinal aspect of a young (?) example; natural size.
 - b. A supero-marginal plate of the same; magnified 4 diameters.
 - c. Abactinal intermediate plates; magnified.

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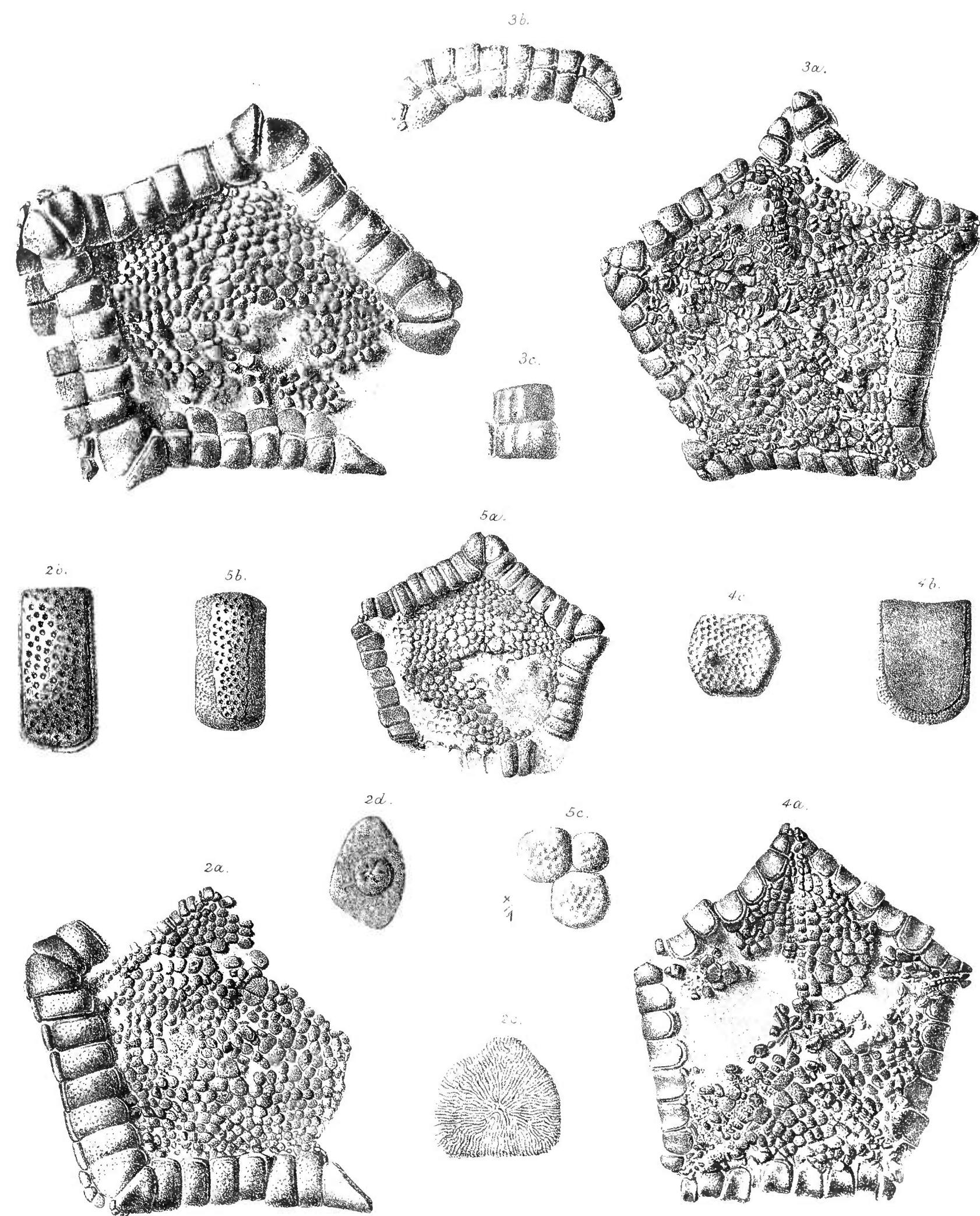


PLATE XI.

METOPASTER PARKINSONI, *Forbes*, sp. (Page 31.)

From the Upper Chalk.

FIG.

- 1 *a.* Abactinal aspect; natural size. (Coll. Brit. Mus.)
- b.* A supero-marginal plate; magnified 3 diameters.
- c.* The madreporiform body; magnified 6 diameters.
- 2 *a.* Abactinal aspect of another example; natural size. (Coll. Brit. Mus.)
- b.* A supero-marginal plate; magnified.
- c.* An abactinal intermediate plate; magnified.

METOPASTER UNCATUS, *Forbes*, sp. (Page 47.)

From the Upper Chalk.

- 3 *a.* Actinal aspect of a specimen from which the whole actinal floor has been removed, showing the inner surface of the abactinal floor; natural size. (Coll. Brit. Mus.)
- b.* Abactinal intermediate plates, inner surface; magnified.

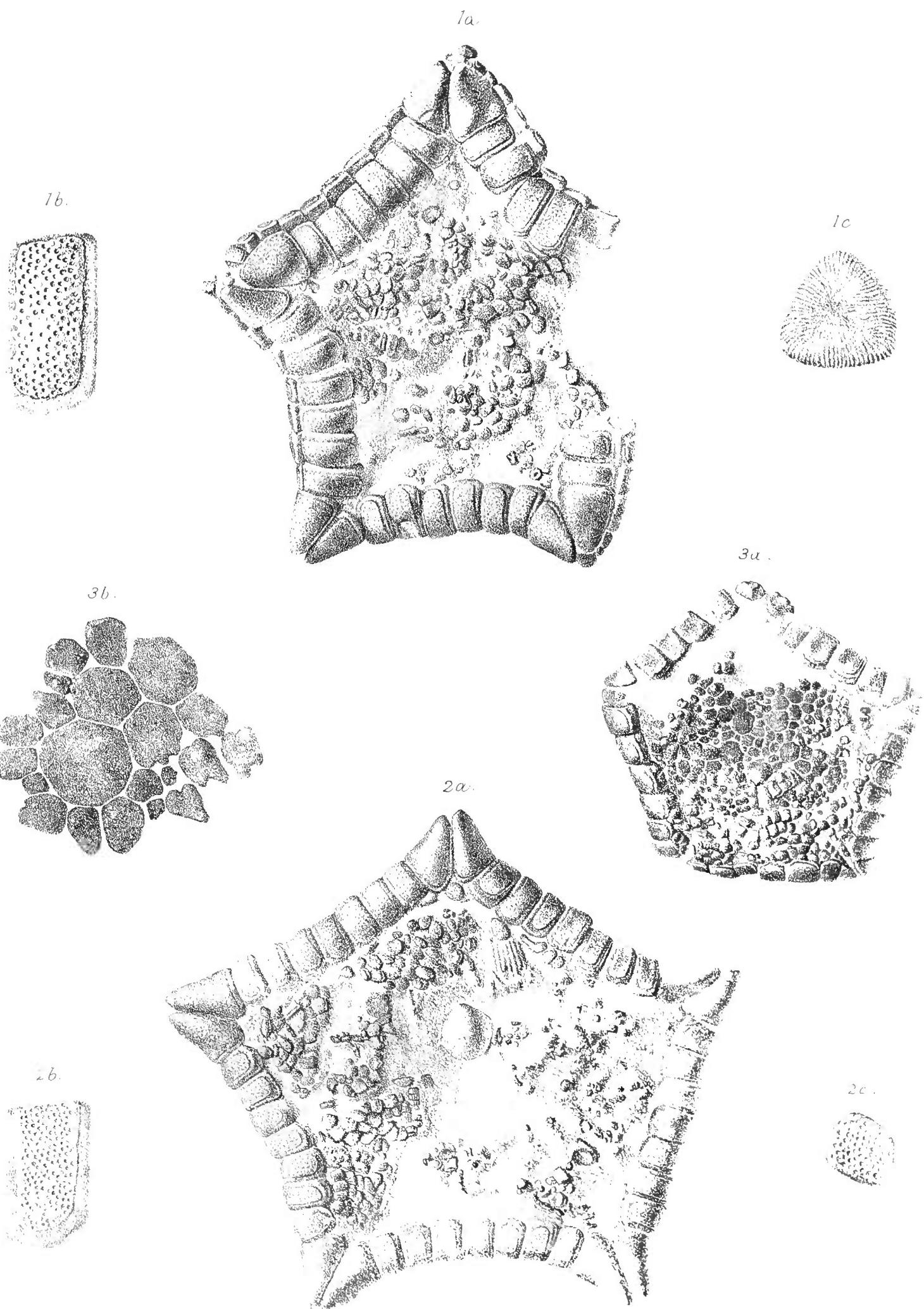


PLATE XII.

METOPASTER PARKINSONI, *Forbes*, sp. (Page 31.)

From the Upper Chalk.

FIG.

- 1 *a.* Abactinal aspect; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin; natural size.
- c.* A supero-marginal plate; magnified.
- d.* The madreporiform body; magnified.
- e.* Abactinal intermediate plates; magnified.

METOPASTER ZONATUS, *Sladen*. (Page 45.)

From the Upper Chalk.

- 2 *a.* Abactinal aspect; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin; natural size.
- c.* The madreporiform body; magnified.

MITRASTER HUNTERI, *Forbes*, sp. (Page 59.)

From the Upper Chalk.

- 3 *a.* Actinal aspect; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin; natural size.
- c.* A supero-marginal plate; magnified.
- d.* An infero-marginal plate; magnified.
- e.* Actinal intermediate plates; magnified.

CALLIDERMA MOSAICUM, *Forbes*, sp.] (Page 9.)

From the Lower Chalk.

- 4 *a.* Actinal aspect; natural size. (Coll. Brit. Mus.)
- b.* Lateral view of the margin; natural size.
- c.* Mouth-plates; magnified.
- d.* An infero-marginal plate; magnified.

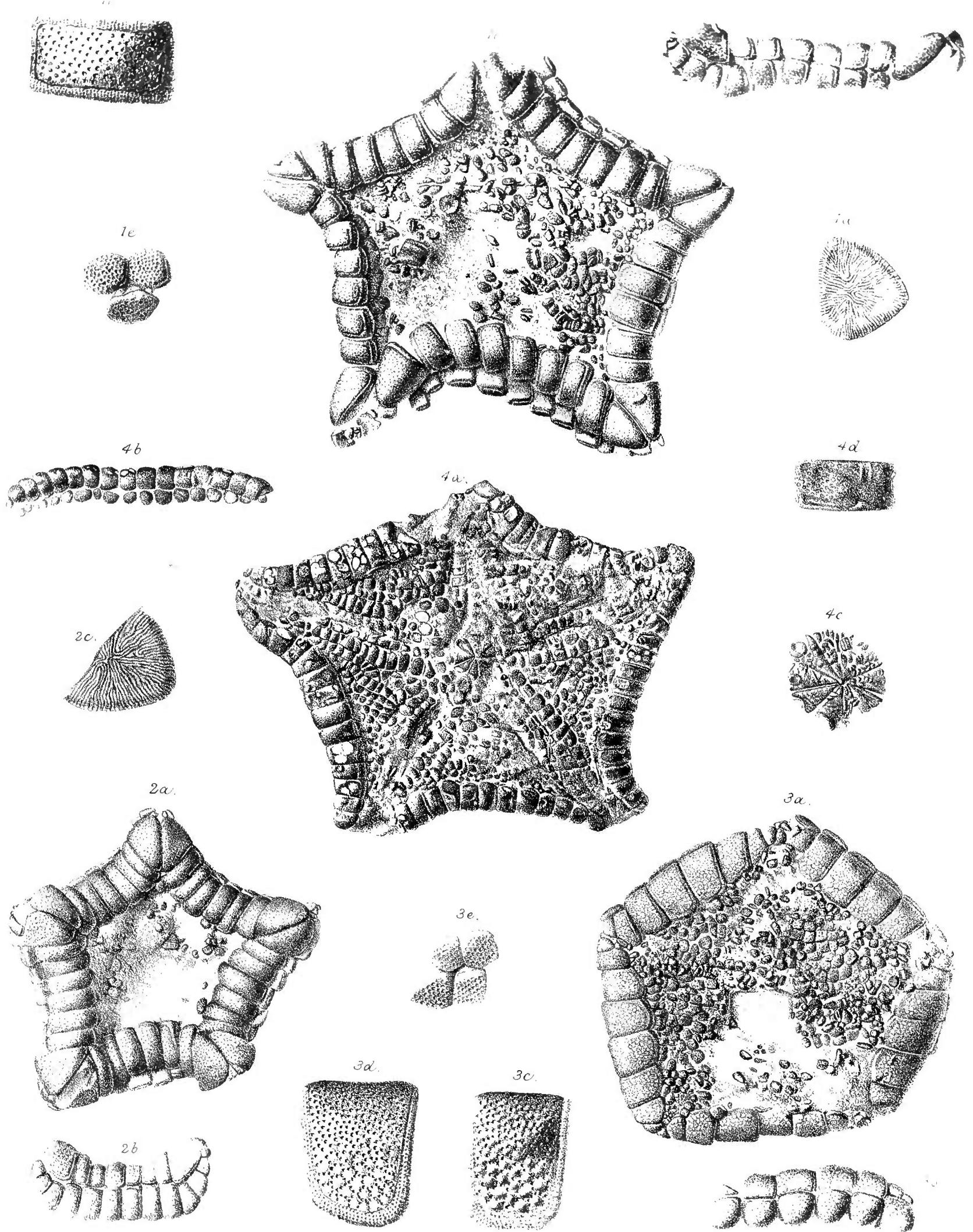




PLATE XIII.

PENTAGONASTER MEGALOPLAX, Sladen. (Page 27.)

From the Upper Chalk.

FIG.

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

METOPASTER MANTELLI, Forbes, sp. (Page 38.)

From the Upper Chalk.

- 2 a. Abactinal aspect ; natural size. (Coll. Brit. Mus.)
- b. A supero-marginal plate (much weathered) ; magnified 3 diameters.
- c. The madreporiform body and surrounding plates ; magnified.
- d. Abactinal intermediate plates ; magnified 6 diameters.
- 3 a. Abactinal aspect of the example figured by Forbes ; natural size. (Coll. Brit. Mus.)
- b. A supero-marginal plate ; magnified 3 diameters.
- 4 a. Actinal aspect of another example figured by Forbes ; natural size. (Coll. Brit. Mus.)
- b. An infero-marginal plate ; magnified 3 diameters.

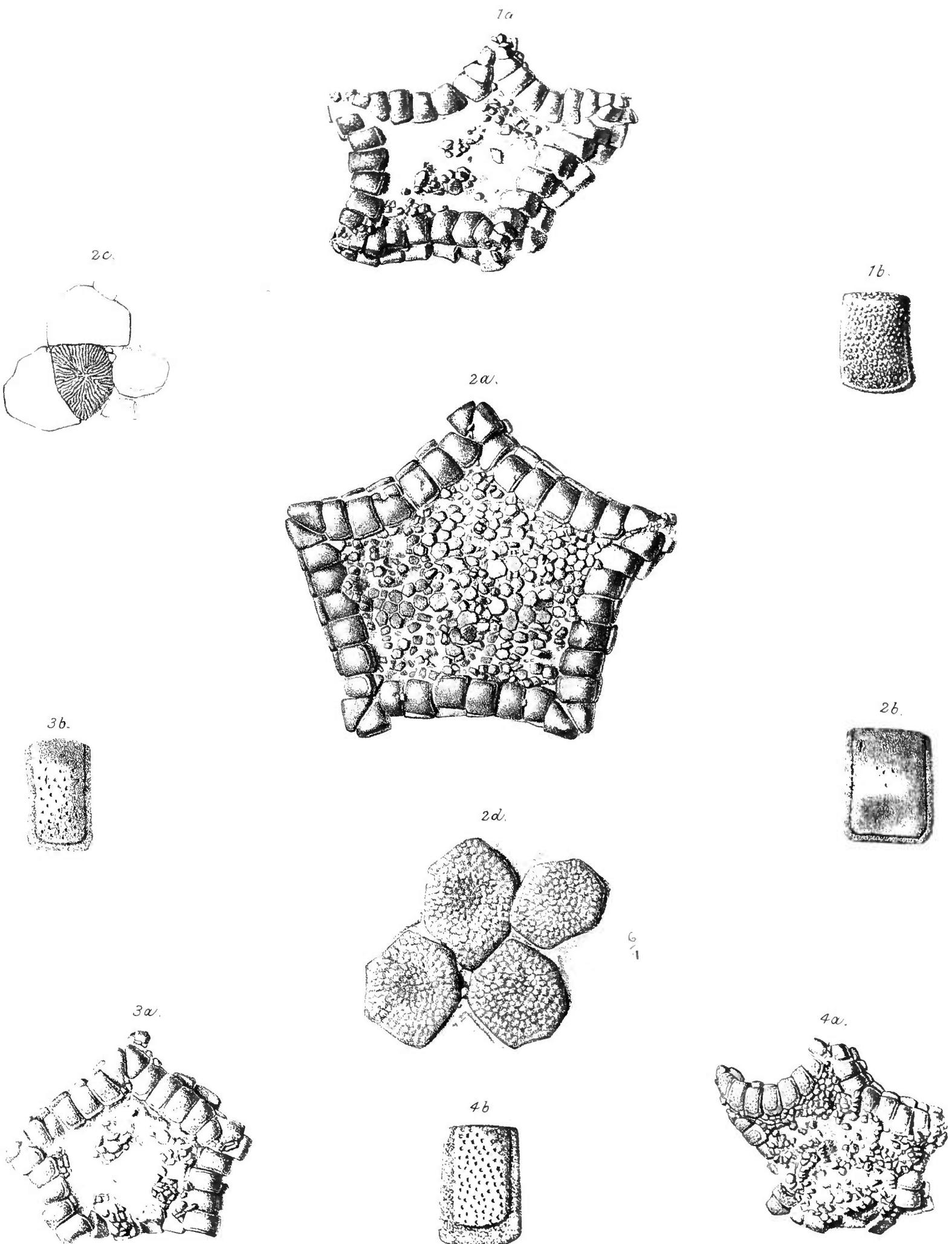




PLATE XIV

METOPASTER UNCATUS, *Forbes*, sp. (Page 47.)

From the Upper Chalk.

FIG.

- 1 a. Abactinal aspect ; natural size. (Coll. Brit. Mus.).
b. An ultimate paired supero-marginal plate ; magnified.
- 2 a. Abactinal aspect of another example ; natural size. (Coll. Brit. Mus.)
b. Lateral view of the margin ; natural size.
c. A supero-marginal plate ; magnified.
d. The madreporiform body ; magnified 4 diameters.
3. Actinal aspect ; copied from the figure given by Forbes in Dixon's Geology of Sussex' (pl. xxi, fig. 5).

METOPASTER CINGULATUS, *Sladen*. (Page 53.)

From the Upper Chalk.

- 4 a. Abactinal aspect ; natural size. (Coll. Brit. Mus.)
b. Lateral view of the margin ; natural size.
c. A supero-marginal plate ; magnified.
d. An abactinal intermediate plate ; magnified.

METOPASTER [CORNUTUS, *Sladen*.] (Page 55.)

- 5 a. Abactinal aspect ; natural size.
b. Lateral view of the margin ; natural size.
c. An ultimate paired supero-marginal plate seen from above ; magnified.
d. The same seen in profile (lateral view) ; magnified.

PLATE XV

METOPASTER UNCATUS, *Forbes*, sp. (Page 47.)

FIG.

- 1 a. Actinal aspect ; natural size. (Coll. Wright.)
- b. Lateral view of the margin ; natural size.

METOPASTER BOWERBANKII, *Forbes*, sp. (Page 42.)

From the Upper Chalk.

- 2 a. Actinal aspect ; natural size. (Coll. Geol. Survey)
- b. Lateral view of the margin ; natural size.
- c. An infero-marginal plate (weathered) ; magnified.
- d. Mouth-plates ; magnified.

MITRASTER HUNTERI, *Forbes*, sp. (Page 59.)

From the Upper Chalk.

- 3 a. Abactinal aspect ; natural size. (Coll. Brit. Mus.)
- b. A supero-marginal plate ; magnified 3 diameters.
- 4 a. Actinal aspect of another example ; natural size. (Coll. Brit. Mus.)
- b. An infero-marginal plate ; magnified 3 diameters.
- c. Extremity of the radial region ; magnified 3 diameters.
- d. Abactinal intermediate plates, seen from within ; magnified 6 diameters.
- 5 a. Actinal aspect of another example ; natural size. (Coll. Brit. Mus.)
- b. An infero-marginal plate ; magnified 3 diameters.

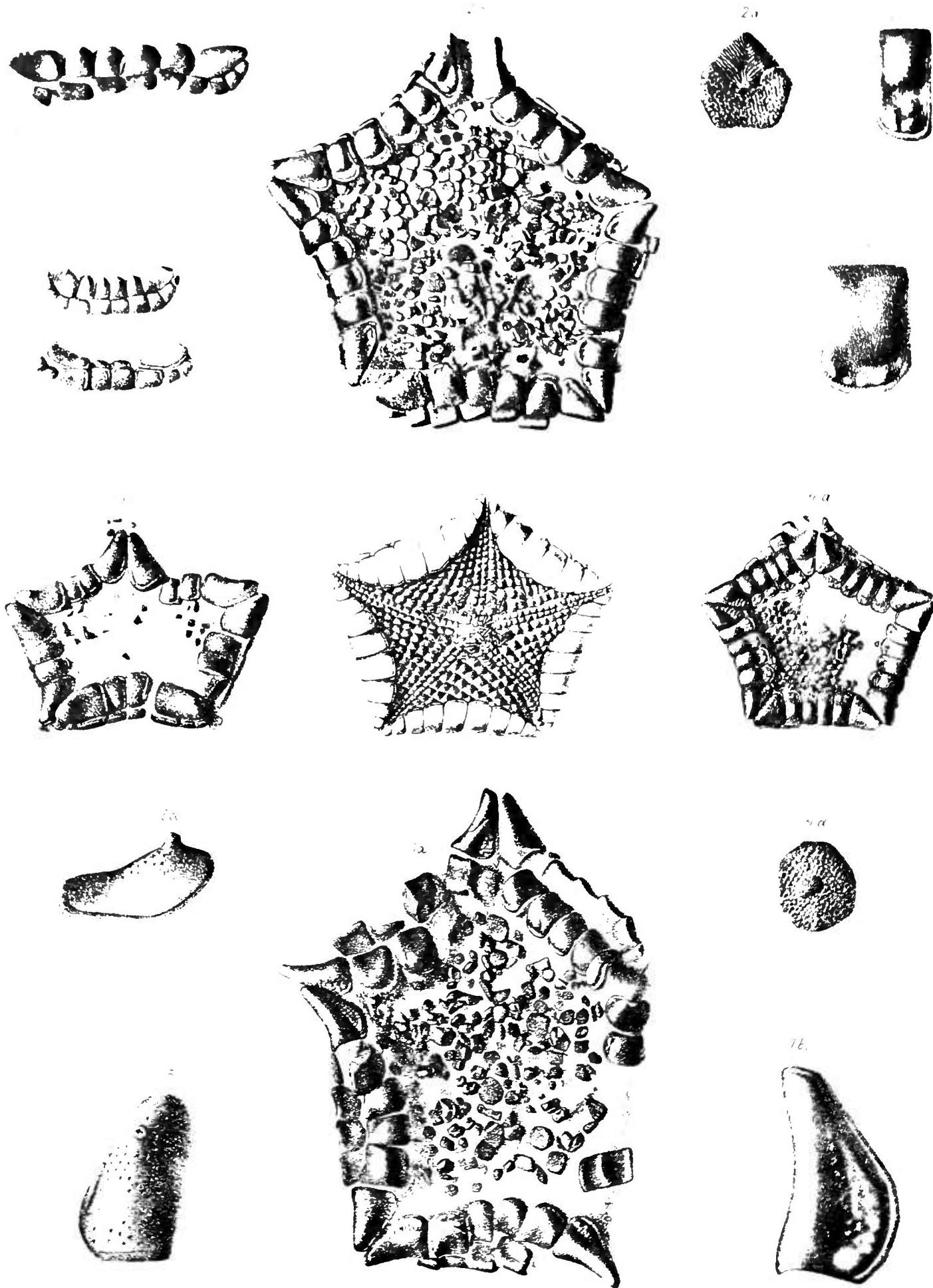


PLATE XVI.

METOPASTER BOWERBANKII, *Forbes*, sp. (Page 42.)

From the Upper (?) Chalk.

FIG.

- 1 a Abactinal aspect of the example figured by Forbes, natural size. (Coll. Brit. Mus.)
- b. Lateral view of the margin; natural size.
- c. The last three supero-marginal plates; magnified 2 diameters.
- d. Abactinal intermediate plates; magnified 6 diameters.

METOPASTER PARKINSONI, *Forbes*, sp. (Page 31.)

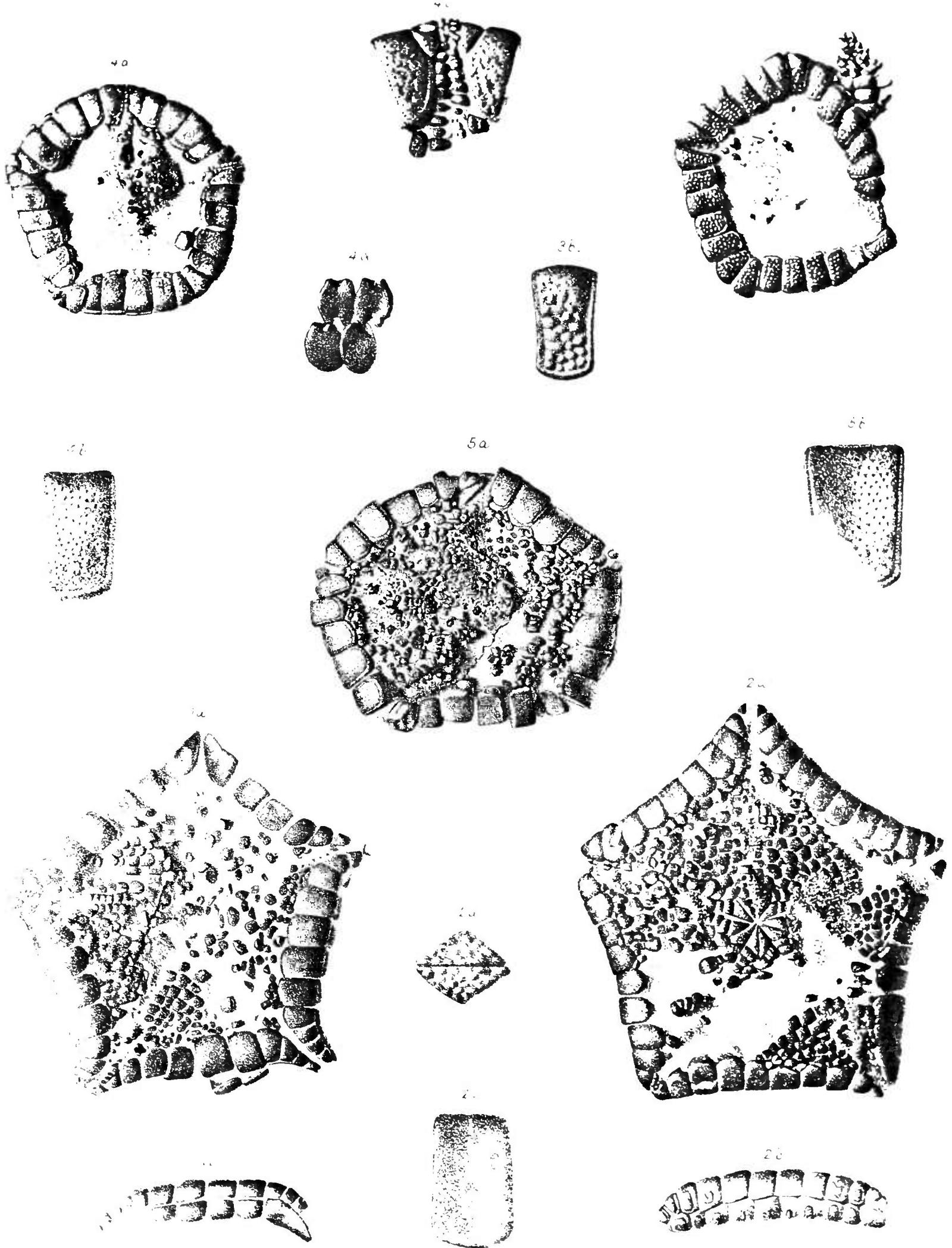
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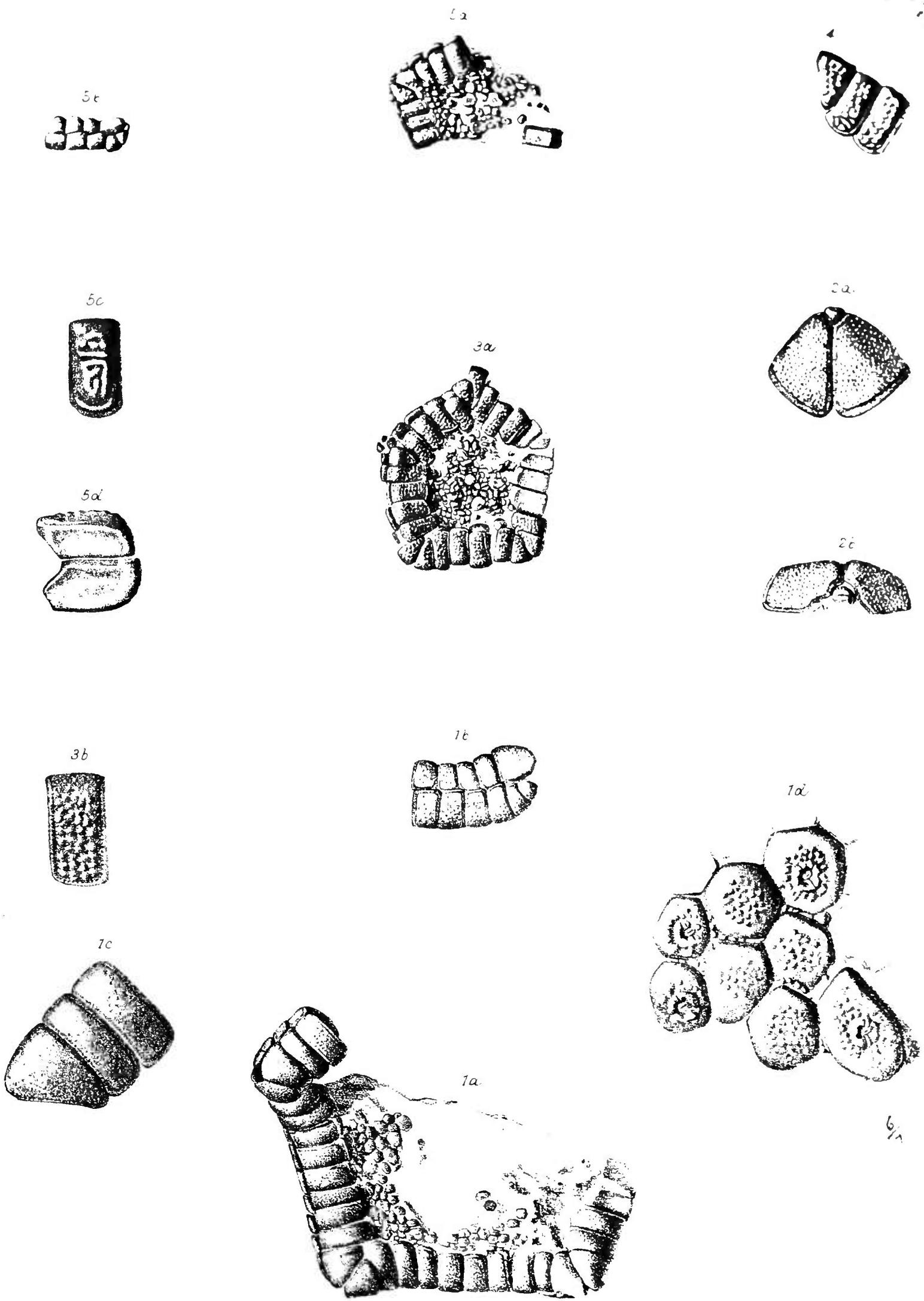
- 2 a. A pair of ultimate supero-marginal plates and the odd terminal or "ocular" plate; magnified 2 diameters. (Coll. Brit. Mus.)
- b. Lateral or marginal view of the same; magnified 2 diameters.

MITRASTER RUGATUS, *Forbes*, sp. (Page 63.)

From the Upper Chalk

- 3 a. Abactinal aspect; natural size. (Coll. Brit. Mus.)
- b. A supero-marginal plate; magnified 3 diameters.
4. Supero-marginal plates of another example; magnified 2 diameters. (Coll. Brit. Mus.)
- 5 a. Abactinal aspect of the example figured by Forbes; natural size. (Coll. Brit. Mus.)
- b. Lateral view of the margin; natural size.
- c. A supero-marginal plate; magnified 3 diameters.
- d. Profile or sectional view of the margin, showing a supero-marginal and an infero-marginal plate; magnified 3 diameters.





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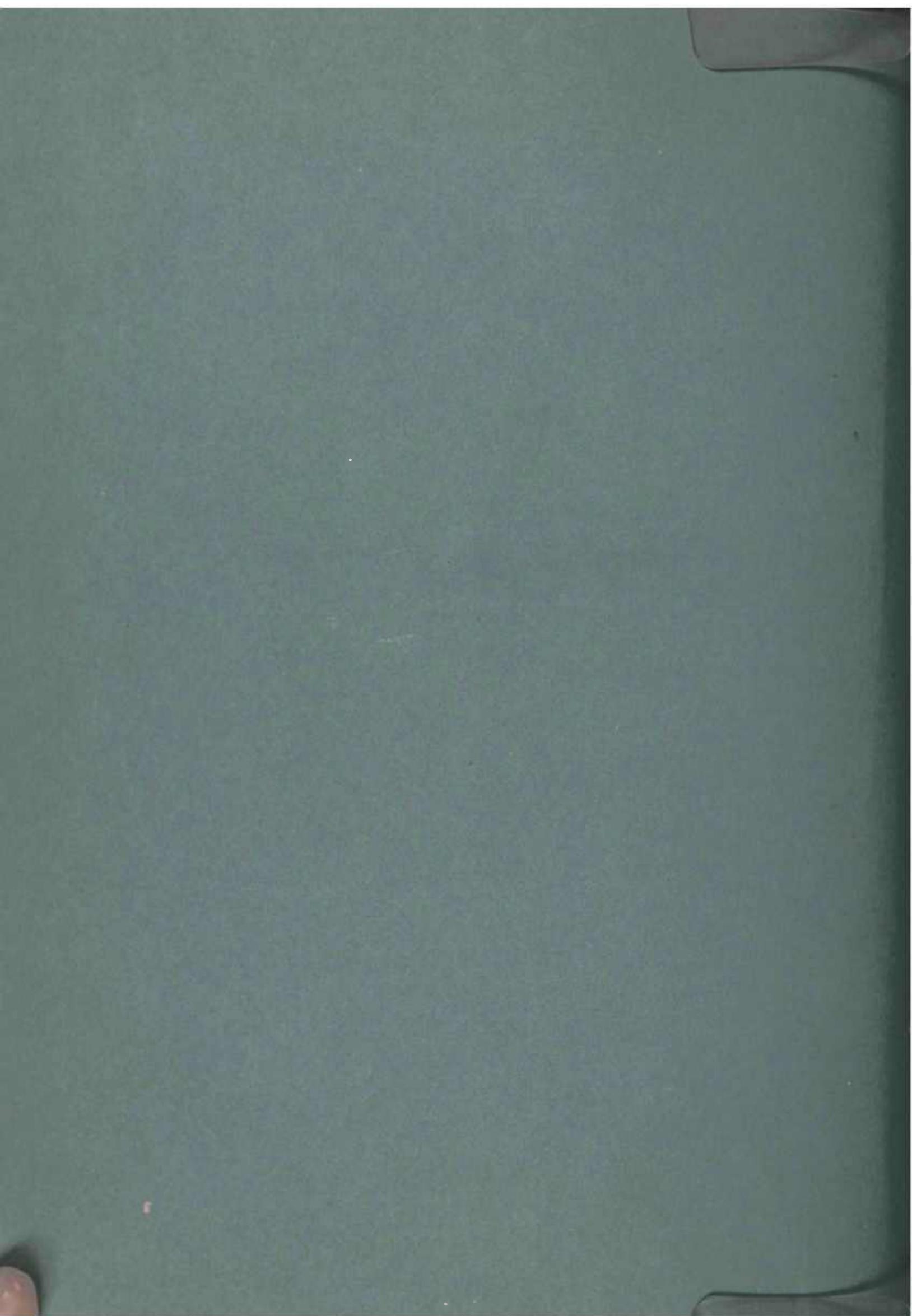
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