

## INTRODUCTION

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In 1925 I received a letter from Dom Grégoire Fournier, O. S. B., of the Abbaye de Maredsous, in Belgium, telling me that he had a large collection of Palaeozoic Echini from the Lower Carboniferous, the Marbre noir de Dinant, from Denée, Belgium. He also extended to me a most cordial invitation to visit the Abbaye and study the material, which he felt contained undescribed forms. Being in Europe in 1926, I took that opportunity to accept Père Fournier's kind invitation, and was both surprised and delighted at the rich store of specimens of Echini from Denée that is in the Museum of the Abbaye de Maredsous.

I was received with the utmost cordiality at the Abbaye, and my good friend, Dom Grégoire Fournier, did everything possible for my personal comfort and to facilitate my work. He had photographs taken for me by Dom Henri Mariage, O. S. B. ; he further sent specimens to the museum at Brussels to have casts made for me, and also sent several specimens to me in America to study. To my great joy Père Fournier generously gave me specimens of three species from Denée, which are now added to the collections of the Museum of Comparative Zoölogy at Cambridge, Mass.

To the Père Abbé and Père Fournier I would express my warmest appreciation of the hospitality enjoyed and for every kindness which I received in my most interesting and scientifically most profitable visit at the Abbaye de Maredsous.

From Maredsous I went to Brussels and there again met with the greatest cordiality and had every opportunity offered me to study the many very choice Palaeozoic Echini in the collections of the Musée Royal d'Histoire Naturelle de Belgique. Dr. Victor Van Straelen, Directeur du Musée, and M. Eugène Maillieux, Conservateur au Musée, extended every courtesy and aid in the work. M. Maillieux had numerous photographs of specimens taken for me by the Museum photographer. He also had very beautiful plaster casts made for me from museum specimens and also from specimens sent there from Maredsous for the

purpose. Drawings were placed at my disposal that had been made by an artist for the late Professor L. G. de Koninck.

At the Musée Royal d'Histoire Naturelle de Belgique they possess the holotype of *Proterocidaris gigantea* Koninck, a magnificent specimen measuring nearly 300 mm. in diameter, one of the largest specimens known of that remarkable species. They also have the extraordinary *Palaeochinus visetensis* sp. nov., a species which is spirally twisted in the vertical axis, a feature absolutely unique in all Echini. Besides these they have much fine material from Denée collected by Dom Grégoire Fournier, and Lower Carboniferous material from other Belgian localities, principally Tournai, Visé and Celles, and including several new species. As a whole, in the Brussels Museum there are some seventeen species of Echini from the Lower Carboniferous of Belgium.

A day was spent in the Museum of l'Université de Liège. There I did not have the pleasure of meeting Professor Charles Fraipont, but he had the great kindness and liberality to have laid out for my inspection and study the fossil Echini from Denée which formed in considerable part the basis of the late Professor Julien Fraipont's Memoir on the Échinodermes du Marbre noir de Dinant. These were a great aid and, while the time was short, I gathered from them much valuable information.

A day was spent at the Institut de Géologie de l'Université de Louvain, where M. le Professeur H. de Dordolot and M. le Professeur A. Salée gave me every opportunity to see their valuable collections. Here they possess the holotype of *Hyattechinus elegans* sp. nov., which is a wonderfully perfect specimen, they also have considerable material from Denée. In a second visit to Belgium in 1928, some additional studies were made in various museums.

In a word, one of the pleasantest experiences of my scientific life was the cordiality, liberality and helpful kindness with which I was met by the scientific men of Belgium. I was deeply touched and gratified when Dr. Victor Van Straelen offered to publish my studies on the Palaeozoic Echini of Belgium in the Memoirs of the Musée Royal d'Histoire Naturelle. As a local paper it most properly belongs there, and it is a great personal satisfaction to me to have it published in Belgium.

As a whole, twenty-five species of Palaeozoic Echini are recorded from the Lower Carboniferous of various Belgian localities. Eleven of these species are new. In addition two forms are recorded generically, but without specific identification.

As regards the several collections studied, that at the Museum of the Abbaye de Maredsous, as far as Palaeozoic Echini are concerned, is wholly from the Marbre noir de Dinant, and, with the exception of one specimen, wholly from Denée. These fossils were collected by the long continued devoted efforts of Dom Grégoire Fournier.

What Palaeozoic Echini I saw at the University of Liége are also from Denée, with the exception of a few specimens from the same formation at Salet, which is a small village some five kilometers east of Denée. The Liége collection is material collected by the Engineer, the late M. Gustave Soreil, with the addition



Text-fig. 1. — Dom Grégoire Fournier, O. S. B.

of specimens collected by Dom Grégoire Fournier. The collections of the Museums, either at Liége or at Maredsous, contain all the material figured by Professor Fraipont in his memoir on the Échinodermes du Marbre noir de Dinant.

The Echinoid material in the Brussels Museum has been referred to briefly above. At the British Museum there are about 26 species of Palaeozoic Echini represented by specimens, and in addition casts of some important types. In this collection a number of species from Denée and other Belgian localities are represented, as will be noted under the description of species.

At the Museum of Comparative Zoölogy in Cambridge there is a large collection of Palaeozoic Echini, including many types. In the collection there are a

number of Belgian Palaeozoic Echini from the L. G. de Koninck collection, purchased by Louis Agassiz, in 1861, and in addition there are the specimens given me by Dom Gregoire Fournier and casts made for me at the Brussels Museum, all as noted under the description of species.

The locality at Denée is the most important in Belgium for Palaeozoic Echini; it is also as far as known the most important locality in the world for this interesting group of Palaeozoic fossils. This from the point of view of the number of genera and species and also the number of individual specimens of some species that have been found in this locality. The specimens at Denée are relatively uncommon, but by the devoted enthusiasm of Dom Grégoire Fournier, he has accumulated one of the most remarkable collections of Palaeozoic Echini extant. No less than twelve species are here recorded from Denée. There are also a few undeterminable fragments which indicate that yet more species may be found at that locality.

The number of species of Palaeozoic Echini found at Denée is in excess of that known from any other one Palaeozoic locality in Europe or America. Even in localities for recent Echini it is only, I believe, in the Mediterranean or in tropical waters that such a number is equalled or surpassed. Dr. Hubert Lyman Clark, of the Museum of Comparative Zoölogy, who is the leading American authority on Recent Echini, tells me that he collected 14 species at Jamaica, West Indies; at Tortugas, Florida; and at Murray Island, Australia. He thinks that only rarely in a similar restricted area in the living fauna would one find so many species of Echini as occur at Denée.

The Denée locality is not only remarkable for the number of genera and species of Echini found there, but also for the number of individual specimens of certain species that have been found. Of *Lovenechinus Lacazei*, I have seen and studied some 45 specimens and of *Proterocidaris gigantea* some 38 specimens from Denée or near-by localities. Usually in Palaeozoic Echini very few specimens of a species are known and often only a single one.

Still more striking and important is the great size and the specialized characters of three of the species known from Denée. *Deneechinus tenuispinus* gen. et sp. nov., with long acicular spines, the only species known from the Palaeozoic with this character, measures about 200 mm. in diameter. *Proterocidaris gigantea* Koninck, with four columns of plates in each ambulacrum and up to thirteen columns in each interambulacrum, measures up to nearly 300 mm. in diameter. The specimen of this species reaching this measurement is from Loyers, near



Dinant, but many specimens from Denée are from 250-295 mm. in diameter. *Fournierechinus deneensis* gen. et sp. nov. with twenty columns of plates in an ambulacrum and fourteen columns of plates in an interambulacrum is the most specialized in number of columns of any echinoid known. The holotype is of such a size that a circle enclosing its lobed margin would be about 360 mm. in diameter. This is by far the largest sea-urchin known, living or fossil. The Aristotle's lantern of this extraordinary form measures some 74 mm. across, greatly exceeding the size in any other known species. The species known from Denée are as follows :

*Archaeocidaris Wervekei* TORNQUIST.

*Archaeocidaris Urii* (FLEMING).

*Deneechinus tenuispinus* gen. et sp. nov.

*Palaeechinus elegans* M'COY.

*Palaeechinus* (?) *regnyensis* JACKSON.

*Maccoya sphaerica* (M'COY).

*Lovenechinus Lacazei* (JULIEN).

*Lovenechinus anglicus* JACKSON.

*Lepidechinus belgicus* sp. nov.

*Perischodomus Fraiponti* sp. nov.

*Proterocidaris gigantea* KONINCK.

*Fournierechinus deneensis* gen. et sp. nov.

Denée is a small village in the province of Namur, and not far distant from the Abbaye de Maredsous. The Marbre noir de Dinant (Viséen inférieur VIa) as it occurs at Denée, is highly prized as an ornamental marble. The microscopic structure of the rock shows that it is filled with the debris of small Protozoa and various other fossils, and with siliceous sponge spicules and Radiolaria in the chert. The working of the marble at Denée is very ancient and still continues in subterranean quarries, and so valuable is it commercially, that it is now quarried from a great depth underground. The marble has also been worked at Dinant, but there the quarries are abandoned. The formation was first studied at Dinant, whence it is called Marbre noir de Dinant. It has been considered very poor in fossils, but on the contrary, at Denée, while fossils are not abundant, it is very rich. The fossils occur in the pure black marble or in the similar dark coloured gritty layers. The Marbre noir at Denée is a deep black crystalline marble; as listed by Professor Fraipont (1904) it has yielded a considerable fauna of corals, brachio-

Pods, Bryozoa, mollusks, etc. besides the echinoderms and a few fishes. The echinoderms as described by Professor Fraipont consist of a new crinoid *Scaphio-crinus longicaudatus* Fraipont <sup>(1)</sup>, a new ophiuran *Taeniaster Fournieri* Fraipont <sup>(2)</sup>, and a number of species of Echini.

As stated, the marble at Denée is highly crystalline. The condition of sedimentation must have been very quiet, for specimens of Echini, even exceptionally large ones are rarely distorted, and usually are not crushed or mutilated. As pointed out by Professor Fraipont, however, the finer structure of the Echini is very largely destroyed by crystallization, and even the interambulacral structure is often more or less obliterated. It is rarely that details of ambulacral structure can be ascertained, so that the generic status of some species is open to doubt from lack of this important evidence. Two courses are open to a student, one to leave the material severely alone, the other to study and make the best of it with available evidence. I have chosen the latter course. As I have studied specimens of almost all the known species of Palaeozoic Echini, and very largely have studied the types of these species, either in Europe or in America, I could compare this material with that from other localities and make a fair estimate of the relations of the species. This will have to serve unless better material becomes available, or someone with a fuller knowledge studies the collections.

The remarkable conditions of sedimentation at Denée are emphasized by the recent discovery of impressions of Medusae as described by Dr. Van Straelen <sup>(3)</sup>, and also by the preservation of the impressions of small, or larger soft-bodied organisms that may well be holothurians. The conditions of sedimentation may favourably be compared to those that existed at Solenhofen.

Of publications on Palaeozoic Echini of Belgium, Münster (1839) described *Archaeocidaris Nerei* (Münster) from Tournai. L. G. de Koninck, who was pro-

<sup>(1)</sup> The types of this crinoid, two specimens, the originals of Fraipont's Plate I, figs. 1, 2, are in the Museum at Liège, n° 11,220.

<sup>(2)</sup> The types of this ophiuran are in the Musée Maredsous, one, n° 67, is the original of Fraipont's Plate I, fig. 4, which is life size. The other, n° 68, is the original of Fraipont's Plate I, fig. 3, which is slightly reduced. Casts of both of these are in the Museum of Comparative Zoölogy, n° 48, 49.

<sup>(3)</sup> Sur les premiers restes de Méduses trouvés dans le calcaire carbonifère de la Belgique. (*Bull. Acad. roy. Belg.*, Déc. 1926, pp. 1-4, 1 pl.) Dr. Van Straelen l. c. indly sent me a cast of his *Medusina Boulengeri* for the Mus. Comp. Zoöl.

fessor at the University of Liège, in his Carboniferous fossils of Belgium, records *Archaeocidaris Nerei* from Tournai and describes *Archaeocidaris Muensteriana* (as *Cidaris Muensterianus*) from Visé. Later (1882), de Koninck described the remarkable *Proterocidaris gigantea*, the holotype of which is in the Brussels Museum. In this last publication de Koninck expresses the intention of publishing a memoir on the Palaeozoic Echini of Belgium, but this intention was not carried out. In pursuance of his plan de Koninck had drawings made which I have had the privilege of using in this memoir as later noted.

Desor (1858) described *Archaeocidaris Konincki* from Tournai and records *A. Nerei* (Münst.) from the same locality.

Messrs. Dollo and Buisseret (1888) described a new genus and species, *Koninckocidaris Cotteaui*, from the Carboniferous of Belgium. They also list three species of *Lepidocentrus* and three species of *Palaeochinus* as new, but without any description. These latter are considered in my Phylogeny of the Echini (p. 457-458).

The late Professor Julien Fraipont, who was also professor of palaeontology at the University of Liège, published (1904) a memoir on the Echinoderms of the Marbre noir de Dinant. All of the specimens described in his memoir are from Denée, and the originals figured are all either in the museums at Liège or at Maredsous. Professor Fraipont gives lists of the species of fossils of various groups that have been found at Denée. He describes a crinoid, an ophiuran and seven species of Echini from Denée, all of which are illustrated by excellent photographic figures. Professor Fraipont does not give measurements of his specimens, but in his description of plates says : « Grandeur naturelle », or gives the relative reduction as the case may be. I give measurements of most of his specimens under description of the several species.

Professor Fraipont's *Palaeochinus Lacazei* I refer to *Lovenechinus Lacazei*; his *Palaeochinus* sp. Plate II, fig. 7-8, I refer also to *Lovenechinus Lacazei*; his *Rhoechinus elegans* is referable to *Palaeochinus elegans*; his *Palaeochinus Konincki* to *Palaeochinus regnyensis*; his *Palaeochinus Lacazei* of Plate II, fig. 6, is referred to *Perischodomus Fraiponti* sp. nov.; his *Oligoporus Soreili* is referred as a synonym to *Proterocidaris gigantea*.

In my Phylogeny of the Echini I gave a revision of the Palaeozoic species known up to that time, including the Palaeozoic Echini of Belgium as far as I was then acquainted with them.

In the Palaeozoic Echini of Belgium, Aristotle's lanterns are very frequently

preserved, which is an exceptional condition to occur. The lanterns of *Proterocidaris* and *Fournierechinus* are the largest known in any sea-urchins, living or fossil. The perignathic girdle was doubtless absent, as it appears to be absent in all Palaeozoic Echini belonging to the order *Perischoechinoida*. This being the character, as a reasonable conclusion the lantern muscles that find insertion on the corona, that is, the retractors, protractors and radial compass muscles, were doubtless inserted directly on the basicoronal interambulacral plates (Phylogeny, p. 190-192).

In no known case in Belgian specimens are the plates of the periproct in place, so that this feature needs no further consideration.

In the description of species the location of specimens in museums is cited. For brevity, Brussels Museum or Mus. Roy. Belg. is used for the Musée Royal d'Histoire Naturelle de Belgique ; Mus. Maredsous is used for the museum at the Abbaye de Maredsous ; Mus. Liège for the museum at l'Université de Liège , Brit. Mus. for the British Museum ; and Mus. Comp. Zoöl. for the Museum of Comparative Zoölogy at Cambridge, Mass., U. S. A.

The main publications referred to are listed at the end of this memoir and are referred to in the text by the author's name with the date of publication. My *Phylogeny of the Echini with a Revision of Palaeozoic species* is of necessity referred to so often that the word *Phylogeny* alone is used for that publication.

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# PALAEOZOIC ECHINI OF BELGIUM

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## ORDER PERISCHOECHINOIDA M'COY

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### FAMILY ARCHAEOCIDARIDAE M'COY.

#### Genus ARCHAEOCIDARIS M'COY.

*Archaeocidaris* M'COY, 1844, p. 173.

The species of *Archaeocidaris* from Belgian localities for the most part are represented by separate spines, interambulacral plates and parts of lanterns, as is usual in the genus. The new species *Archaeocidaris setosa* and *A. propinqua* are known only from primary spines. *Archaeocidaris Nerei* is known from primary spines, plates and an exceptionally large number of well preserved lantern elements. *Archaeocidaris Urii* is known from spines, plates, a quite complete test from Denée and an exceptionally perfect lantern. *Archaeocidaris Wervekei* and *Urii* are the only species of the genus known from Belgium in which comparatively complete tests are known.

Quite a number of lots of unidentified fragmentary spines, plates and jaws of *Archaeocidaris* are in the collections of the Brussels Museum, from the Lower Carboniferous of Visé, Tournai and Pont-à-Rieu. While not complete enough to be worth publishing, they indicate that other species may be found. The most completely known species of the genus are *Archaeocidaris rossica* (Buch), from the soft yellow clays of Russia and *A. Wortheni* Hall from America (Phylogeny, p. 259, 263). The type-species of the genus is *Archaeocidaris Urii* (Fleming).

#### *Archaeocidaris setosa* SP. NOV.

Plate I, fig. 6.

*Archaeocidaris setosa* is known only from primary spines which are slender, tapering, longitudinally finely striate, expanded at the base in a milled ring. The longest spine measures about 8.5 mm. in length.

The characters of the spines of *A. setosa* are nearest to those of *A. Nerei* (Münster), but differ in that the spines are more slender and tapering and the longitudinal striae are finer than in *Nerei*. The figures were drawn by de Koninck's artist. The material consists of a considerable number of primary spines in the Mus. Roy. Belg. n° 87, I. G. (1) 3031, Lower Carboniferous, Tournaisian, Tournai, coll. Le Hon.

### *Archaeocidaris Nerei* (MÜNSTER).

Text-fig. 2, Plate I, fig. 4a-4d.

*Cidarites Nerei* MÜNSTER, 1839, p. 40, Plate 3, fig. 6a-6d.

*Cidaris Nerei* KONINCK, 1842-1844, p. 34, Plate E, fig. 1a-1i.

*Archaeocidaris Nerei* MÜLLER, 1857, p. 262, Plate III, fig. 11, 12a, 12b.

Interambulacral plates hexagonal, or pentagonal with rounded adradial border, primary tubercle prominent, perforate, basal terrace marked, radial plications beyond the scrobicular circle. Numerous secondary tubercles beyond the scrobicular circle. Primary spines cylindrical, tapering, vertically finely striate. Desor (1858) figures a spine with terminal well developed spinules directed distally. I have not seen such. Pyramids of lantern wide-angled, foramen magnum moderately deep, pyramids laterally with ridges for attachment of interpyramidal muscles, teeth grooved, all as usual in lanterns of *Archaeocidaris* and also other Palaeozoic Echini.

*Archaeocidaris Nerei* is known only incompletely from dissociated interambulacral plates, primary spines and portions of the lantern, which last are unusually frequent. An adambulacral plate in the Mus. Comp. Zoöl., n° 3339, from Tournai, measures 8 mm. in width by 5 mm. in height. Another larger adambulacral plate n° 3338 from Tournai measures 9 mm. in width by 7.5 mm. in height. No spine is complete distally, but the longest one in the Mus. Comp. Zoöl. measures 8 mm. in length.

Münster (1839) records *A. Nerei* from Tournai. His figures were copied by de Koninck (1842-44), who also cites Tournai as a locality. Münster's cotypes are in the Munich Museum.

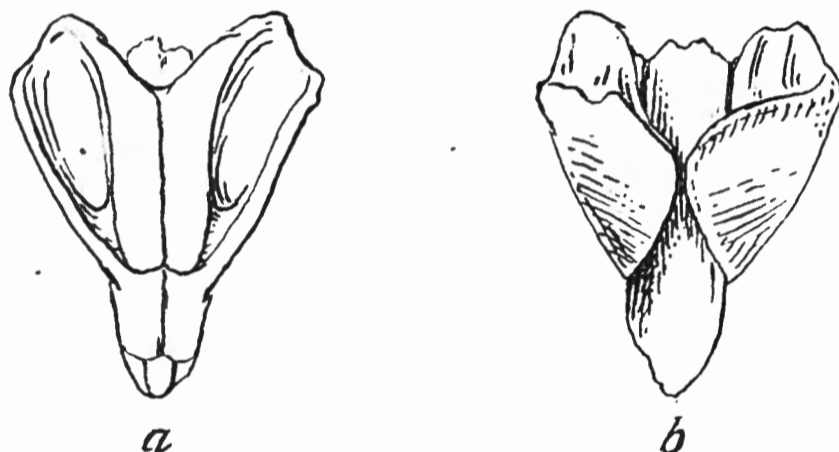
Portions of a lantern in the Brussels Museum n° 51, I. G. 6938, are shown in Plate I, fig. 4a-4d. The pyramids are wide angled, indicating an inclined lantern. On the right, the half-pyramid in fig. 4a shows the suture for attachment of the epiphysis. The foramen magnum is moderately deep, laterally the pyramids show

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(1) The letters I. G. signify Inventaire General; as applied to the collections in the Brussels Museum. It is the equivalent of accession number.

ridges for the attachment of interpyramidal muscles. Internally Plate I, fig. 4b, c, the half-pyramids show the styloid process which is the dorsal limit of the dental slide for supporting the tooth. In the Mus. Comp. Zoöl., n° 3338, a specimen from Tournai, text-fig. 2, has two half-pyramids with a tooth in place, showing adorally, and also extending above the base of the foramen magnum. Portions of lanterns of this species with teeth and braces are quite abundant in Belgian localities as seen in several museums. No compasses were seen, but they are so small they are easily lost. When lanterns or portions of lanterns occur isolated, it is obvious that the specific identity may be doubtful, but in *A. Nerei* so many of these parts are found in association with spines and interambulacral plates, there is reasonable assurance in referring them to this species. Another evidence in favor of the same conclusion is the fact that *A. Nerei* is the only common species of *Archaeocidaris* found in Belgium.

*Archaeocidaris Nerei* is represented in various museums by the following



Text-fig. 2. — *Archaeocidaris Nerei*. Tournai, Belgium, *a* seen in front view and *b* seen in rear view, the pyramids show sutures for attachment of epiphyses. (Mus. Comp. Zool. n° 3338 X 8.)

rather numerous lots of specimens. In the Mus. Roy. Belg., n°. 54, 59, 58, I. G. 3031, Calcaire Carbonifère, Tournaisien, Tournai, coll. Le Hon, four lots, including plates, spines, teeth and braces of lantern. Same museum and locality, coll. Ryckholt, n°. 58, 62, I. G. 3440, a large number of dental pyramids. Same museum, Tournai, n°. 52, I. G. 5096, plates. Same museum, Pont-à-Rieu, carrière Delwart, n°. 51, 55, 57, I. G. 6938 and n°. 53, 56, 60, 61, I. G. 8353, seven lots including a large number of plates, half-pyramids and teeth.

In the British Museum there are a number of lots referable to *Archaeocidaris Nerei*. From Tournai n°. [32,846] four half-pyramids, the largest 7 mm. wide and 13 mm. high. Tournai n°. [32,847] 19 spines, fine, slender, all incomplete, but the longest measures 10 mm. in length. Tournai, n° E 18,184-88, in this lot are five small plates referable to *A. Nerei*. Brit. Mus. from Tournai, purchased of Piret, n° E 9323. fourteen teeth; E 9324 nine teeth, and E 9328, eleven half-pyramids; E 9331 and E 9332, ten interambulacral plates and five spines.

These last plates are very well preserved. One is hexagonal, from a



median column and measures 7 mm. in width by 3.5 mm. in height. Nine plates are pentagonal, with one side rounded, from adradial columns. One of these pentagonal plates measures 8 mm. in width by 4 mm. in height, another 6.5 mm. in width by 4 mm. in height. The spines of this lot (E 9332) are the stoutest and longest seen in the species. None are complete distally, but the longest measures 21 mm. in length and 2 mm. in diameter. Some of these spines show well the fine longitudinal striae characteristic of the species.

In the Mus. Comp. Zoöl. n°. 3338 ; 3339 from Tournai, Koninck coll. interambulacral plates, spines, a complete pyramid with tooth in place (text-fig. 2), and half-pyramids <sup>(1)</sup>.

#### *Archaeocidaris Konincki* DESOR.

*Archaeocidaris Konincki* Desor, 1858, p. 155, Plate XXI, fig. 7-10.

This species is known only from dissociated interambulacral plates. Desor says that the plates are the size of those of *A. Nerei*, but differ in that in *Konincki* the scrobicules are surrounded by tubercles quite prominent and widely spaced. This species, I believe, is quite unknown except for Desor's original description. In the Phylogeny (p. 446) I referred it to incertae sedis.

Carboniferous, Tournai, coll. Michelin.

#### *Archaeocidaris Wervekei* TORNQUIST.

Plate I, fig. 7.

*Archaeocidaris Wervekei* TORNQUIST, 1897, p. 778, Plate XXI, fig. 4; Plate XXII, Fig. 1-3, 9, 10; Fraipont, 1904, p. 11, Pl. I, fig. 6, 7.

Ambulacra narrow, interambulacral plates hexagonal, or pentagonal in adradial columns, four columns of plates in each interambulacral area. Interambulacral plates exceptionally high in proportion to their width, relatively higher than in any other species of the genus known in Belgium. Primary tubercle prominent, elevated. Basal terrace strongly marked, strong radial plications extend from margin of plate inward, primary spines long, slender, nodose, with fine longitudinal striae.

In the Musée Maredsous there are three specimens from Denée which are referable to this species. All of these are comparatively complete tests viewed from the ventral side and in all the outline of a protruding lantern is visible. The most complete test at Maredsous, n° 69, is the original of Frai-

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<sup>(1)</sup> Münster (1839, p. 41) records *Archaeocidaris prisca* (Münster from Regnitzlosau, Germany, and says that it is similar to *A. Nerei*. Agassiz and Desor's (1846, catalogue raisonné, p. 340) record of *prisca* from Tournai is apparently an error, as is also my record (1912, p. 276) of Belgium.

pont's Plate I, fig. 7. It measures 34 mm. in diameter in one plane and 30 mm. in diameter at right angles to the same. Four columns of plates exist in an interambulacral area, which supports Tornquist's view, where in a reconstruction he shows four columns in each interambulacral area. This Denée specimen has three spines in place, the longest measuring up to about 17 mm. in length. A second specimen at Maredsous, n° 70, also from Denée, again is a complete test, but the structure is less visible, as it is largely clothed with spines. It is the original of Fraipont's Plate I, fig. 6. The spines, which are well preserved, measure up to about 21 mm. in length. Fraipont's figures of these two specimens are just life size. The third specimen at Maredsous, n° 100, is an external mould, it is less complete in outline, but not having any spines, is the clearest of any for interambulacral plates. It shows, Plate I, fig. 7, the high interambulacral plates with prominent tubercles and four columns of plates to an area. The largest interambulacral plate measures 5 mm. in width by about the same in height.

The specimens of *Archaeocidaris Wervekei* from Denée are the most complete individuals known in the species and are amongst the most complete known in the genus. It is somewhat remarkable with the large number of species of *Archaeocidaris* recognized how few occur in which a comparatively complete test is preserved. While in the Denée specimens quite complete tests are known, the crystalline character of the rock has unfortunately destroyed the finer structure.

The following is a list of the known Belgian specimens of *A. Wervekei*. Musée Maredsous, n° 69, Marbre noir de Dinant. (Viséen inférieur V1a) Denée, the original of Fraipont's Plate I, fig. 7, counterpart in Mus. Liège, cast in Mus. Comp. Zoöl., n° 3312. Mus. Maredsous, n° 70, Denée, original of Fraipont's Plate I, fig. 6, cast in Mus. Comp. Zoöl., n° 3344. Mus. Maredsous, n° 100, Denée, original of my Plate I, fig. 7, cast Mus. Comp. Zoöl., n° 3343. Brit. Mus., n° E. 11,506, Denée, a test labelled *A. Wervekei* but very obscure.

### *Archaeocidaris Urii* (FLEMING).

Plate I, fig. 1-3; Plate V, fig. 8-9.

*Cidaris Urii* FLEMING, 1828, p. 478.

*Archaeocidaris Urii* ROEMER, 1852-1854, p. 228, Plate IV, fig. 2; Fraipont, 1904, p. 11, Plate I, fig. 5.

Ambulacral plates low, wide, interambulacral plates of median columns hexagonal and those of adradial columns pentagonal, with strongly rounded line on adradial suture; four columns of plates in an area. Interambulacral plates with prominent perforate primary tubercle, basal terrace and secondary tubercles and strong radial plications which extend inward from the margin

of the plate. Primary spines long, up to 64 mm. in length in a recorded case (Phylogeny, p. 278), with strong spinules extending distally from elevated ridges.

The species *Archaeocidaris Urii* is widely distributed, being recorded from England, Ireland, France, Germany and Belgium. It is a robust form, probably the largest species known in the genus. A single adradial interambulacral plate in the Mus. Comp. Zoöl., n° 3340, from the Carboniferous of Settle, England, measures 21 mm. in width and 14.5 mm. in height. From the size of this plate the width of the interambulacrum in the zone from which it came must have been in the vicinity of 70 mm., allowing 5 mm. for the width of an ambulacrum which is very low, the circumference of the test would have been about 375 mm. and the diameter some 119 mm.; very large for the genus.

At the University of Liège Museum, n° 11,221, there is a specimen from Denée which represents a whole test with several spines attached, an unusual occurrence. The specimen, which is the original of Fraipont's (1904) Plate I, fig. 5, is not clearly preserved. The test measures 50 mm. in diameter and the longest primary spine 65 mm. in length. Four columns of plates can be made out in two of the interambulacral areas. It is not well enough preserved to show the spinules on the primary spines or finer details of structure, but without doubt it is referable to *A. Urii*. It is the most complete test known in the species. The only other specimen seen which is even complete enough to show the four columns in an interambulacrum is from Scotland and is in the Museum of Practical Geology, London, n° 16,319 (Phylogeny, Plate 15, fig. 1).

In the British Museum, n°. E 11,512, there is a specimen from Denée, purchased of Piret, labeled « *Archaeocidaris radiole* ». It is a long, straight, narrow spine-like body, swollen at the base. It measures 178 mm. in length and about 3.5 mm. in width. It is too rough and badly preserved for any identification but coming from Denée it is worth recording.

In the Brussels Museum, besides isolated plates, spines and fragments of lanterns as listed below, there is a very fine complete lantern, n°. 49, I. G. 3440, from Tournai, Ryckholt coll., which is referred to *Archaeocidaris Urii*. This lantern, Plate I, figs. 1-3, is somewhat compressed but very complete, with five teeth, ten half-pyramids, eight of the ten epiphyses are in place, capping the half-pyramids, and in one area the brace is in place resting on the two adjacent epiphyses. The pyramids are wide, inclined, measure 16 mm. in height and 13 mm. in width across the widest part. The foramen magnum is only moderately deep, as in other species of the genus, and in fact in all other Palaeozoic Echini as far as known. This lantern is the first one recorded in the species and is one of the most perfect lanterns known from the Palaeozoic. It bore the identification of *Archaeocidaris Nerei* in de Koninck's handwriting, but from its size it is more reasonably referable to *A. Urii*, the largest, and the only large species of the genus known from Belgium.

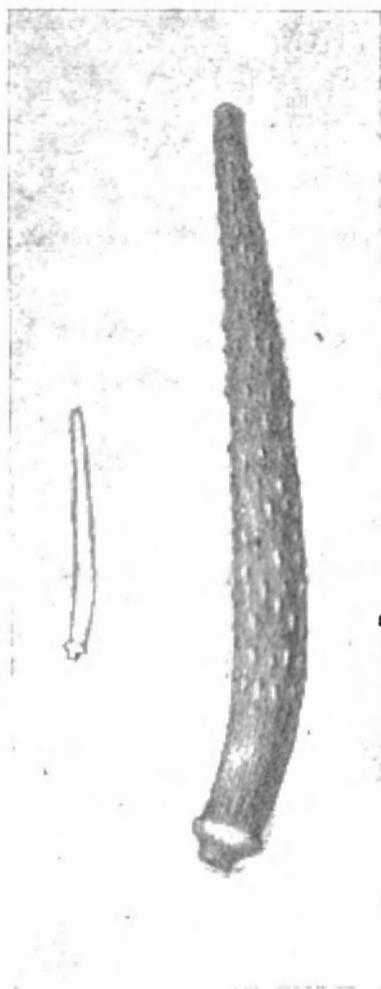
Besides those considered above, the following lots of *Archaeocidaris Urii* may be recorded. Mus. Roy. Belg. n<sup>o</sup>. 39 40, 41, 92, I. G. 3440, Calcaire Carbonifère, Visé, Ryckholt coll. two large interambulacral plates, the largest 13 mm. wide by 11 mm. high ; another lot with same data consists of 14 spines, an interambulacral plate and a pyramid of a lantern ; still a third lot with same data, consists of two fragmentary spines and seven interambulacral plates. Mus. Roy. Belg. n<sup>o</sup>. 106, 107 and 108, I. G. 9083, several external moulds of interambulacral plates (Plate V. fig. 8, 9) from Nouvelle carrière Mutsaerts à Bioul, Houiller, Namurien. Assise de Chokier base, Nm. 1 a.

In the British Museum, from Tournai, n<sup>o</sup> E 18,189-90, there are two large interambulacral plates, and n<sup>o</sup>. E 9322, two large teeth also two distal fragments of teeth that are referable to *A. Urii*. The largest tooth measures 22 mm. in length by 7 mm. in width.

*Archaeocidaris propinqua* sp. nov.

Text-fig. 3, Plate I, fig. 5a-5b.

Known only from primary spines which are arcuate, tapering, vertically finely striate, with numerous nodose spinules directed distally, a prominent



Text-fig. 3. — *Archaeocidaris propinqua* sp. nov. Tournai.  
(Mus. Roy. Belg. n<sup>o</sup> 86, I. G. 3031, Nat. size and X 3.)

milled ring exists proximally, above which the spine is smooth for a short distance. Spines measure 20-26 mm. in length.

This species resembles most nearly the American *A. aculeata* Shumard, but differs in that in *propinqua* the spinules are more appressed and directed distally. The drawings of Plate I, fig. 5, were made by an artist for Professor de Koninck.

Mus. Roy. Belg. n° 86, I. G., 3031, Tournaisien, Tournai, coll. Le Hon, several spines, holotypes, British Museum, n° E 9321, Tournai, purchased of Piret, nine spines, paratypes. Also British Museum, Tournai, n° E 18,191-2, two spines with spinules directed distally are referable to *A. propinqua*.

### *Archaeocidaris Muensteriana* (KONINCK).

Plate I, fig. 8a-8c.

*Cidaris Muensterianus* KONINCK, 1842-1844, p. 35, Plate E, fig. 2a-2d.

*Cidarites Muensterianus* KONINCK, 1842-1844 (description of), Plate E.

*Lepidocentrus Münsterianus* KONINCK, 1870, p. 260.

*Archaeocidaris Münsteriana* LOVÉN, 1874, p. 43.

Known only incompletely from dissociated plates and primary spines. Interambulacral plates high, rounded, hexagonal or polygonal, primary tubercle perforate, with moderately large scrobicular circle, small secondary tubercles scattered over area beyond the scrobicular circle without apparent order. Primary spines elongate, fusiform, with numerous vertical denticulate ribs regularly arranged in parallel longitudinal series. A primary spine as figured about 37 mm. long.

De Koninck in his original description records this species from the Carboniferous of Visé. The location of his type specimens is not known to me. Mus. Roy. Belg., Tournaisien, the original of Plate I, fig. 8a-c is unfortunately lost. Mus. Roy. Belg. n° 97, I. G. 8353, six primary spines, the largest 27 mm. in length, from Tournaisien, Tournai, Carrière Dutoit. Musée Maredsous, twelve spines from Tournai.

In the British Museum there are several lots of *A. Muensteriana* as follows : n° [56,991], Calcaire Carbonifère, Visé, five spines and five plates, three plates in this lot are different, but I do not know what they are. Brit. Mus. Tournai, n° E 18,193-5, three spines with fine denticulate spinules, the longest spine measures 15 mm. in length, but is incomplete distally. Brit. Mus. Tournai, n° E 9329 and n° E 9330, five interambulacral plates and six spines ; the spines are rather slender for the species but they may be younger spines of an adult or from a young individual. Brit. Mus. another lot of *A. Muensteriana* from Tournai, n° 32,848 consists of three ambulacral plates, which are low, wide, with

secondary tubercles, they are the only ambulacral plates I know of in the species; also three interambulacral plates. The largest of these interambulacral plates measures 10 mm. wide by 8 mm. high, and one of them has lobing of the borders as shown in de Koninck's figures.

#### FAMILY LEPIDOCENTRIDAE LOVÉN.

##### Genus KONINCKOCIDARIS DOLLO and BUISSET.

*Koninckocidaris*, DOLLO and BUISSET, 1888, p. 959. Messrs. DOLLO and BUISSET described the genus with one species *K. Cotteaui* which is the type. I later described a second species, *K. silurica*, from the Upper Silurian of New York State. It is the oldest known species of American Echini.

##### *Koninckocidaris Cotteaui* DOLLO and BUISSET.

*Koninckocidaris Cotteaui*, DOLLO and BUISSET, 1888, p. 959.

This species is known only from a fragment of a test and isolated plates, but it was probably spheroidal as in *K. silurica* Jackson. Ambulacra with two columns of plates in an area, plates high, two about equalling the height of an interambulacral plate. Each ambulacral plate with two pores. Messrs. Dollo and Buisseret say that the pore nearer the middle of the ambulacral area is higher up, adapically. This is opposed to what I have found in all Palaeozoic species, where the outer, or the adinterambulacral pore is the higher of the two. It is possible that this statement was due to a mistake in the orientation of the specimen, for if it were viewed with the ventral part up, then the inner pore would appear to be the higher of the two. Ambulacral plates bear numerous secondary tubercles similar to the secondary tubercles of interambulacral plates.

Interambulacra with seven columns of plates, strongly imbricating. The central columns of plates are narrower than the lateral columns, which are about equal. The plates of adambulacral columns bear a perforate primary tubercle, with, in addition, secondary tubercles, the other columns with secondary tubercles only. Spines are of two types, the larger belonging without doubt to the primary tubercles of the adambulacral plates, the other, slender and extremely delicate, are referable to the secondary tubercles. Both types of spines are described as cylindrical and longitudinally striate. This species has never been figured and is known only from Messrs. Dollo and Buisseret's original description. They give Carboniferous Limestone of Belgium for all the Echini they consider, but do not give a detailed locality or geological horizon for this species, and the present whereabouts of the specimen is unknown.



I described a second species, *Koninckocidaris silurica* Jackson, from the Upper Silurian of Rochester, New York (Phylogeny, p. 285, Plate XIX, fig. 1; Plate XX, fig. 5, 6). In this species also the ambulacral plates are high, three about equalling the height of an interambulacral plate. There are eight columns of plates in an interambulacral area, the central column being distinctly narrower than the others. As it is an internal view of the test, data of spines and tubercles are wanting.

In the young of modern Echini, ambulacral plates are relatively higher than they are in the adult, therefore in nearly associated types, high ambulacral plates may be considered more primitive than low plates. For this reason *Koninckocidaris* with high ambulacral plates is considered more primitive than the nearly allied *Lepidocentrus* with low ambulacral plates. The species *Koninckocidaris Cotteaui* and very possibly the genus differs from species of *Lepidocentrus* in having primary tubercles only on adambulacral plates.

#### Genus LEPIDOCENTRUS MÜLLER.

*Lepidocentrus* MÜLLER, 1857, p. 258.

Three species of *Lepidocentrus* are known from Germany and two are recorded from America. Messrs. Dollo and Buisseret (1888, p. 959) also record three species from the Carboniferous of Belgium, but without description. These I have already considered in the Phylogeny (p. 457).

The type-species of *Lepidocentrus* is *Lepidocentrus eifelianus* Müller.

#### *Lepidocentrus eifelianus* MÜLLER.

Text-fig. 4a-4f; Plate I, fig. 9a-9g; Plate X, fig. 7a-7b.

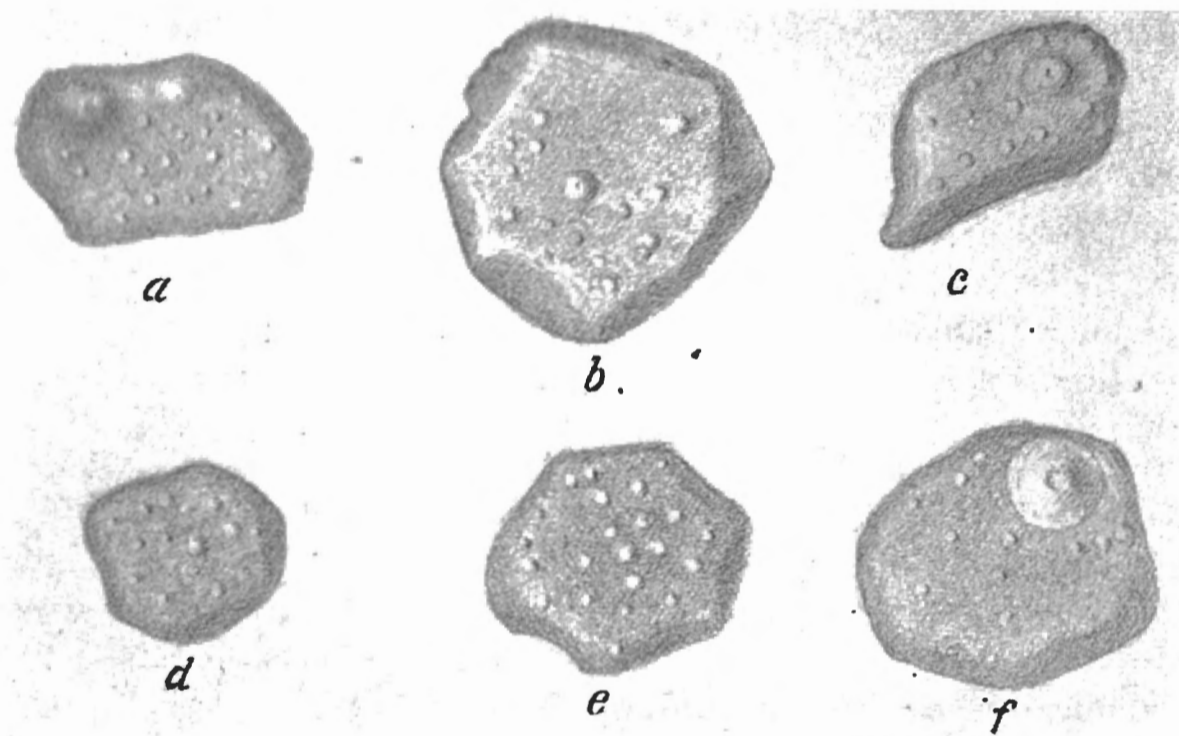
*Lepidocentrus eifelianus* MÜLLER, 1857, p. 258, Plate III, fig. 1-8.

This species is known only from interambulacral plates which are thin, scaly, strongly imbricating, hexagonal, rhombic, polygonal, or irregular in outline. The plates mostly have a single perforate primary tubercle of varying size with scrobicule and in addition secondary tubercles. Or occasional plates have secondary tubercles only. The largest interambulacral plate measured in Belgian material is 7 mm. wide and 5 mm. high, the plates are usually wider than high. What I consider as *Lepidocentrus eifelianus* is represented by over 100 specimens from Tournai. This species was previously known only from the Devonian of Germany, and with this difference of geological horizon, it is quite possible that the material from the Lower Carboniferous of Tournai is a different species. After comparing specimens that I borrowed from the Brussels Museum with specimens of *L. eifelianus* from Nohm and Rommersheim, Germany, in the Schultze collection, in the Museum of Comparative Zoölogy, I fail to see any



basis for separating the Tournai materia' as a distinct species. With more complete specimens, grounds for making it a distinct species would quite likely be found.

The following lots of specimens have been seen : Mus. Roy. Belg. n<sup>os</sup> 73, 74, 77, 81 and n<sup>o</sup> 86, I. G. 3031, Tournaisien, Tournai, Coll. Le Hon, some 90 interambulacral plates; another lot with same data, 15 plates. Same museum, n<sup>os</sup> 75, 76, 79, I. G. 3440. Tournai, coll. Ryckholt, a specimen with seven plates in contact, forming a fragment of an interambulacrum (Plate X, fig. 7a). Same museum, Tournai, coll. Ryckholt two lots of dissociated interambulacral plates. Same museum an external mould of a single interambulacral plate, associated



TEXT fig. 4. — *Lepidocentrus eifelianus* MÜLLER. Tournai, Belgium.  
(Mus. Roy. Belg. n<sup>o</sup> 86, I. G. 3031. X 4.)

with similar moulds of plates of *Archaeocidaris Uriei*, n<sup>o</sup> 108, I. G. 9083, from Nouvelle carrière, Mutsaarts à Bioul, Houiller, Assize de Chokier, base, Nm. 1 a.

*Lepidocentrus mammillatus* sp. nov.

Plate I, fig. 12a-12d.

This species is based on an interambulacral plate which is thick, polygonal in outline, strongly beveled on the edges indicating strong imbrication. On the surface is an elevated, perforate, excentrically placed primary tubercle with scrobicule. Surrounding the area of the primary tubercle are numerous small secondary tubercles. It measures about 7 mm. in height, 8 mm. in width and 2 mm. in thickness.

This species is based on a single specimen. It differs from any other species of *Lepidocentrus* in the relative great thickness of the interambulacral plate and also differs in the great development and prominence of the primary tubercle.

Mus. Roy. Belg. n° 48, I. G. 3440, Carbonifère inférieur (Viséen), Visé, holotype.

*Lepidocentrus* sp.

Plate I, fig. 10a-10d.

A single interambulacral plate reasonably referable to *Lepidocentrus* is thick, rounded in outline, strongly beveled on the sides, indicating strong imbrication. On the surface it is thickly studded with secondary tubercles varying considerably in size, but there is no primary tubercle.

The plate measures 8 mm. in width, 7 mm. in height, and 3.5 mm. in thickness. It is without reasonable doubt referable to the genus *Lepidocentrus*, but cannot be referred to any known species of that genus, and is quite insufficient to make the basis of a new species. The drawings were made by an artist for de Koninck.

Mus. Roy. Belg. n° 50, I. G. 3440, Carbonifère inférieur, Viséen, Visé, only one plate.

Genus *DENECHINUS* gen. nov.

In each ambulacral area two columns of low plates, imbricating adorally. In the interambulacra in each area many columns of thin scaly plates, imbricating adapically. Interambulacral plates each with several small perforate primary tubercles, which give rise to long but fine primary spines. Secondary tubercles very probably existed, but unknown. This genus is named for Denée, Belgium, in recognition of the remarkable number of genera and species of Palaeozoic Echini found in that locality. *Denechinus* comes nearest to *Lepidocentrus*, but differs in that there are several primary tubercles to an interambulacral plate, instead of a single primary tubercle. It also differs in that the primary spines are long and slender, instead of relatively short. Type-species, *Denechinus tenuispinus* sp. nov.

*Denechinus tenuispinus* sp. nov.

Plate I, fig. 11.

Ambulacrum narrow, with two columns of low wide plates, the plates with two pores near the adinterambulacral suture. Tubercles of ambulacral plates not preserved, but they were probably small secondaries. Interambulacra

wide, with thin, polygonal, scale-like plates, imbricating adapically. The interambulacral plates are small for such a large sea-urchin and do not extend completely across the width in any of the five areas, so that the number of columns is not definitely known. Judging from the size of the known plates there were probably about twelve columns in an area. Interambulacral plates each bear several small perforate primary tubercles, three or four such tubercles were counted on several plates. The most striking feature of this sea-urchin as far as preserved is the spines, which are swollen at the base, long, acicular, all of approximately the same length as far as preserved. There is no evidence of the existence of small secondary tubercles and spines, but the specimen is not clearly preserved and such may have existed. The structural detail is largely obliterated. A prominent lantern exists, protruding from the centre of the test.

This new sea-urchin is represented by a single specimen, seen in ventral view, so the lettering of the areas is anticlockwise, instead of clockwise, as it would be if seen in dorsal view (compare Plate VII). It is flattened on the slab, is almost completely smoothed out on the rock and shows the structure very imperfectly excepting at selected spots. Yet as a new type for the Palaeozoic it is an interesting form. The specimen is nearly circular in outline. It measures 205 mm. in diameter through interambulacrum A and the opposite side, and 195 mm. in a plane at right angles to the same. As an average, therefore, it measures about 200 mm. in diameter. The fact that the details, even the outlines of plates, are largely obliterated, seems to indicate that the plates were very thin. The ambulacra are largely obliterated, but show in part in areas H and J, as indicated by white lines in the figure. The ambulacra are narrow and measure about 15 mm. in width on the periphery. The interambulacra are wide, measuring about 110 mm. in width in a straight line on the periphery. The Aristotle's lantern which projects from almost the exact centre of the test is somewhat oval in outline, indicating compression or displacement of parts; on the longer axis it measures about 40 mm. across.

In area J, toward the periphery, there are ambulacral plates which reach half-way across the width of the area; there are also obscure plates on the other half of the same area. These plates are low, wide, imbricate adorally, and with two pores near the interambulacral suture. No tubercles were seen on the ambulacral plates but there were probably small secondaries as in other genera of the family.

Interambulacral plates as well as ambulacral are very imperfectly preserved, and only here and there can one get the outlines of individual plates. The interambulacral plates are polygonal, thin, scale-like and imbricate adapically. They are very small for such a large sea-urchin. The largest plate measured is about 8 mm. wide, by 5 mm. high. Interambulacral plates are fragmentarily preserved and in no area do the interambulacral plates extend

completely across the width of the area, so that one cannot say how many columns existed; as the width of an area at the periphery is about 110 mm., there must have been a large number of columns, probably at least twelve in an area. The interambulacral plates each bear several small perforate primary tubercles. The most striking feature of this specimen and species is the spines, which are quite numerous preserved. They are swollen at the base, long, acicular; several spines measured are 19-23 mm. in length. They are the longest slender spines that I know of in the Palaeozoic. Small secondary spines may have existed, but such are not preserved.

*Deneechinus tenuispinus* stands out strikingly as a type in having several small perforate primary tubercles to an interambulacral plate, in having long, slender primary spines, and in its great size, which is exceeded in the Palaeozoic by only two other species, namely, *Proterocidaris gigantea* Koninck and *Fournierechinus deneensis* gen. et sp. nov., both of which also occur at Denée.

The holotype and only known specimen is in the Maredsous Museum, n° 147. Marbre noir de Dinant (Viséen inférieur V1a), Denée. A cast of the same is in the Mus. Comp. Zoöl., n° 3327.

#### Genus HYATTECHINUS JACKSON.

*Hyattechinus* JACKSON, 1912, p. 291.

Three species have previously been referred to this genus, all from the Lower Carboniferous of America. The type-species is *Hyattechinus Beecheri* Jackson.

#### *Hyattechinus elegans* sp. nov.

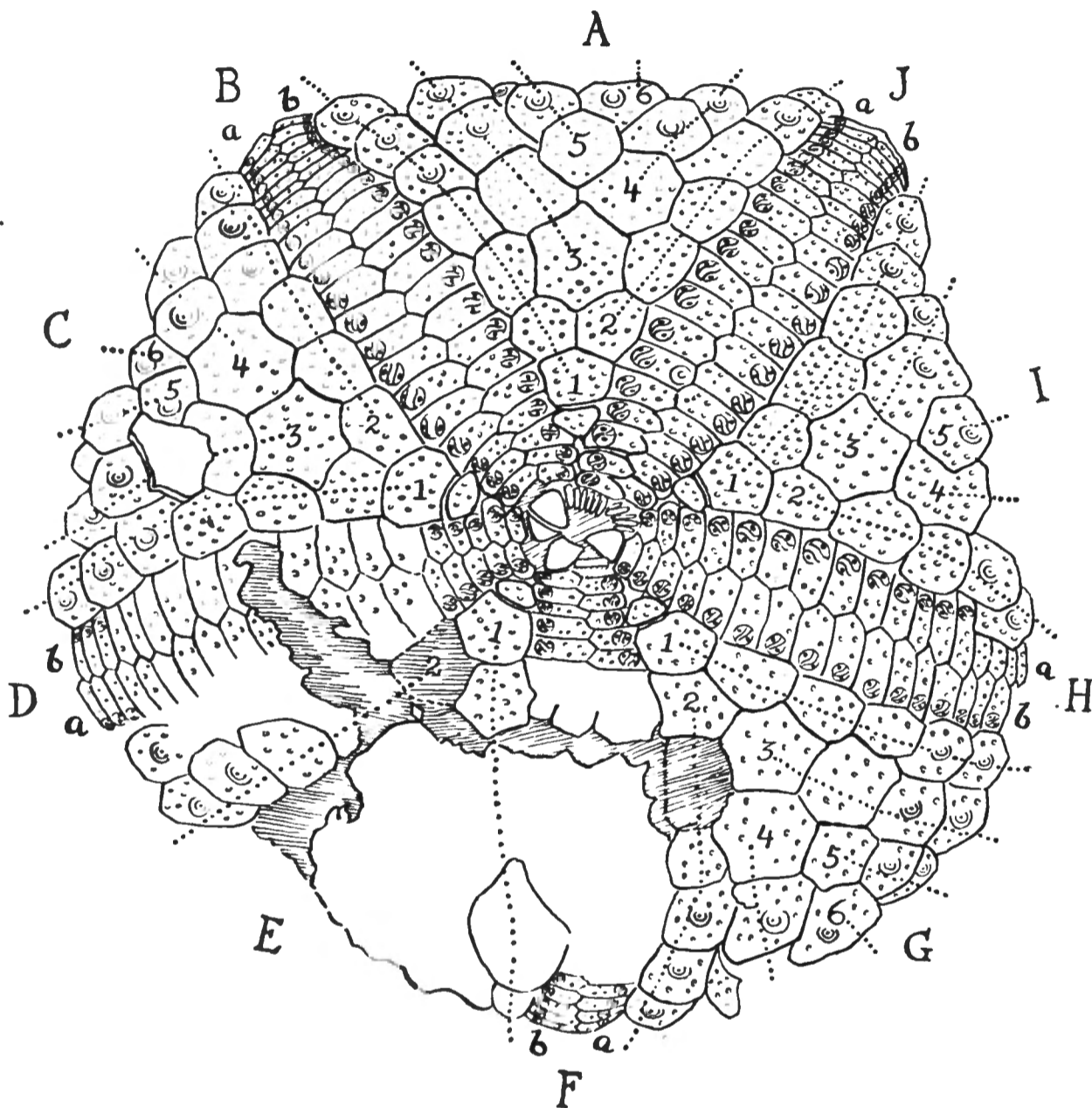
Text-fig. 5. Plate IV, fig. 2, 3; 4a-g. Plate V, fig. 5a-r.

The holotype is a ventral view of a test very complete as far as the mid-zone. Test spheroidal or lower, pentagonal in horizontal outline at the mid-zone, ambulacra relatively wide and petaloid adorally, narrow above this zone. Ambulacral plates relatively wide and high in the petaloid portions adorally, two plates equalling the height of an adambulacral plate. Narrow and lower above this zone, where about five ambulacral plates equal the height of an adambulacral plate. Ambulacral plates each with two pores, the outer pore higher, and the pores separated by a median elevated ridge, surrounded by a marked peripodium. Numerous small secondary tubercles on ambulacral plates. The ambulacral plates imbricate strongly adorally (Plate IV, fig. 3).

On the interior of the test certain adoral ambulacral plates bear a spinose projection, situated between the pores and the perradial suture. These projections were not seen in the holotype, but were seen (Plate IV, fig. 4g) in disso-

ciated ambulacral plates from the Maredsous and British Museums. as described. They are evidently comparable to similar internal spinose projections that I previously described in two species of the genus (*Phylogeny*).

Interambulacra with, as far as known, six columns of plates which imbricate strongly adapically and from the centre outward and over ambulacrals on



Text-fig. 5. — *Hyaltechinus elegans* sp. nov.

Tournaisien, Tournai, holotype  $\times 2$ . Drawn from photograph by Miss Esther Jackson. Remains of dental pyramids in centre, ambulacral plates on peristome, a non-ambulacral plate below each primordial interambulacral plate. Coronal ambulacral plates high, wide adorally, low and narrower toward periphery. Five primordial interambulacral plates succeeded by additional columns passing adapically. Interambulacral plates adorally with secondary tubercles only, adapically with primary and secondary tubercles.

the adradial suture. The first four rows of interambulacral plates adorally bear secondary tubercles only. Above this zone primary tubercles appear and on attaining the fifth to the seventh rows from the peristomal border each plate has

a perforate primary tubercle with scrobicule and in addition many secondary tubercles.

The holotype shows nothing of the dorsal side, but the evidence from the marginal plates is that the ambulacra are narrow with low plates, and the interambulacra broad with rounded polygonal plates, with at least usually a perforate primary tubercle and secondary tubercles. There are a few small delicate spines on the holotype measuring about 2 mm. long, seen in areas C and I. These are doubtless spines associated with the secondary tubercles. There are no remains of primary spines in the holotype, but primary spines apparently referable to this species exist in the Maredsous specimens as there noted (p. 29, Plate IV, fig 4e).

The holotype of this most interesting species is from the Tournaisien, Tournai. It is the collection of Prof' H. de Dorlodot in the « Institut de Géologie », Louvain, where I had the privilege of studying it. M. le Prof' A. Salée most kindly undertook to have photographs of the specimen made for me. It is a keen pleasure to me to find in Belgium a new species of the genus which I named in honour of my great master, the late Professor Alpheus Hyatt. It is an exceptionally perfect specimen, for, while one interambulacrum with its two associated ambulacra are partly wanting, it is practically complete from the mouth to the mid-zone in seven areas. It is one of the most beautifully preserved specimens of a Palaeozoic Echinoid that I have ever seen (Plate IV, fig. 2, 3).

The test measures 58 mm. in diameter through an ambulacrum and opposite interambulacrum in two different planes. The pentagonal outline of the test is a most interesting feature. A pentagonal outline is a very unusual feature in regular Echini and in the Palaeozoic (excepting in so far as *Fournierechinus deneensis* sp. nov., may be considered pentagonal) I have only seen it in *Hyattechinus pentagonus* Jackson (Phylogeny). In *Hyattechinus pentagonus* the pentagonal form is strongly developed as the name indicates. The fact that a similar form crops out in a distinct species of the same genus is striking. In *Hyattechinus elegans* on the periphery each interambulacrum presents very nearly a straight line across from one ambulacrum to the next, so that the tips of the several ambulacra coincide with the angles of the pentagon. An ambulacrum broad adorally, somewhat petaloid in character, and narrowing adapically is also a very unusual character in Regular Echini and in the Palaeozoic is known only in the genus *Hyattechinus*. Ambulacrum J on the periphery measures 7 mm. in width and half-way between the periphery and the peristome measures 9 mm. in width. The other ambulacral areas are all practically the same, as shown in areas B, D and H, and partially in area F. Interambulacrum A on the periphery measures 30 mm. in width, and the other interambulacra are practically the same, except area E, which is incompletely preserved.



The peristomal area, which is very perfectly preserved, measures 12 mm. in diameter. In the centre of the peristome in areas C, G and E, the tips of dental half-pyramids are seen in place, shown best in area C, where the two half-pyramids are in contact adorally. From the oral centre to the basicoronal row of the corona the peristome is covered with ten vertical series of ambulacral plates, all in contact. These ambulacral plates are similar to those of the corona, excepting that they become progressively narrower adorally in the confined space. The plates imbricate adorally, each has two pores and numerous secondary tubercles. Below each of the five primordial interambulacral plates of the corona there is a small triangular plate about 2 mm. in height and 2.5 mm. in width where in contact with the adoral border of the primordial interambulacral plates. These five small interradial plates bear secondary tubercles. It seems that they may be considered as non-ambulacral peristomal plates. Similar non-ambulacral peristomal plates apparently occur in *Hyattechinus pentagonus* Jackson, as figured (Phylogeny, Plate XXIV, fig. 4, and Plate XXV, fig 1), but they were not recognised as such, or described in my original publication of the species. These plates may be compared to the non-ambulacral plates seen on the peristome in the Cidaridae, but I have never seen a case before (unless in *Hyattechinus pentagonus*) in which there was only a single plate in each area as shown in this choice specimen. Single non-ambulacral peristomal plates, however, have been described by A. Agassiz (Panamic Echini, 1904) in *Porocidaris Cobosi* A. Ag., but these are thin irregular plates not in contact with coronal plates and of an apparently different character from those here described in *Hyattechinus*.

The view has been suggested to me by Dr. H. L. Clark that what I have called the non-ambulacral peristomal plates of the peristome in *Hyattechinus elegans* should properly be considered the primordial interambulacral plates, succeeded in each area by a second single plate as known in some recent types (*Urechinus Naresianus* A. Ag. ; Lovén, On Pourtalesia, 1883, Plate XXI; *Plexechinus cinctus* A. Ag. and other Urechinidae and Pourtalesiidae, A. Agassiz, Panamic Echini; Phylogeny, text-fig. 27 p. 70). This view would be very satisfactory to me as indicating a closer resemblance to *Bothriocidaris* which, with its single column of plates in each interambulacral area, and with other characters, I consider the most primitive known echinoid.

The ambulacral plates of *H. elegans* have been considered sufficiently above. The interambulacral plates of the corona are extremely interesting. In each of the five areas the primordial interambulacral plate is in place and perfectly preserved in the basicoronal row. Each of these plates is pentagonal, with a straight edge adorally, inclined sides in contact with the ambulacra laterally, and adapically the apex of the pentagon is in contact with the two plates of the second row in four of the five areas. Above the first row each of the interambulacra A, C, G and I are practically complete to the periphery,



but area E is largely wanting. Area A is perhaps the clearest and a description of it will answer for the four most nearly complete areas. In the second row two plates immediately succeed the primordial interambulacral plate and mark the introduction of a second column of plates. These two plates of the second row are in place in areas A, C, G and I, but in area E only one of the two is in place, the second plate and most of the succeeding plates of the area having been lost. In the third row there are three plates, the initial plate of column 3 being a hexagon as usual. To and including the third row the interambulacral plates bear numerous secondary tubercles, but no primary tubercles. In the fourth row there are four plates, and two of these bear very small primary tubercles in addition to the secondary tubercles. In the fifth row there are five plates and in the sixth row six plates, marking respectively the introduction of the fifth and sixth column of plates in the area. On the periphery in area A there are four plates of the seventh row, but this row is not complete, and it marks the limit of the specimen. In the fifth to the seventh rows the interambulacral plates are more rounded in outline than are the more adoral plates of the area and each plate has a relatively large perforate primary tubercle with scrobicule and in addition secondary tubercles.

The development of the interambulacrum in *Hyattechinus elegans* from the adoral border adapically is structurally the same as I showed in three other species of the genus (Phylogeny), with the exception that here the plates are in place, whereas those previously described existed as external or internal moulds of the plates. The structural characters of development of the interambulacra, with the primordial interambulacral plates in the basicoronal row, succeeded by additional columns of plates passing adapically are again the same as I showed (Phylogeny) in *Perischodomus biserialis* M'Coy and *Pholidocidaris irregularis* Meek and Worthen. Similar structural characters are also shown by Bather (1918, 1920) in *Pholidocidaris anceps* (Austin).

The initial plate of column 3 adorally is hexagonal with somewhat incurved borders. It is apparently directly comparable to the star-shaped plate shown in Plate V, fig. 5 k, compare Plate IV, fig. 2.

The dorsal portion of the holotype of *Hyattechinus elegans* is quite invisible. It is possible that more columns of plates were added, but of this there is no evidence. It is assumed therefore that the six columns seen on the periphery is the full number attained by the species.

This species is nearest to *Hyattechinus pentagonus* Jackson, from the Lower Carboniferous of Pennsylvania (Phylogeny), but differs essentially in the much smaller number of columns of interambulacral plates attained. *Hyattechinus pentagonus* has fourteen columns in an area.

Besides the holotype there are some lots of dissociated plates that seem referable to *Hyattechinus elegans*. A tablet in the Brussels Museum, n° 71, I. G. 8353, from the Tournaisien, Tournai, has many dissociated interambula-

cral plates and six ambulacral plates, Plate V, fig. 5 *a-r*. The ambulacral plates are low, wide, Plate V, fig. 5 *m-r*, strongly imbricating, with pores, peripodia and tubercles similar to those seen in the holotype adorally. The interambulacral plates, Plate V, fig. 5 *a-j* and *l*, are polygonal, rounded, with strongly bevelled edges and bear a perforate primary tubercle, with secondary tubercles, or in a few cases secondary tubercles only. There is one very peculiar star-shaped plate, Plate V, fig. 5 *k*. This plate has six rays, symmetrically arranged, and the surface bears numerous secondary tubercles only. In the Brussels Museum, n° 67, I. G. 3031, from Tournai, Coll. Le Hon, there is a second star-shaped plate, similar to that just described. This second plate evidently had six rays, though one is broken off, and measures 6 mm. in diameter. These star-shaped plates I think are doubtless cases of the preservation of the initial plate of column 3, which, as described, is six-sided, with something of a star-shaped form (Plate IV, fig. 2).

In the Musée Maredsous, n° T. 211, are specimens of dissociated plates and spines from Tournai, collected by the late Dr. A. S. Piret that I would refer to *Hyattechinus elegans* (Plate IV, fig. 4 *a-g*). Of these there are two ambulacral plates, one of which (Plate IV, fig. 4 *g*) on the inner or proximal side has the remains of a relatively stout spinose projection lying between the pores and the inner border of the plate, which is evidently similar to the spinose projections that I described in *Hyattechinus Beecheri* Jackson and in *Cidarids* (Phylogeny, p. 61 and 297; Plate XXIV, fig. 3; Plate XXVI, fig. 1). Such spinose projections on ambulacral plates as far as I am aware occur only in the *Cidaroida* and in *Hyattechinus*. There are in the same lot four interambulacral plates (Plate IV, fig. 4 *a-d*) three with primary and secondary tubercles and one with secondary tubercles only, also there are three primary spines (Plate IV, fig. 4 *e*) which are slender, tapering, swollen at the base, with fine longitudinal striae. The longest spine measures 9 mm. in length. These spines are closely similar to those of *Pholidocidaris tornacensis* (Plate V, fig. 7), but are probably referable to *Hyattechinus elegans*.

In the British Museum, n° E 9333 and E 9334, there is a series of dissociated plates from the Tournaisien, Tournai, purchased of Piret, Nov. 1905. There are five ambulacral and thirteen interambulacral plates closely similar to those shown in Plate IV, fig. 4, and are doubtless referable to the same species. One of the ambulacral plates has a spinose projection internally similar to that described in the Maredsous specimen.

In the British Museum, n° 12,262, from the Pilton Beds, Top Orchard, Pilton, there is an undescribed species that I would refer to the genus *Hyattechinus*. The specimen consists of counterparts, mutually supplementary. It shows ambulacra wide, sub-petaloid, with high plates adorally, narrow with low plates adapically. Ambulacral plates imbricate adorally and the internal moulds adorally show pits near the perradial suture which are casts of internal

spines such as I have shown in *Hyattechinus rarispinus* (Hall) and *H. Beecheri* Jackson. Interambulacra with about eight columns of plates imbricating adapically. The specimen consists of external and internal impressions of plates and is somewhat confused. It is hoped to describe this in a later publication.

#### FAMILY PALAEECHINIDAE M'Coy.

There are a number of species of this family occurring in the Palaeozoic of Belgium and including some very interesting forms. Of those species found at Denée, the ambulacral detail is usually obscure, and in some cases cannot be made out at all, so that one has to judge of the generic and specific identification from other characters. This is a somewhat questionable procedure, but it is the only one possible with the material in hand.

Of the genera of this family represented by Belgian material, in *Palaeechinus* there are two columns of plates in each ambulacrum; in *Maccoya* there are also two columns in an area, but with the difference that at and near the mid-zone every alternate plate is nearly or quite cut off from contact with the interambulacrum by the marginal enlargement of their fellows; in *Lovenechinus* at the mid-zone (in which zone the typical ambulacral characters are developed) there are four columns of plates in an ambulacrum, consisting of two median columns of wider plates and two lateral columns of narrower plates.

#### Genus PALAEECHINUS M' Coy.

*Palaechinus* (pars) M' Coy, 1884, p. 171; POMEL, 1883, p. 114.

The genus *Palaeechinus* in its restricted sense with two columns of plates in each ambulacrum was known previously by only three species from Europe and one species (referred doubtfully to the genus) from America. The type-species of *Palaeechinus* is *P. ellipticus* M'Coy.

#### *Palaeechinus globulus* sp. nov.

Plate II, fig. 10-14.

Test spherical, ambulacra narrow with two vertical columns of low, wide plates in an area, each plate extending across the half-area, about eight ambulacral plates equal the height of an adambulacral plate. Interambulacra with four columns of plates, high, hexagonal in median columns, pentagonal in adradial columns. Impressions of plates in parts of the external mould show a large number of secondary tubercles to each plate, as is usual in the genus and family.

The specimen measures 47 mm. in height and also 47 mm. in diameter through the mid-zone. It is the most perfectly spherical Palaeozoic sea-urchin that I know of. The width of ambulacrum J on the internal mould in the mid-zone is 6 mm. and the width of interambulacrum A in the mid-zone is 25 mm.

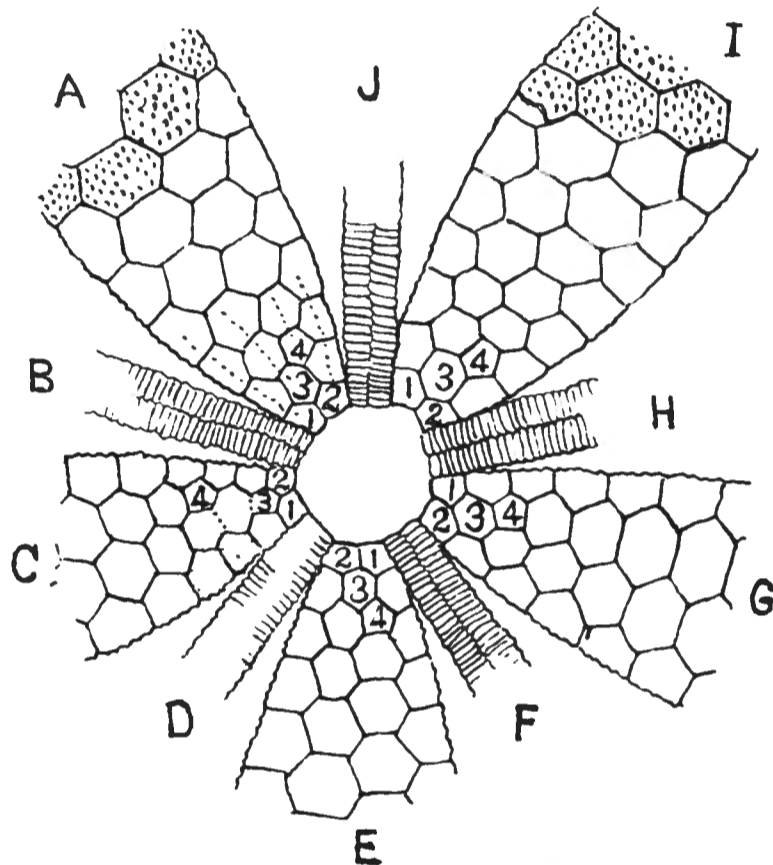
*Palaeechinus globulus* comes nearest to *Palaeechinus quadriserialis* Wright, from the Lower Carboniferous of Ireland, which also has four columns of plates in each interambulacrum; but *P. globulus* differs in that the test is spherical, instead of vertically elongate; it also differs in its more massive build.

*Palaeechinus quadriserialis* Wright is known from several specimens. There are two very choice ones in the British Museum, both of which I have had the privilege of studying. One of these, British Museum, n° E 11,586, from the Lower Carboniferous of Middleton, County Cork, Ireland, Joseph Wright coll., received in 1913, is the holotype of the species (cast in Mus. Comp. Zoöl. n° 3346). A second specimen, British Museum, n° E 193, from Rathkeale, County Limerick, Ireland, is from the W. H. Bailey collection, received in 1882. This latter is one of the most complete of known Palaeozoic Echini, and I described and figured it in detail in the Phylogeny (Plate XXIX, fig. 1; Plate XXX, fig. 1-4).

In the Free Public Museum, Liverpool, there are four incomplete specimens from the Austin collection that are structurally referable to *Palaeechinus quadriserialis*. Through the kindness of the Director, Dr. J. J. Simpson, I examined these. Each has two columns of plates in the ambulacra and four columns in the interambulacra. One of the specimens, n° 375, is from Hook Point, County Wexford, Ireland. Two, n° 377 and 379, are without data, but are doubtless from the same locality. One, n° 380, is from Clifton, Bristol.

This interesting new *Palaeechinus globulus* is in the collection of the Brussels Museum. It consists in part of a mould of the interior of the test, Plate II, fig. 10-13, and in part a mould of the exterior in the rock matrix, in the latter some of the plates themselves are still in place. As stated, the test measures 47 mm. in the vertical axis and the same through the mid-zone, it is therefore perfectly spherical. These measurements are made from the mould of the interior so that if the plates were in place, the measurements would be slightly increased. Again, it is stated that the width of the ambulacrum J in the mid-zone is 6 mm. and interambulacrum A in the same plane 25 mm. These measurements were made on the internal mould. As in *Palaeechinus* and all of its family, the ambulacral plates bevel over the interambulacral on the adradial suture (Phylogeny, p. 302, Plate XXXV, fig. 5), therefore measurements taken on the exterior would differ slightly from those taken on the interior. The specimen is essentially complete ventrally, but incomplete dorsally, no ocular and genital plates being preserved and in some areas the test is wanting dorsally.

Each of the five interambulacra has four columns of plates, though some of the areas are wanting dorsally. Interambulacrum A has two plates in the basicoronal row, three plates in the second row, also three plates in the third row, and four plates in the fourth row. Column 4 originates in a pentagonal plate on the right of the centre. In interambulacrum C the first row of basicoronal plates is wanting, but there are three plates in the lowest row existent, and four plates in the next row, the initial plate of column 4 being a pentagonal plate on the left of the centre. Interambulacrum E is imperfect ventrally. In interambulacrum G (not seen on the internal mould but seen in



Text-fig. 6. — *Palaeochinus quadriseptatis* WRIGHT.

Lower Carboniferous, Rathkeale, County Limerick, Ireland. (*British Mus.*, n° E 193×1.5. Adapted from Jackson, 1912, Plate 30, fig. 3.) Showing development.

the matrix) the basicoronal row of two plates is wanting, but there are three plates in the first row existent and four plates in the next succeeding row. The initial plate of column 4 is a pentagon on the right of the centre. Interambulacrum I has two plates in the basicoronal row, three plates in the second row and again three plates in the third row, and four plates in the fourth row. Above the point of origin of the fourth column in either the third or fourth row in the several areas, no more columns are added. In this specimen it is seen in areas A and I that the fourth column does not originate until the fourth row, there being in these two areas two rows of three plates. Typically in Palaeozoic Echini there is only a single row of three plates before the introduction of the fourth column as in areas A, I, G and E of text — fig. 6.

Rarely there may be two rows of three plates before the introduction of the fourth column as seen in area C of text — fig. 6. However I have never before seen a case in which more than one area had two rows of three plates before the introduction of the fourth column of plates. This study of the introduction of columns in *Palaeechinus globulus* is gathered in part from the internal mould and in part from the plates in place in the ventral part of the matrix, which shows additional features not seen on the internal mould. This detailed structure which is very complete in this choice specimen is not shown in the figures drawn by de Koninck's artist (Plate II, fig. 12, 13). Similar structural details are, however, shown in my figures of *Palaeechinus quadriserialis* from the British-Museum specimen (Phylogeny, Plate XXX, fig. 1, 3). To make clear the structure of *Palaeechinus globulus* the ventral portion of *P. quadriserialis* is here reproduced in text — fig. 6.

As I have shown, in the family Palaeechinidae the primordial interambulacral plates are resorbed in the advance of the peristome <sup>(1)</sup>. They are not retained in place in the basicoronal row as they are in *Hyattechinus* (text — fig. 5; Plate IV, fig. 3), *Perischodomus* and similar forms. The development of the interambulacrum is the same throughout the family Palaeechinidae as I have shown in many species (Phylogeny), differing only in the number of columns of plates attained, which is from four to thirteen in the known species.

The holotype and only known specimen of *Palaeechinus globulus* is in the Mus. Roy. Belg., n° 21, I. G. 2739, « Calcaire carbonifère de Celles (Tournaisien, assise de Celles, facies Waulsortien) », from Celles, near Dinant, coll. Edouard Dupont. Casts in Mus. Comp. Zoöl. n° 3314 and 3315.

#### *Palaeechinus visetensis* sp. nov.

Text fig. 7. Plate II, fig. 1-9.

Test very elongate in the vertical axis, measuring 28 mm. in height and 16 mm. in diameter through the mid-zone. It is therefore not far from twice as high as wide, proportionately by far the most vertically elongate echinoid known, either from the fossil or the recent faunas. In addition to the elongate form, another very extraordinary character appears to be that the ambulacral and interambulacral areas passing from the ventral border dorsally to the apical disc are built on a spiral curve, so that the dorsal limit of each area is about 30° removed from that occupied at its lowest point on the ventral border. In accord with the vertically elongate form and the clockwise spiral

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<sup>(1)</sup> 1896; Phylogeny; also studies of *Arbacia punctulata* and allies and of nonpentamerous Echini. (*Mem. Boston Soc. Nat. Hist.*, vol. 8, n° 4, p. 472.)



twist of the areas, the ambulacral plates are slightly inclined, instead of being horizontal. Coincidentally the interambulacral plates are vertically higher than they are wide and the angles of the interambulacral plates are so altered that they approach the character of a hexagon set on end (Plate II, fig. 8).

There are two columns of low, relatively wide plates in each ambulacrum, with the pores near the interambulacral suture. About seven or eight ambulacral plates equal the height of an interambulacral plate. Ambulacral plates bevel over the interambulacrals on the adradial suture, as in all the family. There are four columns of plates in each interambulacrum. Interambulacral plates are higher than wide, the sides of the individual plates, due to the elongate form and spiral twist of the test, are much altered in position from those of an ordinary member of the genus or family. Interambulacral plates each with numerous secondary tubercles. The height and diameter of this remarkable sea-urchin are given above. The ambulacra in the mid-zone measure 3 mm. in width, and the interambulacra in the same zone measure 8 mm. in width.

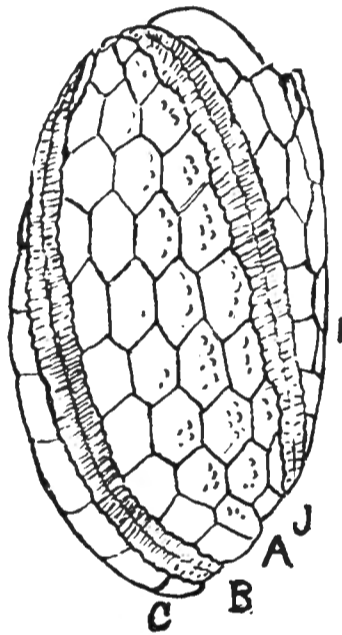
The characters of this remarkable sea-urchin are quite sufficient for generic distinction. However, as the detailed structure of the test and the development of the interambulacra are so essentially the same as in *Palaeochinus*, also as there are so few species in that genus, it does not seem necessary to make a new genus for its reception.

It is somewhat remarkable that a third species of *Palaeochinus* should be found with four columns of plates in the interambulacra. *Palaeochinus viséensis* differs from both *P. quadriserialis* Wright and *P. globulus* sp. nov. in the extreme elongation of its vertical axis; it differs from those species and from all other known Echini in the spiral twist of the vertical axis of the ambulacral and interambulacral areas and concurrent modification in the shape and angles of the plates. As far as size can be considered, it differs from other species of the genus in its very small size and delicately built test. This choice specimen from Visé, which is in the Brussels Museum, is light gray, the gray limestone filling the interior of the test, and where plates are wanting (Plate II, fig. 2), showing an impression of the proximal faces of the same. The question is, is the spiral structure of this specimen due to a mechanical post-mortem torsion, or is the spiral arrangement of the areas a feature normal to the species? I studied the specimen carefully from the point of view of its being a mechanical torsion. It seems, however, that this view-point is precluded because the spiral curvature of each of the areas is so definite and so uniformly alike in the arc of the curves, also the individual angles of each plate are so regular, and the plates are not at all misplaced but fit perfectly in place in their several areas. Whatever other material I have seen from the same beds showed no distortion, and Dr. Van Straelen told me that fossils from Visé are not subject to distortion. Studying the specimen with all possible care, the



view was forced on me that the form is original and is not a form super-induced by mechanical forces. Of course such a form might be an aberrant variant, but, on the principle of chances, it is exceedingly improbable that what must have been an excessively rare variation would be likely to be the only one discovered. I showed photographs to my friend, Dr. F. A. Bather, the eminent Echinoderm authority of the British Museum, and he agreed with me that the spiral form had every evidence of being the original, and not a case of mechanical torsion. I therefore adopt the view that the spiral form is the original character of the species and shall earnestly hope that a confirmatory specimen will be found.

As stated earlier, the ambulacra at the mid-zone measure 3 mm. in width, but as ambulacral plates bevel over the interambulacrals on the adradial



Text fig. 7. — *Palaeochinus visetensis* sp. nov., Visé, Belgium. (*Mus. Roy. Belg.* n<sup>o</sup>. 38, I. G. 3440. X 2.)  
Drawn by J. H. Blake from a photograph.

suture, the width of the ambulacra on the inner side is somewhat less. In a portion where the plates are absent the impression of their proximal face is only about 2.5 mm. wide. The inclination of the ambulacral plates due to the spiral form is shown well in Plate II, fig. 5, 8.

Interambulacral plates measure about 1 mm. in thickness. They are hexagonal in the median columns and pentagonal in the two adradial columns of each area as usual. The interambulacral plates are very peculiar in that in the mid-zone they are about 60 per cent higher than they are wide, whereas in all other species in the family, in the mid-zone the plates are wider than they are high. I have shown, however, in many cases in Palaeozoic Echini that the younger plates dorsally, near the apical disc, are often higher than they are wide (Phylogeny, Plate LIII, fig. 1). The most striking feature of the interambulacral plates in *visetensis* is the fact that the lower and upper sides of each plate, instead of being horizontal, are at a strongly inclined angle from

the horizontal and meeting the inclined sides of the plates, produce a hexagon in which the apices are nearly in a vertical line, widely different from the normal character of such plates (Plate II, compare fig. 8 and 15).

The plates of the interambulacrum are very nearly complete in areas A and I and in considerable part in other areas as well. Ventrally in two areas the interambulacral plates are in place as far as the peristomal border. In interambulacrum A there are two plates in the basicoronal row, three plates in the second row, and four plates in the third row (see text-fig. 6, p. 32), the initial plate of column 4 in this area is a pentagon on the left of the centre. In interambulacrum I also there are two plates in the basicoronal row, three plates in the second row and four plates in the third row. In both areas A and I, above the introduction of the fourth column, the four columns continue to the dorsal limit of the test.

The apical disc, while not very clear, is preserved in part. There is a genital plate above each of the interambulacra A, C and E, and an ocular plate lies above ambulacrum B, but nothing further could be made out. The positions of the apical and peristomal areas are excentrically twisted in accord with the spiral twist of the areas. The holotype and only known specimen of *Palaeochinus visetensis* is in the Mus. Roy. Belg., n° 38, I. G. 3440. Calcaire Carbonifère, Viséen, Visé, Belgium, coll. de Ryckholt.

*Palaeochinus ellipticus* M' Coy.

Plate II, fig. 15, 16; Plate III, fig. 5a-5f.

*Palaeochinus ellipticus* M' Coy, 1844, p. 172, Plate XXIV, fig. 3a-3d.

This species is characterized by a test a little higher than wide, with two columns of plates in each ambulacrum, and five columns in each interambulacrum. This species was, I believe, previously known only from the type which is from Ireland, and is in the Griffith collection, Science and Arts Museum, Dublin, where I studied it.

A well-preserved but fragmentary specimen from Tournai, in the Brussels Museum, is the first reported from Belgium. The specimen (Plate II, fig. 15) has a very clear half-ambulacrum in which the plates extend across the half-area, as is typical of the species and genus. The pore-pairs are beautifully clear and lie near the adradial suture. Six to seven ambulacral plates equal the height of an interambulacral plate. The half-ambulacrum measures 3 mm. in width so that the width of the whole ambulacrum would be about 6 mm. There are five columns of interambulacral plates. In Plate II, fig. 15, a left adambulacral column of pentagonal plates exists, also three intermediate columns of hexagonal plates are in place. In the lower part of the figure the initial pentagonal plate of column 5 is seen with a heptagonal plate on its right lower border. In Plate II, fig. 16, the right adambulacral column of this

area is represented by a single pentagonal adradial plate. This plate representing the right adradial column of the area may be recognized in Plate II, fig. 15 as the plate seen in edge view and lying just below the heptagonal plate of that area. Both the ambulacral and interambulacral plates are thickly covered with small secondary tubercles that are beautifully clear. The interambulacrum in the mid-zone, allowing for the right adradial column, measures about 24 mm. in width.

On the reverse side of this specimen, as shown in Plate II, fig. 16, the remains of an Aristotle's lantern are in place. It is represented by two half-pyramids in contact and also a tooth in place. The height of the pyramid is 8 mm. and the width across the two half-pyramids near the dorsal border of the same is 9 mm. On the left half-pyramid a sutural face exists for the attachment of the epiphysis of that side. Four additional half-pyramids are existent, but somewhat misplaced. The measurements of the complete pyramid show that the lantern was a little wider than high, indicating a lantern strongly inclined, and subtending an angle of some 45°. This is the same character that I have shown (Phylogeny) in other Palaeozoic types (*Archaeocidaris*, *Pholidechinus*, *Melonechinus*, *Meekechinus*). A wide-angled lantern is also characteristic of the young of modern regular Echini (Phylogeny, p. 182). This remnant of an Aristotle's lantern in *Palaeechinus ellipticus* is of much interest as the lantern in the whole family of the Palaeochinidae is otherwise known only in *Melonechinus multiporus* (Norwood and Owen) (Phylogeny, Plate LVI, fig. 9, 10) and in part in *Oligoporus* and *Lovenechinus*.

Besides the choice specimen above described, in the Brussels Museum there are quite a large number (some 100) of isolated interambulacral plates from Tournai that are similar in size and character, and without reasonable doubt are referable to *Palaeechinus ellipticus*, Plate III, fig. 5a-5f. The following lots are referable to *Palaeechinus ellipticus* M'Coy. Mus. Roy. Belg., n° 63, I. G. 3031. Calcaire Carbonifère, Tournaisien, Tournai, coll. Le Hon, original of Plate II, fig. 15, 16. Same museum, n° 84, I. G. 3031, Tournai, coll. Le Hon. Some 77 dissociated interambulacral plates. Same museum, n° 80, I. G. 3440, Tournai, some 14 dissociated interambulacral plates. Same museum, n° 81, I. G. 2737, Tournai, 7 dissociated interambulacral plates.

### *Palaeechinus elegans* M'Coy.

Plate II, fig. 17, 18.

*Palaeechinus elegans* M' COY, 1844, p. 172, Plate XXIV, fig. 6.

*Rhoechinus elegans* DUNCAN, 1889, p. 205; TORNQVIST, 1897, p. 757, Plate XX, fig. 10-12, Plate XXI, fig. 6-7; FRAIPONT, 1904, p. 10, Plate II, fig. 9.

This species is characterized by test spheroidal, two columns of plates in each ambulacrum and five columns of plates in each interambulacrum.

A well preserved specimen of *Palaeochinus elegans* has been found at Denée as recorded and figured by Fraipont (1904, p. 10, Plate, II, fig. 9). This specimen from the « Marbre noir de Dinant », at Denée, is in the Maredsous Museum, n° 72, a counterpart is in the Liège Museum and a cast in the Mus. Comp. Zoöl., n° 3313. It is seen in dorsal view flattened on the rock, Plate II, fig. 17. It measures 65 mm. in width in the longest plane, and 61 mm. at right angles to the same. Fraipont's published figure is therefore somewhat reduced. Four of the ambulacra are in place. The ambulacra about in the plane of the mid-zone measure 5 mm. in width, but do not show sutures and details of structure. The interambulacra measure about 25 mm. in width near the mid-zone and in each of the five areas there are five columns of plates, as is typical of the species. The plates of the apical disc cannot be made out.

A second specimen of *P. elegans* from Denée is in the Musée Maredsous, n° 73, and its counterpart, n° 73'. This specimen (Plate II, fig. 18), is also a dorsal view and is very well preserved but is smaller than the one previously considered. It measures 35 mm. in diameter, and on account of its size may be considered an immature individual. There are five columns of plates in each interambulacrum, but the finer details of structure are obscure.

In M'Coy's type of *Palaeochinus elegans* in the Science and Arts Museum, Dublin, the apical disc is exceptionally well preserved for a Palaeozoic echinoid. There are four imperforate ocular plates, four genitals with three or four pores each and a number of periproctal plates. Bailey figured a reconstruction of the apical disc of this specimen and showed two pores in each ocular plate. I examined this specimen in Dublin and found that he was mistaken, as no pores are visible in the ocular plates (Phylogeny, pp. 309-310, Plate XXIX, fig. 3; Plate XXXI, fig. 1, 4). This species is known from Ireland, Putig, Germany, and from Denée, Belgium.

#### *Palaeochinus* (?) *regnyensis* JACKSON.

*Palaeochinus Konincki* (name preoccupied) JULIEN, 1896, p. 130, Plate X, fig. 20; Plate XI, fig. 27; FRAIPONT, 1904, p. 9, Plate III, fig. 1; (non *Palaeochinus Konincki* DUJARDIN and HUPÉ, 1862, p. 464.)

*Palaeochinus* (?) *regnyi* nom. nov. JACKSON, 1912, p. 451, text-fig. 253.

This sea-urchin is of large size, spherical or subspherical in form, ambulacra narrow, detailed structure unknown, interambulacra broad with five columns of plates in an area.

A specimen in the Liège Museum, n° 11,227, from the « Marbre noir de Dinant », at Denée, is the original of Fraipont's, 1904, Plate III, fig. 1. The specimen measures 125 mm. in height, the ambulacra 12 mm. in width, and

the interambulacrum about 50 mm. in width, so that Fraipont's photographic figure is just life-size. The ambulacrum is very obscure, showing no structure. The interambulacrum, which is wide, has apparently five columns of plates, but the right adambulacral column is obscure. The largest interambulacral plate measures 14 mm. in width by 8 mm. in height. This species is doubtful in its generic standing, as there is no ambulacral structure. In regard to its interambulacrum and size, it seems to be different from other known forms so I leave it as a distinct species. In the Phylogeny (p. 451) I considered it under *incertae sedis*.

The name of this species is confused. Julien gave the name *Palaechinus Konincki*, which was preoccupied by Dujardin and Hupé who, by clerical error, gave that name for *Palaechinus Konigi* M'Coy. I felt therefore obliged to give a new name for this species and called it *Palaechinus regnyi*. It was originally described by Julien from imperfect material from Regny, France.

#### Genus MACCOYA POMEL.

*Maccoya* POMEL, 1869, p. XLVI (1).

In *Maccoya* there are two columns of plates in each ambulacrum, but differing from *Palaechinus* in that alternate ambulacral plates in the mid-zone are primaries meeting the interambulacral areas and enlarged marginally, while the plates between are narrowed laterally and nearly or quite cut off from contact with the interambulacra by the marginal enlargement of their fellows (Phylogeny, Plate XXXIII, fig. 2, 4, 7). Six species of this genus are known, four from Europe, and two from America. The type-species is *Maccoya gigas* (M'Coy), from the Lower Carboniferous of Ireland.

#### *Maccoya sphaerica* (M'Coy).

Plate III, fig. 1.

*Palaechinus sphaericus* M'COY, 1844, p. 172, Plate XXIV, fig. 5a-5c.

*Maccoya sphaerica* JACKSON, 1912, p. 317, Plate 32, fig. 4-5; Plate 34, fig. 4-10.

In the specimens referred to this species in the Phylogeny, there are five or six columns of plates, or in part seven columns in an interambulacral area. It is unusual in Palaeozoic Echini to have such a range in the number of columns of interambulacral plates in an area, but I have shown that in *Melonechinus multiporus* (Norwood and Owen) there may be eight or nine, or rarely seven columns in an area (Phylogeny, p. 377).

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(1) AUGUSTE POMEL, 1869, *Revue des Echinodermes*. Paris, pp. I-LXVII.

In the collections of the Musée Maredsous, there is a specimen, n° 94, from the « Marbre noir de Dinant », at Denée, which appears to be referable to *Maccoya sphaerica*. It is flattened on the slab and shows a considerable part of the dorsal portion of a test. It has a considerable resemblance to a specimen in the British Museum, n° E 361, from Waterford, Ireland (Phylogeny, Plate XXXII, fig. 4; Plate XXXIV, fig. 4-6). The ambulacra in this Denée specimen are narrow, about 8 mm. wide in the mid-zone but they do not show structural details of the plates. An interambulacrum measures about 30 mm. wide in the mid-zone and, while obscure, has apparently five columns of plates. This species has been previously recorded only from Ireland and England. The specimen from Kirkby Stephen, England, described by de Koninck as *Palaechinus sphaericus* is referable to *Lovenechinus Lacazei* (Phylogeny, p. 330-334), and will be considered later (p. 41).

#### Genus LOVENECHINUS JACKSON.

*Lovenechinus* JACKSON, 1912, p. 324.

The genus is distinguished from the other genera of the Palaechinidae by having four columns of plates in the mid-zone in each ambulacrum. There are at present six species of *Lovenechinus* known, four from America and two from Europe. Both of the European species occur at Denée. The type-species is *Lovenechinus missouriensis* (Jackson), from the Lower Carboniferous of America.

#### *Lovenechinus Lacazei* (JULIEN).

Plate III, fig. 2-4.

*Palaechinus Lacazei* JULIEN, 1896, p. 28, Plate XVI, fig. 3-5; FRAIPONT, 1904, p. 9, Plate I, fig. 8, Plate II, fig. 1-5 (non fig. 6).

*Palaechinus* sp. FRAIPONT, 1904, p. 9, Plate II, fig. 7-8.

*Maccoya Lacazei* LAMBERT and THIÉRY, 1910, p. 120.

*Lovenechinus Lacazei* JACKSON, 1912 (including Bather in Jackson), p. 326-335, text-fig. 240-243, Plate XXXV, fig. 4-7; Plate XXXVI, fig. 1-8; Plate XXXVIII, fig. 1-3.

Test spheroidal, ambulacra narrow with four columns of plates in each area in the mid-zone. There are four columns of plates in each interambulacrum in all the known specimens. Spines small, about 2-2.5 mm. long. The apical disc is known well in British specimens, but is incompletely known in specimens from Denée.

*Lovenechinus Lacazei* as a species includes specimens of very various sizes, as indicated by the figures, and is from many and widely separated localities, but as the structure in all, as far as known, is the same, I feel they must all be



considered a single species. More perfectly preserved material may serve to distinguish more than one species. The synonymy of this species is somewhat confused as set forth in detail in the Phylogeny (p. 326).

*Lovenechinus Lacazei* is known from Ireland, Wales, England <sup>(1)</sup>, France, Germany and Belgium, a very exceptional distribution for a species of Palaeozoic Echini. From the « Marbre noir de Dinant », at Denée it is very abundant, and I have here recorded from Denée or near by localities, some 45 specimens in various museums. This represents probably a greater abundance of material than is known in any other Palaeozoic species of Echini with the exception of *Melonechinus multiporus* from the Lower Carboniferous of St. Louis, Missouri. It is however nearly approached by *Proterocidaritis gigantea*, also from Denée and near by localities, with 38 recorded specimens, as described later in this paper. As a whole, the specimens of *Lovenechinus Lacazei* from Denée are very well preserved, with no, or trivial, distortion, but it is only exceptionally that the structural detail of the ambulacra can be ascertained. The more important Belgian specimens with the structure that they show are considered, followed by a list of additional known Belgian specimens.

One of the best specimens of *Lovenechinus Lacazei* from Denée is in the Brussels Museum, n° 5, I. G. 6938, and is shown on Plate III, fig. 2, 2a, 3. The drawings, fig. 2, 2a were made by an artist for de Koninck. This excellent specimen is seen in ventral view, shows an unusual amount of structure for Denée material, and is quite typical of the average size and appearance of specimens from that locality. It measures 56 mm. in diameter through interambulacrum A and the opposite ambulacrum F. An ambulacrum near the mid-zone measures 6 mm. in width and an interambulacrum in the same plane measures about 20 mm. in width. One of the ambulacra, F, is important in that on close inspection it shows a column of narrow plates next to an interambulacrum and a second column of wider plates extending from the first to the middle of the half-area. This shows definitely the character of the species of four columns of ambulacral plates in an area. It is disappointing that it is so rare in Denée specimens to find structural detail in the ambulacra. This same structure of

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(1) A specimen of *L. Lacazei* from Kirkby Stephen, England, is of exceptional importance as the basis of numerous published statements. It was in the collection of Edward Wood, Esq. of Richmond, Yorkshire. The Wood collection was purchased by Dr. Reed, who gave it to the Museum of the Yorkshire Philosophical Society, at York, where I saw it in 1925. This specimen, a cast of which is in the British Museum (n° E 10,944), was described by de Koninck in 1869 and 1870 as *Palaechinus sphaericus*. He said there were no ocular plates. On the basis of this structural anomaly this specimen served as the type of the genus *Eriechinus* Pomel, 1883, and *Typhlechinus* Neumayr 1889. Dr. F. A. Bather, at my request, borrowed the specimen, developed it, showed that ocular plates exist, and redescribed it critically in my memoir, Phylogeny of the Echini (pp. 330-334, text-fig. 240-243, Plate XXXV, fig. 7).

the ambulacra with four columns of plates in an area is shown by Julien in French material and is very clearly shown in British specimens (Phylogeny). Each of the five interambulacral areas in this specimen (Plate III, fig. 3) has four columns of plates and some traces of spines about 2.5 mm. in length are existent. In interambulacrum I there are two plates in the basicoronal row, three plates in the second row, and four plates in the third row, showing development of the area as usual in the genus and family (compare text-fig. 6, p. 32). These plates are not very strongly marked and do not show in the figures of the specimen.

A very large and fine specimen from Denée is in the Musée Maredsous, n° 123. A cast of this is in the Mus. Comp. Zoöl., n° 3324. This splendid specimen, which is partially flattened on the rock, measures 88 mm. in width and 84 mm. in height, including the whole specimen as it lies on the slab. Ambulacrum D measures 8 mm. in width. The configuration of the ambulacra is excellent. There is no trace, however, of ambulacral structure, but there are remains of minute spines in the furrowed depressions. Interambulacrum C in the mid-zone measures 25 mm. in width, and in this, as in all the interambulacral areas, the plates are very convex. A wide hexagonal plate in the mid-zone measures 9 mm. in width and 6 mm. in height. The interambulacral plates show abundant small secondary tubercles, as usual in the genus and family. There are four columns of plates in interambulacra A and C and apparently the same number of columns in the other three areas. This specimen (Plate III, fig. 4) is of importance as showing a very large specimen for comparison with a small specimen (Plate III, fig. 3). At first sight one would consider them different species, but as the structure, as far as known, is the same, I see no basis for separating them.

A specimen from Denée in the Musée Maredsous, n° 76, is the original of Fraipont's (1904) Plate I, fig. 8. A counterpart is in the Liège Museum, and a cast in the Mus. Comp. Zoöl., n° 3319. Two ambulacral areas are in place, the median one 7 mm. wide in the mid-zone. Two interambulacral areas each have four columns of plates and the left one in the mid-zone measures 24 mm. in width. As Professor Charles Fraipont writes me, the original of Fraipont's (1904) Plate II, fig. 1 is at the Liège Museum, n° 11,223, and the original of his Plate II, fig. 2, is also at the Liège Museum, n° 11,222, I did not see these specimens.

The specimen from Denée, in the Musée Maredsous, n° 75, counterpart at the Liège Museum, and cast in the Mus. Comp. Zoöl., n° 3318, is the original of Fraipont's (1904) Plate II, fig. 3. It is a dorsal view, and is not at all compressed or distorted. It measures 38 mm. in diameter and has all ten areas in place. It is not clearly enough preserved to show ambulacral detail, but there are four columns of plates in each interambulacrum. The specimen is not shown as far down as the mid-zone, but on the periphery the ambulacra

measure 5 mm. in width and the interambulacra 18 mm. in width. Genital plates are in place above the interambulacral areas, but oculars cannot be made out. It is the only specimen of the species from Denée seen showing any plates of the apical disc.

A specimen in the Musée Maredsous, n° 74, is the original of Fraipont's (1904) Plate II, fig. 4 (which figure, as he says, is considerably reduced). A cast is in the Mus. Comp. Zoöl., n° 3317. The specimen is a dorsal view, flattened out on the rock. It measures 55 mm. across. The ambulacra in the mid-zone measure 6 mm. in width. The ambulacra are well preserved and three of the interambulacra show four columns of plates each. Small secondary tubercles are seen on interambulacral plates.

The specimen in the Musée Maredsous, n° 81, which is the original of Fraipont's (1904) Plate II, fig. 6, and which he doubtfully referred to *L. Lacazei* is densely clothed with relatively large spines. The spines are entirely different from those of *L. Lacazei*, or for that matter, of any species in the genus or family. This specimen is here referred to *Perischodomus Fraiponti* sp. nov. (p. 50).

The specimen from Denée in Musée Maredsous, n° 93, is the original of Fraipont's (1904) Plate II, fig. 7, which is reduced, not natural size. A counterpart is in the Liège Museum. Fraipont doubtfully refers this specimen, also his Plate II, fig. 8, to *L. Lacazei*, as there is nothing but size to distinguish them, as far as known, from the typically smaller specimens. I refer them both to *L. Lacazei*. This specimen, n° 93, measures, as a whole, about 85 mm. across in one plane by 95 mm. in a plane at right angles to the same. There are four columns of plates in the interambulacra.

The specimen from Denée in the Mus. Liège, n° 11,226, is the original of Fraipont's (1904) Plate II, fig. 8. It is very large, the ambulacra in two areas in the mid-zone measure 11 mm. in width and the interambulacra in the same zone 40 mm. in width. There are four columns of plates in each of the interambulacral areas, but all structural details are smoothed out. The specimen is considered a large individual of *Lacazei* as stated above and as I stated earlier (Phylogeny, p. 335).

A specimen from Denée in the Musée Maredsous, n° 88, shows much detail. A counterpart which was generously given to me by Father Fournier is now in the Mus. Comp. Zool., n° 3316. The specimen is seen in dorsal view. The width of an ambulacrum in the mid-zone is 8 mm. and an interambulacrum in the same zone is about 26 mm. in width. There are four columns of plates in two interambulacral areas. In places the small secondary tubercles are well preserved, and many small spines about 2 mm. long are preserved in the depressions. From this, and other specimens showing spines, it is certain that the specimen with large spines that Professor Fraipont (1904, Plate II, fig. 6) doubtfully referred to *Palaechinus Lacazei* cannot be referred to that species.

A specimen of *L. Lacazei* from Denée in the Mus. Roy. Belg., n° 13, I. G. 8391, is an external mould measuring about 45 mm. in height by 65 mm. in width. Three interambulacral areas each have four columns of plates, an impression of an ambulacrum is about 5.5 mm. wide and an interambulacrum about 29 mm. wide near the mid-zone.

Another specimen from Denée in the Mus. Roy. Belg., n° 8 A and 8 B, I. G. 8391, counterparts, is seen in side view. Details are not clear, but there are four columns of plates in two interambulacral areas. The ambulacra measure about 7 mm. in width and interambulacra about 27 mm. in width.

A specimen from Denée in the Mus. Roy. Belg., n° 15, I. G. 8391, is a dorsal view of an excellent specimen. There are four columns of plates in each of four interambulacral areas, but one area is incomplete. It measures 56 mm. in diameter in one plane and 51.5 mm. at right angles to the same.

Again, a specimen from Denée, Mus. Roy. Belg., n° 18, I. G. 8254, shows four columns of plates in an interambulacral area. The impressions of tubercles of the plates as seen in an external mould are exceptionally clear.

All of the above specimens from Denée are from the « Marbre noir de Dinant » (Viséen inférieur, V1a). Besides those already considered, additional ones seen in various museums may be briefly recorded.

Musée Maredsous, twelve or more catalogued specimens from Denée in addition to those considered above and including n° 80 (cast in the Mus. Comp. Zoöl, n° 3222), n° 87 (cast in the Mus. Zoöl. n° 3323), n° 89 (cast in the Mus. Comp. Zoöl. n° 3325), and n° 82 (cast in the Mus. Comp. Zoöl. n° 3321). In the Mus. Roy. Belg. from Denée n° 2, 4 and 6, I. G. 6938 : n° 11, and 12 I. G. 8391 : also n° 19, I. G. 8917. In the Mus. Roy. Belg. there is a specimen from Furnaux, carrière Cordier, a locality near Denée, n° 105, I. G. 8997. Four additional specimens of *Lovenechinus Lacazei* from Denée were seen in the Institut de Géologie in Louvain. In the Mus. Liège were seen from Denée four specimens of which the numbers were not recorded, also two specimens from Salet, a village near Denée.

British Museum, from Denée, n° E 11,507, an external mould, showing four columns of plates in an interambulacrum and the outline of two ambulacra. Same Museum, n° E 11,508, Denée, an obscure specimen, but showing four columns of plates in an interambulacrum. British Mus. n° E 10,121, counterparts, under one number. This specimen, purchased of F. Krantz, is labeled as from Dinant, bei Namur, Belgium. It is coarse, gritty material, not as fine as that usual at Denée. The specimen is only poorly preserved, is about 65 mm. in diameter, shows no ambulacral area but a mass of interambulacral plates more or less misplaced. These plates bear secondary tubercles as characteristic of the Palaeochinidae. It is a doubtful specimen, but can with probability be referred to *L. Lacazei* and is of some interest as a record from Dinant. A specimen in the British Museum, n° 10,509, purchased of F. Krantz in 1905, bears on

Krantz's original label the inscription « Visé, Belgien ». This locality is certainly a mistake. The lithological character of the specimen is exactly that of Denée material and it is doubtless from Denée, or a near-by locality. The specimen shows parts of three ambulacra and four columns of plates in an interambulacrum.

*Lovenechinus anglicus* JACKSON.

Plate IV, fig. 1.

*Lovenechinus anglicus* JACKSON, 1912, p. 346, Plate 46, fig. 5-6; Plate 47, fig. 3-5.

This species is one of the largest known in the family Palaeochinidae. Complete test unknown, but probably spherical or spheroidal. Ambulacra with four columns of plates in the mid-zone, interambulacra with six or perhaps as an exception only five columns of plates in an area.

The holotype of *Lovenechinus anglicus* from the Lower Carboniferous of Clitheroe, Lancashire, is in the Museum of Practical Geology, London, n° 6576. In the Museum of the Yorkshire Philosophical Society, at York, there is a small slab, also from Clitheroe, on which are ambulacral and interambulacral plates and spines that I identified in 1925 as belonging to this species. The ambulacral plates though fragmentary are typical of the species as are also the dissociated interambulacral plates. A hexagonal interambulacral plate measures 11.5 mm. wide by 9 mm. high. There are a number of spines that measure up to 5 mm. in length. This is of interest as the second recorded occurrence of *L. anglicus* in England.

A splendid great specimen from the « Marbre noir de Dinant » at Denée, Musée Maredsous, n° 138 (cast in Mus. Comp. Zoöl. n° 3345), is referred to this species. The specimen is flattened out on the slab (Plate IV, fig. 1) and shows several ambulacra and interambulacra, in part seen from the exterior, and in part seen from the interior of the test. The total width of the specimen is 195 mm. and the height about 180 mm., this of course in its flattened state. The ambulacra are high and convex, as seen from the exterior in area B, or somewhat concave as seen from the interior in areas H and J. While the detailed structure of the ambulacra cannot be made out, there are evidently four columns of plates in an area as seen obscurely in area F. Ambulacrum B seen from the exterior measures about 11 mm. in width, and ambulacrum H seen from the interior, but further adorally, measures also about 11 mm. in width. Interambulacral plates are high, convex, thick. A single adambulacral plate measures 15 mm. in width by about 10 mm. in height. No interambulacral area is complete in width as regards the number of columns, but there are certainly five and perhaps six columns in an area.

Looking into the detail of the specimen, in area A on the right two columns of interambulacral plates are seen from within; further to the left, also



two columns of interambulacral plates of area A are seen but from the exterior. Ambulacrum B is seen for a considerable extent vertically, viewed from the exterior. Interambulacrum C is seen from the exterior, it is confused on the left but apparently has five or possibly six columns of plates in the area. Ambulacrum D is seen only imperfectly in part, viewed from the exterior. Interambulacrum E is seen in part viewed from the exterior, and two columns of this area seen from the interior lie in contact with ambulacrum F. Ambulacrum F as far as visible is seen from the interior. Interambulacrum G is seen only fragmentarily, adorally in contact with areas F and H respectively. Ambulacrum H is viewed from the interior both adorally and adapically, where it extends beyond the covering of the plates of interambulacrum C. Interambulacrum I is seen only in part ventrally, viewed from within, and lying in contact with ambulacra H. and J. Ambulacrum J viewed from within is seen adorally and also in part though imperfectly adapically. This specimen certainly represents an extremely large individual, perhaps if complete the largest known in the family. The largest previously known species is *Melonechinus giganteus* (Jackson) from the Lower Carboniferous of Kentucky, the type of which (Phylogeny, Plate LX, fig. 3) measures 115 m. in height and 155 mm. in greatest diameter through the mid-zone. It is an interesting and remarkable feature of the Deneé Echini that the present species, as well as species of *Deneechinus*, *Proterocidaris* and *Fournierechinus* should all attain such extraordinary size.

FAMILY LEPIDESTHIDAE JACKSON.

Genus LEPIDECHINUS HALL.

*Lepidechinus* HALL, 1861, p. 18.

In this genus there are two columns of plates in the ambulacra. In the interambulacra there are four to eight columns of plates in the known species. Interambulacral plates are relatively thick, and imbricate adapically and from the centre outward and over the ambulacrals on the adradial suture. Previously there were three species known from America and one species, *Lepidechinus irregularis* (Keeping), from the Lower Carboniferous of Ireland and France. The type-species is *Lepidechinus imbricatus* Hall.

*Lepidechinus belgicus* sp. nov.

Plate V, fig. 1, 2.

Complete test unknown, but apparently spherical or spheroidal. Ambulacra narrow, moderately convex, not showing detailed structure in the known



specimens. Interambulacra wide, with five columns of plates in each area. Interambulacral plates thick, convex, imbricating adapically, and from the centre outward and over the ambulacra on the adradial suture. In the holotype no trace of primary tubercles on interambulacral plates but there are small irregularities of the surface which may represent the remnants of secondary tubercles. In the paratype however impressions of secondary tubercles exist.

*Lepidechinus belgicus* comes nearest to *Lepidechinus iowensis* Jackson, from the Lower Carboniferous, of Burlington, Iowa (Phylogeny, p. 397, Plate LXII, fig. 1; Plate LXIII, fig. 3-4), which also has five columns of plates in an interambulacrum, but differs in that the interambulacral plates are relatively lower in *belgicus*. If more perfectly preserved, the Belgian species would probably yield other characters to distinguish it from the American species.

The holotype of *Lepidechinus belgicus* is from the « Marbre noir de Dinant » (Viséen inférieur V1a), at Denée, and is in the Musée Maredsous, n° 101. A cast is in the Mus. Comp. Zoöl., n° 3329. The specimen (Plate V, fig. 1) is a dorsal view, flattened on the rock. It shows more or less completely four ambulacra and three interambulacra. The ambulacra at the widest part, about in the plane of the mid-zone, measure 6 mm. in width, and the interambulacra in the same zone measure about 25 mm. in width. Ambulacral plates do not show detailed structure. The interambulacra show five columns of plates in an area. An important feature is the fact that the interambulacral plates bevel adapically and over the ambulacra on the adradial suture. This is characteristic of *Lepidechinus* and of all the *Lepidesthidae*, whereas in the *Palaeochinidae* interambulacral plates do not have any imbrication, but ambulacral plates bevel over the interambulacral on the adradial suture (Phylogeny, p. 73-77).

A second specimen of *L. belgicus* from Denée, a paratype, is in the Mus. Roy. Belg., n° 16, I. G. 8391. This specimen, Plate V, fig. 2, is also a dorsal view. It measures 83 mm. in diameter and represents a larger individual than the holotype. The plates are much separated but the specimen is helpful in showing characters. A fragment of an ambulacrum seen from within measures 7.5 mm. in width. As interambulacral plates bevel over the ambulacral on the adradial suture, the ambulacra are naturally somewhat wider on the inside than they are on the outside of the test. A large interambulacral plate measures 8.5 mm. in width and 6 mm. in height. An external mould of an interambulacral plate shows the impressions of numerous small secondary tubercles.

#### Genus PERISCHODOMUS M' Coy.

*Perischodomus* M' Coy, 1849, p. 253.

Test spheroidal. Ambulacra with two columns of plates in an area. Interambulacra broad, with many columns of plates in an area. Interambulacral plates

imbricating adapically and from the centre outward and over ambulacrals on the adradial suture. Adambulacral plates bear small primary tubercles with secondary tubercles or the latter only.

Only two species of *Perischodomus* were previously known, the type-species *P. biserialis* M'Coy, from the Carboniferous of Ireland and England, and *P. illinoisensis* Worthen and Miller, which is incompletely known from the Lower Carboniferous of Illinois, U. S. A.

***Perischodomus Fraiponti* sp. nov.**

Plate V, fig. 3-4.

Test probably spheroidal, circular in outline, ambulacra narrow dorsally, broader ventrally, but do not show structural detail. Interambulacra broad, with in the mid-zone seven columns of plates which imbricate adapically and from the centre outward and over the ambulacra on the adradial sutures. Adambulacral plates each bear a prominent primary tubercle close to the adradial suture, and these tubercles of successive plates being in a continuous vertical line make a marked feature that is very distinctive. Ambulacral plates also bear secondary tubercles. The interambulacral plates of median columns, at least usually, each bear a primary tubercle with secondary tubercles, but the primary tubercles do not fall in vertical lines so as to form a prominent feature as do those of the adradial columns. Primary spines quite stout, tapering and measuring up to 12 mm. in length. Secondary spines small, acicular, measuring up to about 4 mm. in length.

It is interesting that a new species of *Perischodomus* should occur in Belgium. It differs from *P. biserialis* M'Coy in the number of columns of plates in the interambulacra, which are seven instead of five, and also it differs in that the primary tubercles of adradial columns fall in such definite regular series, and again in that most if not all of the plates of the intermediate columns bear primary tubercles. I take pleasure in naming this species in honour of the late Professor Julien Fraipont, in recognition of his studies of the echinoderm fauna of Denée.

The holotype from the « Marbre noir de Dinant » (Viséen inférieur V1a) of Denée is in the Musée Maredsous, n° 78, 78', counterparts. A cast is in the Mus. Comp. Zoöl., n° 3228. The specimen in a dorsal view flattened on the rocks Plate V, fig. 3. It is well preserved and the central portion is pushed up, indicating the vertical thrust of the lantern which ensued when the dorsal portion of the test settled down after death. It is practically perfectly circular in outline and measures 55 mm. in diameter. The ambulacra at the periphery, which corresponds with the mid-zone, measure about 5 mm. in width and the interambulacra about 22 mm. in width. Unfortunately the ambulacra do not

show structural detail, which is the common condition of Denée material, but as the area is so narrow, it is reasonable to assume two columns of plates, which is the character of *Perischodomus*. There are seven columns of plates in each interambulacral area, the plates imbricating adapically and from the centre outward. A very marked feature is the primary tubercles of the adradial columns of plates. These tubercles fall in definite vertical series, which make a very marked character by which the species is easily recognized. The plates of the intermediate interambulacral columns apparently all bear a primary tubercle, but they do not fall in definite series. A considerable number of primary spines are in place in this specimen scattered over the test and extending from the peripheral margin. These primary spines measure up to about 12 mm. in length. Small secondary spines also occur, and measure up to about 4 mm. in length.

A second specimen, a paratype, from Denée, in the Musée Maredsous, n° 71, is also a very excellent specimen. It is seen in ventral view, Plate V, fig. 4. While not complete on the periphery, it is so in part. It measures 40 mm. in diameter in two planes. The peristome is pushed up by the extruding adoral face of the lantern, but details of these parts are not distinguishable. The ambulacra measure about 6 mm. in width and are evidently a little wider than they are as seen in dorsal view, a similar condition to what obtains in *Perischodomus biserialis*. On the periphery of interambulacrum A, six columns of plates can be counted, and passing from this zone to the centre or adorally, it is found that there are progressively less columns existent, though the specimen is not clearly enough preserved to make out the details of the progressive addition of columns passing adapically. In areas C, G and I, there also appear to be six columns of plates on the periphery. The seventh column existing in the holotype is evidently added above the zone of the ambitus, unless it is an individual difference in the number of columns attained in the two specimens. The peristome in this ventral view measures about 11 mm. in diameter. The sutures of interambulacral plates in this specimen are indistinct and one has to judge of the number of columns by the convex character and the tubercles of the individual plates. Judging from these, in interambulacrum E, which is the clearest area, there is apparently a single interambulacral plate on the peristomal border, and two plates in the next row. From this point passing adapically, the number of columns progressively increase as usual and as I showed them to do in *Perischodomus biserialis* (Phylogeny, Plate LXIV, fig. 2).

A third specimen from Denée in the Musée Maredsous, n° 107, is referable to *P. Fraiponti* as a paratype. It is poorly preserved and shows little structure. It does, however, show the prominent primary tubercles in a linear series on the adambulacral plates, and is referable to the species. Still another specimen in the Musée Maredsous, n° 148, 148', counterparts, shows the typical spines and a trace of the plates. This specimen measures 50 mm. in diameter.

A specimen from Denée in the Mus. Roy. Belg., n° 3, I. G. 6938, is also referable to this species. It is a very complete individual, seen in dorsal view, and measures 69 mm. in diameter. It does not show details of plates well, but does show the unmistakable series of prominent tubercles on the adambulacral columns of plates.

A second specimen from Denée in the Mus. Roy. Belg., n° 20, I. G. 8254, is an impression only, but the shape of the test, a few spines and interambulacral plates with the typical tubercles makes it referable to *P. Fraiponti*.

An important specimen which I would identify as *Perischodomus Fraiponti* is one from Denée in the Musée Maredsous, n° 81, and a cast is in the Mus. Comp. Zoöl., n° 3320. This specimen was figured by Professor Fraipont (1904), Plate II, fig. 6, and he doubtfully referred it to *Palaechinus Lacazei*. The specimen is finely preserved, flattened on the rock, but quite complete in its entirety. It is evidently a ventral view as shown by the upward protruding mass of the lantern. It is densely clothed with spines, and shows plates only at intervals. From top to bottom in the same plane as Professor Fraipont's figure and including the spines it measures 64 mm. across. Professor Fraipont's figure is somewhat reduced, not natural size. I do not think I have ever seen another Palaeozoic Echinoid which was so fully covered with spines as this one. The spines are stout, tapering, similar to those of Plate V, fig. 3, and of those measured are up to 8-10 mm. in length. These measurements are not quite as great as those on the holotype, but the spines may easily have been a little incomplete distally. The spines are entirely different from those of *Lovenechinus Lacazei* which are all secondaries only, measuring from 2-2.5 mm. in length. From its characters I have no hesitation in referring this specimen to *Perischodomus Fraiponti*. In the « Institut de Géologie », Louvain, there is a second specimen, n° 6, from Denée, densely clothed with spines and similar to the one just described. There are thus eight specimens which are identifiable as belonging to this species, some of which are indistinct, but sufficient to be recognizable. This is an unusual number for a Palaeozoic species.

#### Genus PROTEROCIDARIS KONINCK.

*Proterocidaris* KONINCK, 1882, p. 514, Plate VIII; emended, JACKSON, 1912, p. 409.

Test very large, spheroidal or flattened, ambulacra narrow, composed in each area in the mid-zone of four columns of low plates which imbricate adorally. Interambulacra broad with numerous columns of plates which imbricate adapically and from the centre outward and over the ambulacrals. Interambulacral plates usually bear one small perforate primary tubercle, with secondary tubercles and corresponding spines. The type and only known species of this remarkable genus is *P. gigantea* Koninck, from the Lower Carboniferous of Belgium.

***Proterocidaris gigantea* KONINCK.**

Text-fig. 8-10; Plates VI, VII; Plate VIII, fig. 1-2.

*Proterocidaris giganteus* KONINCK, 1882, p. 514, Plate VIII; JACKSON, 1912, p. 410, Plate 65, fig. 3; Plate 67, fig. 4-7.

*Oligoporus Soreili* FRAIPONT, 1904, p. 10, Plate III, fig. 2; Plate IV, fig. 1-2; Plate V, fig. 1-2.

*Oligoporus giganteus* LAMBERT and THIÉRY, 1910, p. 121.

This remarkable species, known only from the Lower Carboniferous, « Marbre noir de Dinant » of Belgium, is represented by a wealth of known material. Sea-urchins of truly gigantic size, measuring up to nearly 300 mm. in diameter, test apparently subspherical, or lower, circular in outline. Ambulacra, known in exceptional specimens, composed of four columns of low, narrow plates in each area, imbricating adorally. About four or five ambulacral plates equal the height of an adambulacral plate. The ambulacral structure is best shown in fragmentary specimens (as in text-fig. 8 and 10). Tubercles on ambulacral plates, small secondaries only. Interambulacra broad with twelve or thirteen columns of plates in each area. Plates moderately thick, imbricating strongly adapically and from the centre outward and over ambulacrals on the adradial sutures. Interambulacral plates bear a small median perforate primary tubercle (rarely the primary tubercle is absent), with a small primary spine and in addition numerous secondary tubercles with secondary spines. The primary spines with curious regularity nearly always lie in such position that they radiate outward from their point of attachment toward the periphery of the specimen, as seen well in Plate VII. Genital plates low, wide, oculars unknown, an entire apical disc is unknown, but the evidence is that it was small. A very large lantern, obscure in details, exists in many specimens.

Numerous specimens seen measure from 230 to 295 mm. in diameter. The ambulacra measure up to about 12 mm. in width and the interambulacra in the mid-zone measure up to about 160 mm. in width in a large specimen. A single large interambulacral plate measures up to about 16 mm. in width by 10 mm. in height, and about 1 mm. to 1.5 mm. in thickness. Primary spines measure up to about 8 mm. in length and secondary spines about 4-6 mm. in length. The massive character of the lantern is shown by the fact that in a large specimen 260 mm. in diameter (Plate VII), the lantern measures about 41 mm. diameter across its dorsal face.

*Proterocidaris gigantea* with its great size, highly specialized interambulacra and numerous known specimens, is one of the most striking of all known Palaeozoic Echini. Coming from a limited region in a single geological horizon, it is as far as at present known essentially a Belgian type. A large part of the known specimens are completely flattened on the rock, without

distortion and often are nearly or quite circular in outline. This indicates that the test was probably not very high in life, and further is strong evidence of the quiet conditions of sedimentation that would inter such large specimens without any marked disturbance of the original form. Further, the lantern is often in place in the centre of the test, strong evidence of an undisturbed burial.

Professor de Koninck in his description says that the ambulacra are wanting and an examination of his original specimen from Loyers (Plate VI) shows no indication of ambulacral structure. Professor Fraipont overlooked de Koninck's paper and described his material, all of which was from Denée, as a new species, *Oligoporus Soreili* Fraipont. The structure of both the ambulacra and interambulacra separate *Proterocidaris* from *Oligoporus* or any genus of the Palaeochinidae. Lambert and Thiéry (1910) refer the species to de Koninck's *gigantea*, but retain the generic name *Oligoporus*. In the Phylogeny I reinstated de Koninck's full name *Proterocidaris gigantea* and placed the form in the family Lepidesthidae.

On account of the great interest of this species, I take up in the following paragraphs individual descriptions of the more important specimens known, succeeded by a list of those of secondary importance seen in the various museums visited.

The holotype of *Proterocidaris gigantea*, Plate VI, is in the Brussels Museum, n° 1, I. G. 2739. A cast kindly made for me by M. Maillieux, is in the Mus. Comp. Zoöl., n° 3333. The specimen is from the « Marbre noir de Dinant » (Viséen inférieur VIa), Loyers, carrière à carreaux, about 5 km. northeast of Dinant. The label does not state the fact but M. Maillieux informs me that it was collected by the late Édouard Dupont, former Director of the Brussels Museum. The original label bears in de Koninck's handwriting the words, *Archaeocidaris* nov. sp. It was not labeled as *Proterocidaris gigantea*, but without question is de Koninck's original specimen.

This holotype is an external mould of the dorsal side on a large slab of rather coarse, gritty character. A crack across the slab where broken and mended shows in the lower half of my figure, and the same crack is shown in the lower half of de Koninck's figure (1882, Plate VIII). This crack with other mechanical features of the specimen, which are portrayed by de Koninck's artist, will serve for orienting in comparing de Koninck's original figure with the photographic figure given here. The specimen is in a remarkable condition of preservation for an external mould. When the photograph is reversed the light coming from the left, it then looks like moulds of the plates, as it is. I was amused on showing this photograph to my friend, Dr. Bather, to have him ask : « Well, which is it? » This illustrates the importance of care in the direction of lighting when making photographs for scientific illustration. De Koninck's figure is drawn as representing the plates



themselves rather than an external mould of the plates. The specimen in the vertical axis of the figure (Plate VI) measures 295 mm. in diameter, and in a plane at right angles to the same 293 mm. It is fair to say, therefore, that the specimen averages 294 mm. in diameter. De Koninck says 300 mm. in diameter, and this measurement is quite accurate if drawn in a diagonal plane through the figure 1 on the photograph. When the photograph was made, as well as in several other instances, I pasted a centimeter rule on the specimen to serve as an aid in calculating the reduction of the figure, or for verifying measurements given. No ambulacral plates show on the specimen and the same is true of many, indeed of the majority of specimens seen. This absence induced de Koninck to describe the form as having no ambulacra, a condition which seems to me inconceivable in a sea-urchin. The dorsal impression of the interambulacral plates is remarkably well shown. I counted sixty-five columns on the periphery of the test which represents about the plane of the mid-zone. This is the same number described by de Koninck and would be an average of thirteen columns to an area, which, with slight variations is found in other specimens of the species. Impressions of primary tubercles with primary spines radiating from the same are seen on almost every plate, also faintly the impressions of secondary spines. The impression of the dorsal limits of the lantern about 50 mm. in diameter is seen almost exactly in the centre of the specimen. The almost perfectly circular form of this specimen, the absence of distortion and the presence of primary and secondary spines, also the central position of the lantern, all attest to quiet conditions of sedimentation and burial. This is the only specimen of the species known from Loyers. It is one of the largest of all known sea-urchins, living or fossil, and is surpassed in size only by certain living Echinothurids and by *Fournierechinus* as later described. Two photographs enlarged to life size were made for me at the Brussels Museum. One of these I gave to Dr. Bather, Plate VI is about 78 % life size.

In the Musée Maredsous there is a specimen, n° 131, from the Carrière Watrisse, Devant-Bouvignes, a small village near Dinant, from the collection of F. Dupiereux. Excepting this specimen and the holotype from Loyers, all other specimens of *Proterocidaris gigantea* seen are from Denée. The rock in which this specimen, n° 131, lies is from the same formation and lithologically is just like that from Denée. The specimen is flattened on the rock, is 120 mm. in diameter, but is obscure and of interest principally as coming from another locality.

The specimen from Denée in the Musée Maredsous, n° 127, Plate VII, is a magnificent one. It is labeled as from the Soreil collection and determined by Fraipont as *Oligoporus Soreili*. It therefore may be considered a cotype of Fraipont's species. The specimen is a dorsal view, nearly flat with plates in place and is practically perfectly circular, measuring 260 mm. in diameter in

two planes respectively through the planes A, F and D, I. The photographic figure is a little reduced, but a centimeter scale photographed with the specimen shows the proportionate reduction of the figure and serves as a basis of measurement. An impression of the distended gut shows through the test, I believe a unique case. The ambulacra show in part in area F and are more or less recognizable also in areas H, J, B and D. In the flattening of the test it has separated somewhat on the lines of the ambulacral areas so that on the periphery they are wider than if not so separated. In area B, little or no separation has occurred. Ambulacrum F is the most instructive area. Here there are two columns of plates seen in a half-area. The pores of ambulacral plates are nearer the interambulacral suture than they are to the middle of the plate. Ambulacral plates imbricate strongly adorally and the spines are fine acicular, the largest measuring up to 5 mm. in length. In each interambulacrum at the periphery there are twelve columns of plates, and each of the areas measures about 130 mm. in a straight line across at the periphery. Interambulacral plates are hexagonal, or pentagonal in the adradial columns. They imbricate strongly adapically and from the centre laterally and over the ambulacra on the adradial suture. Interambulacral plates measure up to 13 mm. in width by 9 in height. The interambulacral plates bear a relatively small perforate primary tubercle, usually at or near the middle of the plate except in adambulacral columns, where they are nearer the adradial suture. There are also numerous secondary tubercles. Primary spines are relatively stout, measuring up to about 7 mm. in length. The secondary spines are very slender, acicular, numerous, crowded, and measure up to about 5 mm. in length. In interambulacrum I on the periphery the dorsal plates are wanting and one sees an external mould of the ventral plates seen from above. Practically in the exact centre, the dorsal part of a complete lantern is in place, standing upright, with the ten half-pyramids entire, and measuring about 41 mm. in diameter.

In the Brussels Museum there is a very fine *Proterocidaris gigantea* n° 10 A, 10 B, I. G. 8391, (counterparts) from the Carrière Piette, Denée. It is seen in dorsal view and measures 225 mm. in diameter. The ambulacra are obscure, but they show secondary spines about the same as those on the interambulacra. The interambulacra are not complete, but are very good for showing surface characters, Plate VIII, fig. 2. The interambulacral plates bear one moderate-sized perforate primary tubercle and numerous secondary tubercles. The primary tubercles are usually in about the centre of a plate, but they may be excentric. Occasionally, as seen in the figure, the primary tubercle may be absent from a plate and secondary tubercles alone exist. This absence seems to be without any order and is distinctly exceptional. An impress of a large lantern is in place.

A relatively small specimen of *Proterocidaris gigantea* from Denée is in the

Musée Maredsous, n° 151. This specimen, Plate VIII, fig. 1, is seen in dorsal view, flattened on the rock, and is of interest as an apparently immature individual. It measures about 170 mm. in diameter through the planes G, B and D, I. It is therefore a little more than half the maximum size known in the species. The ambulacra are best seen in area B, but may be seen obscurely in the four other areas, namely, in D, F, H. and J. The plates of the interambulacra are in parts misplaced, and somewhat obscure, but there are apparently twelve or thirteen columns of plates in an area, as in the adult, a large interambulacral plate measuring about 10 mm. in width by 7 in height. The dorsal remains of an Aristotle's lantern exist near the middle of the test. In interambulacra C and I some plates of the ventral side are seen from above, where plates of the dorsal side are absent. Interambulacrum I is seen in part rolled outward so that it is seen from the interior much as an interambulacral area is similarly rolled outward in Fraipont's remarkable figure (1904, Plate IV, fig. 2). Really immature specimens of Palaeozoic Echini are very rare, the youngest one known being an immature *Lovenechinus missouriensis* (Jackson) which is only 32 mm. in diameter, whereas a full-sized adult is about 95 mm. in diameter (Phylogeny, Plate XXXIX, compare fig. 1 and 5). The immature *Proterocidaris*, Plate VIII, fig. 1, has apparently as many columns of plates as a full grown adult. This is in accord with what I have found in Recent Echini for I show in Arbacia (1927, p. 471 <sup>(1)</sup>) that growth of the test is attained much more by increase in size of plates than it is by the addition of new ones.

Dom Grégoire Fournier most liberally gave me a specimen of *Proterocidaris gigantea* from Denée which was in the Musée Maredsous, n° 137. It is now in the Mus. Comp. Zoöl., n° 3330. It is seen in dorsal view, flattened on the rock, measures 280 mm. across in one plane and 270 mm. in a plane at right angles to the same, so that it is very nearly circular. It shows nothing of the ambulacra but the interambulacra are quite well preserved in parts. About 62 columns of plates can be counted on the periphery. Interambulacral plates show the surface characters with primary and secondary tubercles and primary spines measuring up to about 8 mm. long, and fine secondary spines measuring up to about 4-5 mm. long. A large interambulacral plate measures about 12 mm. wide by 8 mm. high. In part, on the periphery, where the dorsal plates are wanting, an external mould of the plates of the ventral side are seen from above. The remains of a large lantern, seen in dorsal view, and measuring about 47 mm. across, exists in the exact centre of the specimen. A counterpart of this specimen, n° 137' is in the Maredsous Museum.

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(1) R. T. JACKSON, 1927. Studies of *Arbacia punctulata* and allies and of non-pentamerous Echini. (*Mem. Boston Soc. Nat. Hist.*, vol. VIII, n° 4, pp. 435-565, text-fig. 1-75.)

The specimens which were figured by Professor Fraipont (1904) are of great importance, as they include much of the finest known material of the species, and are represented by such excellent figures.

A specimen from Denée at the Musée Liège, n° 11,228, is the original of Fraipont's Plate III, fig. 2. It is a magnificent individual, seen in dorsal view and flattened on the rock. It measures 245 mm. in diameter in one plane and 235 mm. in diameter at right angles to the same. Fraipont's figure is reduced as he says, and is about six-tenths of the natural size. The ambulacra are very obscure. In one interambulacrum twelve columns of plates can be made out; the number of columns in the other interambulacra could not be ascertained with certainty. The interambulacral plates show finely the primary spines radiating outward and secondary spines are seen as well. The primary spines measure up to 8 mm. in length and the secondaries up to 5 mm. in length. An imperfect mass of the dorsal part of the lantern is in place.

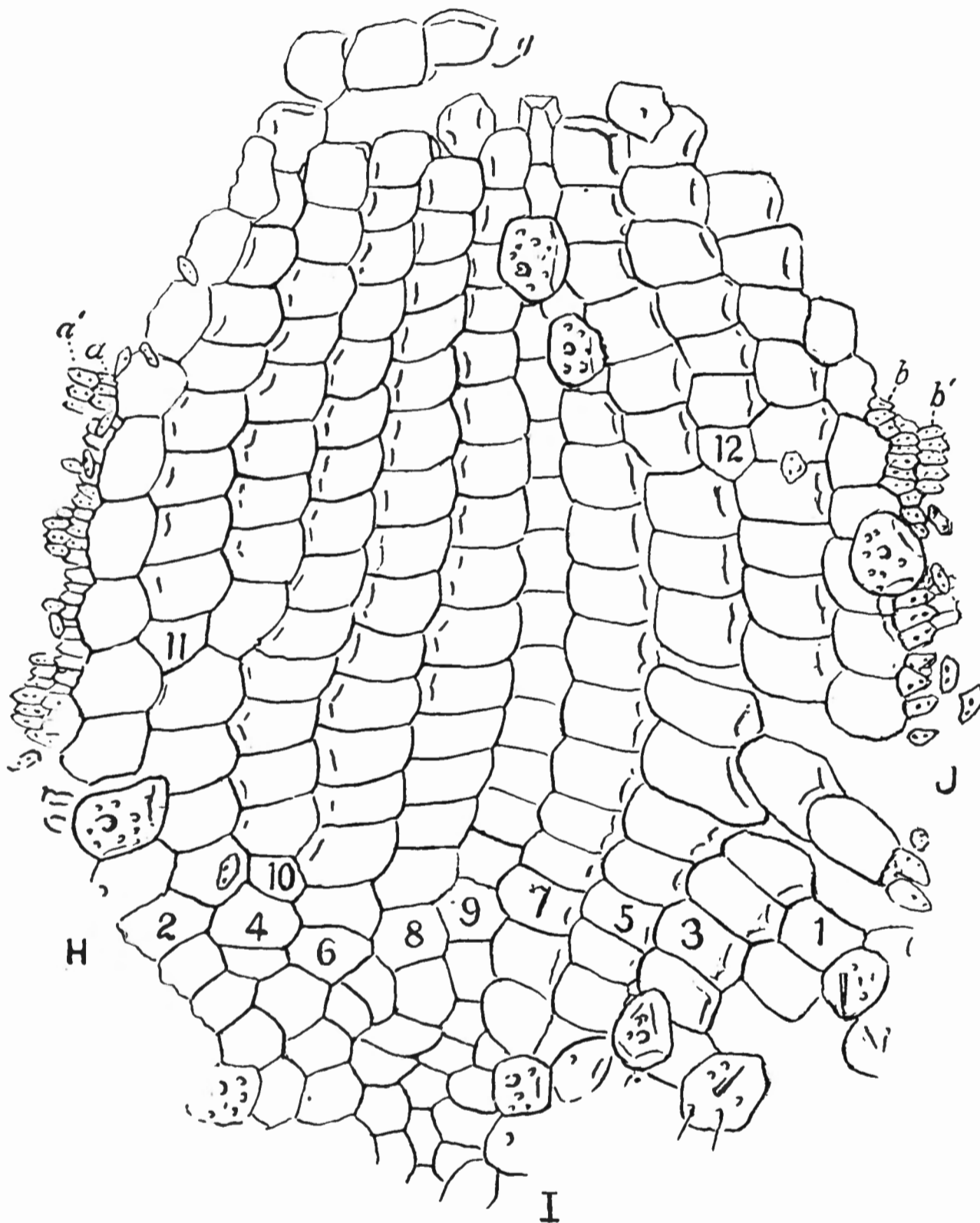
Another specimen of *Proterocidaris gigantea* at the Musée Liège, n° 11,229, is the original of Fraipont's Plate IV, fig. 1. The label does not give the locality, but it is undoubtedly from Denée. The specimen is an external mould of the dorsal side. It measures 230 mm. in diameter in one plane and 210 mm. in diameter at right angles to the same. Fraipont's figure is therefore considerably reduced; two-thirds life-size, he says. The impress of the ambulacra are quite clear in all five areas and in this respect it is the most complete of any known specimen. They are marked A in Fraipont's excellent figure. The impress of interambulacral plates is not very sharp, but one can make out eleven columns of plates in two areas, twelve in two areas, and thirteen in one area, all these as counted near the periphery. It is quite possible, even probable, that more columns might be added in some of the areas above the peripheral portion as seen in text-fig. 8-10. In very nearly the exact centre are the remains of the Aristotle's lantern with sides sloping outward as it is seen in ventral view, and the lantern is strongly inclined as in all Palaeozoic Echini. The details of the structure of the lantern cannot be made out. In some respects this is one of the best specimens known.

One of the most instructive specimens of *Proterocidaris gigantea* seen is that from Denée in the Musée Maredsous, n° 125, a cast of which is in the Mus. Comp. Zoöl., n° 3331. This specimen is the original of Fraipont's Plate IV, fig. 2 (1). Most of the specimen is a dorsal view seen from above, but one interambulacrum (on the left of Fraipont's figure) with parts of two associated half-ambulacra are rolled open like the peeling of an orange and are therefore seen from within. The total width of the specimen throughout the plane of

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(1) In the Phylogeny I copied Fraipont's figure in my Plate 65, fig. 3 and Plate 67, fig. 6-7. My statement in the text and description of plates as regards size are incorrect, as it is larger than there stated.

the rolled out interambulacrum is 350 mm. and the height at right angles to the same and across the diameter of the test proper is 250 mm. This latter



Text-fig. 8. — *Proterocidaris gigantea* KONINCK, Denée, Belgium.

Interambulacrum with parts of associated ambulacra seen from within, and a few interambulacral plates seen from without. Drawn from plaster cast in Mus. Comp. Zool. Original Mus. Maredsous, n° 125. Life size. (Compare Fraipont's Plate IV, fig. 2.)

measurement can properly be considered the diameter of the specimen. Fraipont's figure is reduced as he indicates and is only a little more than half

the natural size. The main mass of the specimen shows the exterior of interambulacral plates clothed with primary and secondary spines as usual and in fine condition of preservation. The rolled out interambulacrum seen from within shows beautifully the character of imbrication of interambulacral plates and parts of the associated ambulacra in place, text-fig. 8. In this view the interambulacral plates bevel over one another adorally and from the sides toward the centre just the reverse of what is true as viewed from the outside of the test. As a result of this beveling the median column (column 9) appears very narrow in inner view, whereas it would be about the usual width in external view (compare Phylogeny, text-fig. 32-35, p. 75). The introduction of the tenth, eleventh and twelfth columns of plates are seen in this view passing adapically. On either side of the interambulacrum in text-fig. 8 are seen remnants of ambulacral plates representing half-areas seen from within. A few interambulacral plates with tubercles, or tubercles and spines are seen from without that have been plastered on to the plates seen from within. The centre of the specimen as seen in Fraipont's figure is pushed up by the dorsal portion of the lantern, but no structure of the lantern is recognizable.

A specimen from Denée, at the Mus. Liège, n° 11,230, is the original of Fraipont's (1904) Plate V, fig 1 <sup>(1)</sup>. It is an unusual specimen in that it shows a single interambulacrum in external view with fragments of the ambulacra on either side of the same. The specimen, text-fig. 9, while incomplete ventrally, measures 142 mm. in height from the base of the interambulacrum to the top, and 110 mm. in width at the widest part near the base. Fraipont's figure is therefore just life-size. The interambulacrum has only nine columns of plates at its adoral portion, but passing adapically, new columns are added progressively, and some columns drop out as indicated by the X marks. In about the lower third, thirteen columns of plates may be counted, but toward the upper part there are only nine columns as in the adoral portion shown. It is unusual for such irregularity to occur in Palaeozoic Echini. Fragmentary remains of ambulacra exist on either side, but they do not show the full structure of an ambulacral area. One of the most important features of this specimen is the existence of a genital plate adapically. It is the only plate of the apical disc yet known in the species. This genital is very low and about 14 mm. wide, and from its size and shape would indicate a small periproctal area, as is usual in specialized types of Echini.

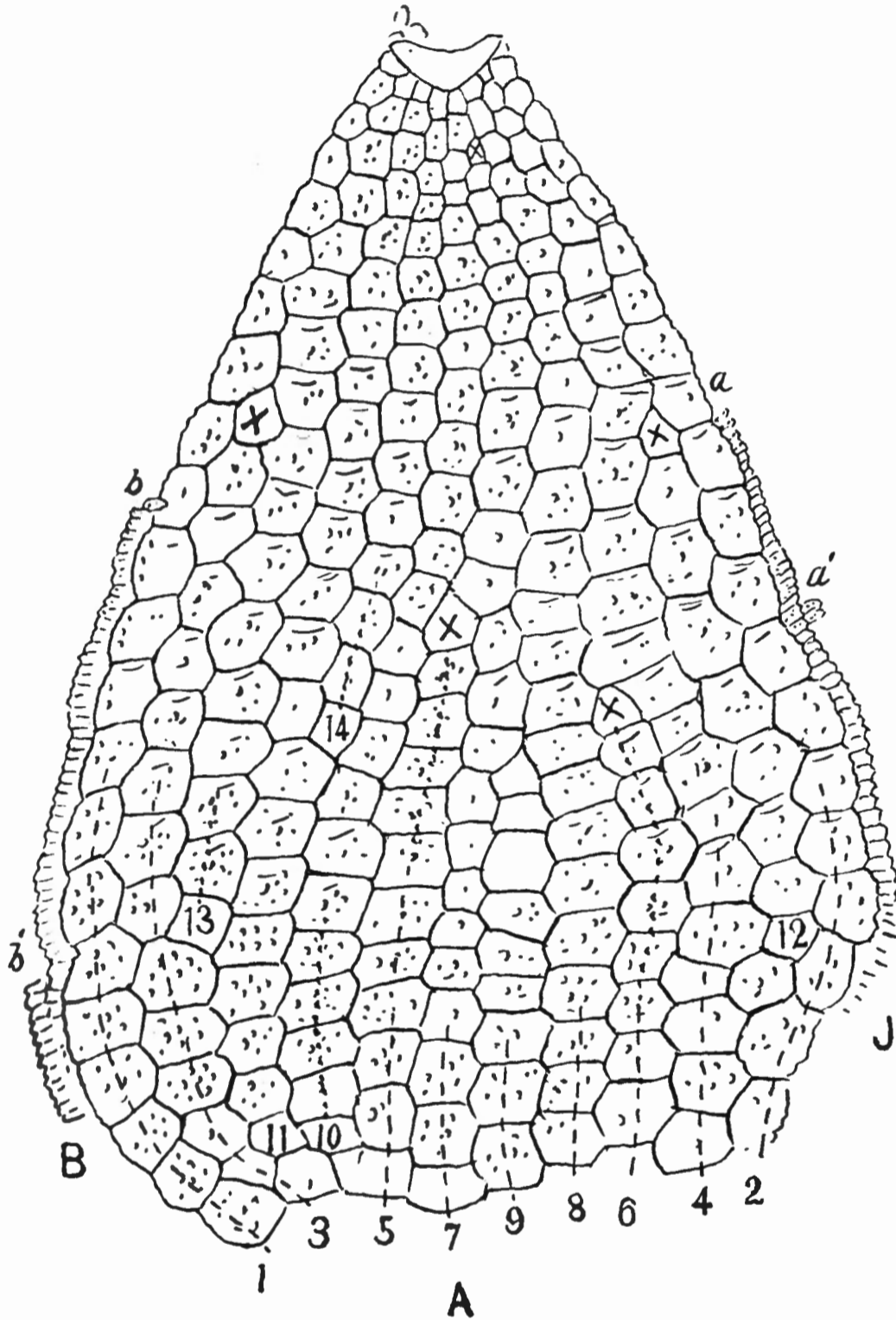
One of the most important specimens for the structure of *Proterocidaris gigantea* is from Denée in the Liège Museum, n° 11,231. It is the original of Fraipont's, Plate V, fig. 2. It is a view of two interambulacra seen from within and mechanically pulled apart. Two half-ambulacra may be seen bor-

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(1) I copied this figure in part in the Phylogeny, Plate 67, fig. 1.



dering the interambulacra. Professor Fraipont's figure is inverted, but in a sketch from his figure here reproduced as text-fig. 10, the orientation is corrected. Interambulacrum A from top to bottom measures 130 mm., there-



Text-fig. 9. — *Proterocidaris gigantea*, Denée, Mus. Liège, n<sup>o</sup>. 11,230.

Drawn from Fraipont's Plate V, fig. 1. Natural size. Shows interambulacrum with introduction and dropping out of columns of plates, remnants of ambulacra and a genital plate.

fore Fraipont's figure is just natural size. The interambulacral plates in this internal view imbricate adorally and laterally toward the centre. This is of course just the reverse of that as viewed from the exterior, in which they

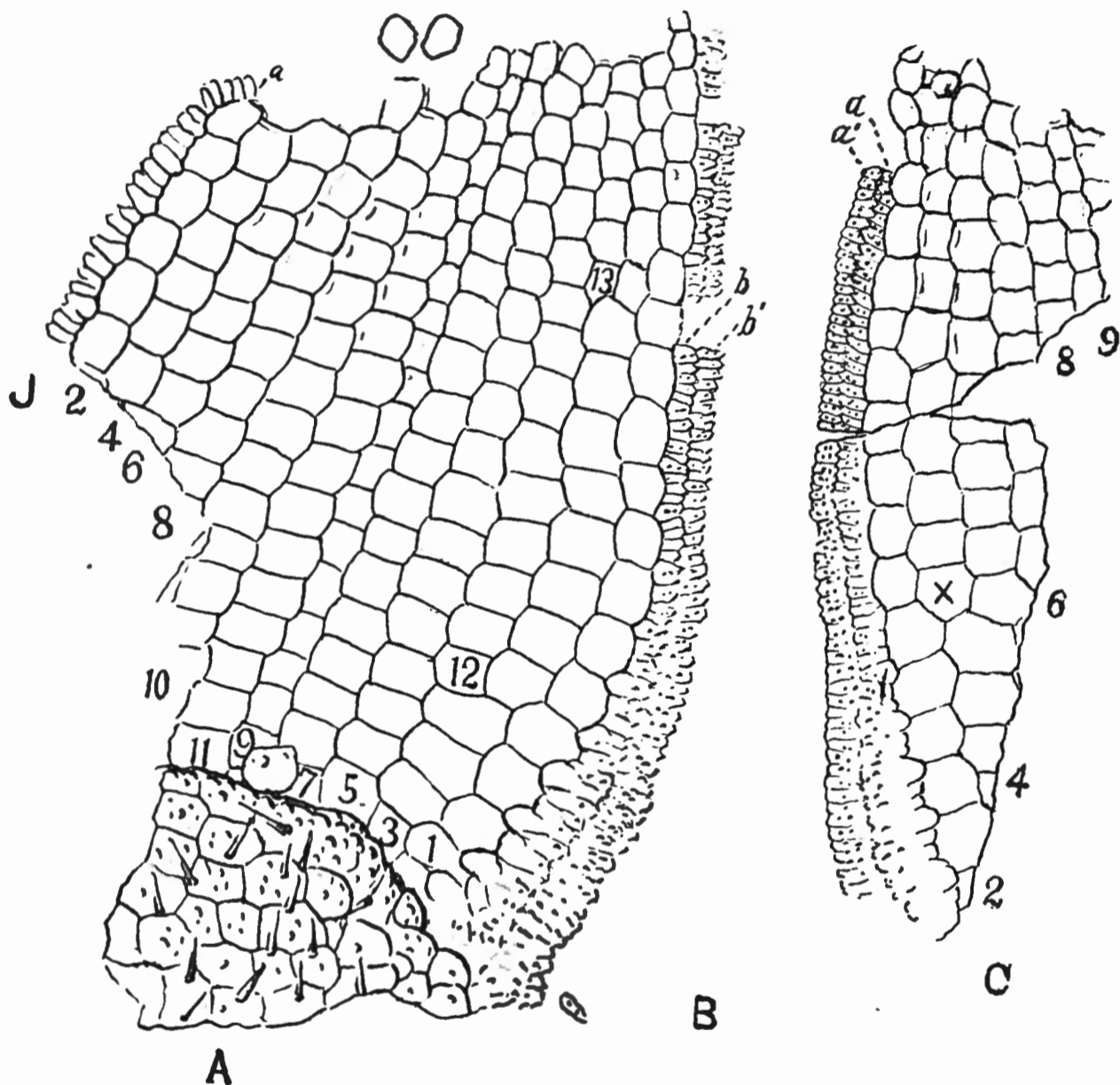
imbricate adapically and from the centre outward. From this direction of imbrication, as seen in internal view, the median columns appear as very narrow plates, because the adjacent columns bevel over them on either side. At the adoral portion of interambulacrum A a mass of plates with tubercles and spines represent plates of the upper side plastered on to those seen from the inside. In interambulacrum A at about the middle of the area there are twelve columns of plates, the twelfth originating below this plane. A thirteenth column originates quite far dorsally. In interambulacrum C a new column originates at the point X. Ambulacrum B is represented by two columns of plates *a'a* in contact with area C and also two columns of plates *b'b* in contact with area A. Again, a single column of ambulacral plates *a* is in place on the left side of interambulacrum A. This specimen is the most definite and satisfactory for showing ambulacral structure of any seen in the species.

In addition to the above considered specimens of *Proterocidaris gigantea* which represent the more important known specimens, there are many seen in museums visited which may well be put on record with a few words in regard to each.

In the Musée Maredsous there are from Denée the following specimens, n° 136, a specimen somewhat elongately drawn out. It measures 298 mm. in the longer plane and 215 mm. at right angles to the same, shows two ambulacra obscurely, and interambulacra with spines, etc. N° 126, from Denée, cast in Mus. Comp. Zoöl., n° 3332, is seen in side view, flattened out. It has twelve columns of plates in one interambulacrum and also has parts of two ambulacra, one of which shows the four columns, which are typical of an area. There are many spines measuring up to 5 mm. in length. N° 133 is a ventral view, flattened and injured by slickensiding, but not distorted. It measures 255-265 mm. in diameter. N° 132 is practically a perfect specimen seen in dorsal view. It measures in different planes 265-277 mm. in diameter. The lantern is in place and measures about 35 mm. across the dorsal face of pyramids. N° 146, a large and somewhat elongately distorted specimen, is too obscure to show details. It measures 270 mm. across in the longer plane and 195 mm. across at right angles to the same. Remains of a lantern protrude as a knob. N° 134, a very large specimen, in part a dorsal view seen from above, and in part an external mould of the ventral side seen from above; the impressions of spines are good. It measures 285 mm. across in the longer plane and 270 and 250 across in two other planes. N° 135 is an impression of the test only, details obscure; it measures about 225 mm. in diameter. N° 128, a good dorsal view, a little elongate, measures 255 mm. across in the longer plane and 225 mm. at right angles to the same. N° 130, this specimen is a ventral view as shown by the lantern and direction of imbrication of interambulacral plates. The adoral face of the lantern is covered with impressions of fine spines which I

think must have been spines on the peristomal membrane, but I could not make out any plates. N° 129, a magnificent specimen seen in dorsal view, is perfectly flat with the lantern about in the middle. The test in one plane measures 270 mm. in diameter, and in another plane 255 mm. in diameter. The lantern measures about 47 mm. in diameter. N° 143 is a relatively small fragmentary specimen. N° 155, 155' (counterparts), and n° 156 are incomplete specimens but perfectly recognizable

Besides the above splendid series of specimens of *Proterocidaris gigantea*



Text-fig. 10. — *Proterocidaris gigantea* KONINCK, Denée, Mus. Liège, n°. 11,231.

Drawn from Fraipont's Plate V, fig. 2. Natural size. Two interambulacra seen from within, with parts of ambulacra.

from Denée in the Maredsous Museum, there are in the same museum from Denée n° 144, 144' and 145, 145' (both counterparts). These are two specimens of Aristotle's lanterns which from their size probably belong to *Proterocidaris gigantea*. They are not sufficiently well preserved to show structural detail.

In the Musée Royal d'Histoire Naturelle de Belgique, besides those previously considered there are the following specimens of *Proterocidaris gigantea* from Denée. N° 7 A, 7 B, I. G. 8391 (counterparts) from the Carrière Piette, Denée. The specimen is a combination of an internal view of the ventral side and an external view of the dorsal side seen from above. It measures 190 mm. in diameter in one plane, and 150 mm. in a plane at right angles to the same. One ambulacrum shows two columns of plates in a half-area. The interambulacra show numerous tubercles and spines as usual. A lantern in place measures about 35 mm. across in one plane and 30 mm. at right angles to the same. N° 9, I. G. 8391, is a magnificent specimen in dorsal view. It measures 265 mm. in diameter in one plane and 242 mm. in diameter at right angles to the same. In part, where the dorsal plates are lacking, one sees the interior of the ventral plates seen from above. The ambulacra, as is usually the case in this species, show little, but in one area two columns of plates are seen in a half-area. Eleven columns of plates are visible in three areas and eleven or twelve columns in another area. When less than the usual number of columns is seen in an interambulacrum, it is quite likely, even probable, that one or more columns may have come in late, as seen in the late origin of the twelfth column in text-fig. 8. The spines in this specimen are very perfect, radiating toward the periphery as usual. The primary spines measure up to 8 mm. in length, and the secondaries, which are very much finer, up to about 5 mm. in length. The adapical and lateral imbrication of interambulacral plates is well shown. A large interambulacral plate measures 12 mm. in width by 8 mm. in height. The lantern in place measures about 45 mm. across the top, but is probably somewhat opened out by the decay of the muscles after death and before burial.

N° 14, I. G. 8391, from Denée is much worn, being merely an impression of the test and shows little structure. It measures 155 mm. in diameter in one plane and 130 mm. at right angles to the same. N° 17 A, 17 B, I. G. 8713, (counterparts), Carrière Piette, Denée. This is a very fine specimen, measuring 295 mm. in diameter, the maximum size of the species. It is a view of the dorsal side seen from above. The counterpart as an external mould is an impression of the dorsal part seen from below just like the holotype, Plate VI. There is an impression of the dorsal aspect of the lantern in the centre. One ambulacrum is quite clear and shows two columns of plates in a half-area. One cannot get the number of columns of interambulacral plates as well as in some other specimens. The primary spines are abundantly preserved and are directed radially as usual.

In the Institut de Géologie, Louvain, eight specimens of *Proterocidaris gigantea* from Denée were seen. Some of these are very complete and of great size, others are fragmentary.

At the Musée Liège there is a specimen with counterpart from Denée which is an Aristotle's lantern. Like the two similar ones mentioned from the Musée Maredsous, it is probably the lantern of *Proterocidaris gigantea*. This

lantern is seen in dorsal view, measuring 40 mm. across the top, and the half-pyramids which are in place standing erect, are about 15 mm. apart on the outer limits of their radii.

In the British Museum there are two specimens of *Proterocidaris gigantea* from Denée as follows : N<sup>o</sup> E 11,510 and E 11,509, the latter a counterpart. This specimen was purchased of A. Piret, 1912. It is a dorsal view, 130 mm. in diameter. In parts where the dorsal plates are wanting are seen the imprints of the plates of the ventral side seen from above. The vertical height between the exterior of the dorsal plates and the external imprint of the ventral plates measures only a few millimeters, demonstrating the extreme flatness of the fossil as preserved. The specimen shows three ambulacra in part, one of which has two columns of plates in a half-area. The ambulacra are obscure, but one of the areas measures 7 mm. in width at the periphery. One very good interambulacrum has apparently twelve columns of plates near the periphery. One of the largest interambulacral plates measures 6 mm. in width by 5 mm. in height. An interambulacral plate seen in section measures about 1 mm. in thickness. The lantern in the centre shows four half-pyramids, and between the outer limits of two of the half-pyramids the dorsal tip of a tooth is seen in place. This is the only case of a tooth seen in the species. The counterpart E 11,509 shows external moulds of the plates, which, in E 11,510 are seen as the plates themselves.

The second specimen from Denée in the British Museum, n<sup>o</sup> E 11,511, was also purchased of A. Piret in 1912. It is a fine specimen seen in dorsal view with plates in place. It measures 192 mm. in diameter in one plane and 190 mm. at right angles to the same, so it is practically circular. The ambulacra show quite clearly in one area and obscurely in two additional areas. There are two columns of plates in a half-ambulacrum. Primary spines mostly radiate toward the periphery as usual. These spines are relatively robust, taper gradually from the base and measure up to 8 mm. in length. The secondary spines are fine, slender, and measure up to 4.5 mm. in length. The lantern is in place in the centre and measures about 37 mm. across its dorsal face. The ten half-pyramids stand vertically and radiate from near the centre like the spokes of a wheel. A single half-pyramid on its dorsal face measures about 12 mm. from its proximal to its distal limits.

In the above rather lengthy consideration of the known specimens of *Proterocidaris gigantea* it is seen that the holotype is from Loyers, one specimen is from Devant-Bouvignes and thirty-six specimens are from Denée. This is an extraordinary wealth of material for a Palaeozoic Echinoid, surpassed, I believe, only by *Melonechinus multiporus* of St. Louis, Missouri, of which species a great many specimens are known and by *Lovenechinus Lacazei* as described in this paper with 45 specimens recorded from Belgium.

None of the specimens of *Proterocidaris gigantea* seen are sufficiently clear

to show the developing characters of the ambulacra and interambulacra adorally. In all probability there were two columns of ambulacral plates on the peristomal border, passing into four columns adapically, as I have shown in the development of *Lovenechinus* and *Oligoporus* (1896; Phylogeny). In the interambulacra of *Proterocidaris* probably there was a single primordial plate in the basicoronal row, succeeded by two plates in the second row, three in the third row and additional columns introduced progressively passing adapically as I have shown in the development of a number of species in the *Lepidocentridae* (text-fig. 5) and the *Lepidesthidae* (1896: Phylogeny).

Genus PHOLIDOCIDARIS MEEK and WORTHEN.

*Pholidocidaris* MEEK and WORTHEN, 1869, p. 78; JACKSON, 1912, p. 432.

Of the genus *Pholidocidaris*, one species, the genotype, *P. irregularis* Meek and Worthen, has been described from the Lower Carboniferous of America. Four species, one each from Ireland <sup>(1)</sup>, England, Germany and France also have been described, but these last three are known very incompletely.

*Pholidocidaris tornacensis* sp. nov.

Plate V, fig. 7; Plate X, fig. 3-6.

Complete form of test unknown but probably spheroidal. Ambulacral plates low, wide, or rounded, strongly imbricating, pores separated by a median elevated septum and surrounded by a large peripodium, surface with secondary tubercles, the number of columns of ambulacral plates in an area unknown. Interambulacral plates hexagonal, or polygonal, thick, strongly imbricating, with perforate primary tubercle and secondary tubercles, or with secondaries only. Apparently five or six columns of interambulacral plates in an area. Primary spines small, stout, swollen at the base, tapering and measuring up to about 9 mm. in length.

*Pholidocidaris tornacensis*, while incompletely known, differs from other described species in that the interambulacral plates are thicker and more

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(1) Dr. F. A. BATHER (1918, 1920), referred *Protoëchinus anceps* Austin from the Lower Carboniferous of Ireland, to *Pholidocidaris anceps* (Austin). The holotype of this species from Hook Point, County Wexford, Ireland, is in the Austin collection, n° 401, Free Public Museum, Liverpool, where I saw it through the kindness of the Director, Dr. J. J. Simpson. A cast of this well preserved and interesting specimen is in the British Museum, n° E 11,732 and another in the Mus. Comp. Zoöl., n° 3347.



angular and there is no evidence of large adradial plates such as occur in the genotype *P. irregularis*, and in at least one other species. It is of interest as the first known occurrence of the genus in Belgium. Also, while incomplete, it is more complete than most material of the genus previously recorded from European formations.

The holotype which is in the Brussels Museum, n° 64, I. G. 3440, is from the Lower Carboniferous, Tournaisien, Tournai, collection Ryckholt. The material consists of a fragmentary test and three associated but separate plates, Plate X, fig. 3-5. The test presents two faces as represented by photographs and drawings made by an artist for Professor de Koninck, Plate X, fig. 3, 5 and 6. On one face, Plate X, fig. 3 and 6 *a*, the interambulacral plates are thick, rounded, hexagonal, with inwardly curved lines on the sides of the hexagons. These large plates bear numerous secondary tubercles and are strongly imbricating adapically and laterally from the centre outward. A large hexagonal plate in the central column of Plate X, fig. 3, measures 9 mm. in width and 7 mm. in height. Two smaller interambulacral plates in the upper left side of Plate X, fig. 3 and 6 *c*, have each a perforate primary tubercle and scrobicule as well as secondary tubercles. These two plates probably represent plates of an adradial column, for in *Pholidocidaris irregularis* the adradial plates bear both primary and secondary tubercles. As in this view, Plate X, fig. 3, there are three columns which may be considered median columns, therefore we may reasonably assume an additional adambulacral column on each side, which would make five columns at least in the complete interambulacral area. Of course there may have been more than five. In the upper right side of Plate X, fig. 3, are three (perhaps four) ambulacral plates. Two of these plates (and apparently a third hidden partially beneath the other two) are low, wide, each with two pores separated by a median elevated septum and surrounded by a large peripodium. These pores lie near the right hand side of the plates and are typical of *Pholidocidaris*. They are closely similar to the isolated ambulacral plate seen in Plate X, fig 4 *c*. These several ambulacral plates bear secondary tubercles only. A large ambulacral plate, seen in Plate X, fig. 3, rounded in outline, lies just below the low ambulacral plates described. The pores in this larger plate are large, separated by an elevated median septum and surrounded by a very large peripodium. This large, rounded ambulacral plate as well as the lower plates, is essentially similar to what occur in *Pholidocidaris irregularis* (Phylogeny, Plate LXXIII, fig. 6, 7; Plate LXXIV, fig. 3, 4). The ambulacral plate, Plate X, fig. 4*c*, measures 8 mm. wide by 3.5 mm. high and shows strongly beveled sides, indicating adoral imbrication.

On the reverse side of this specimen, Plate X, fig. 5, 6 *b*, we have a view in which the right side corresponds with the top of fig. 3, and the left side similarly corresponds with the bottom of fig. 3. On the left side of fig. 5, a large plate seen from within is the same plate that in fig 3 is at the base of the figure



and seen from without. On this reverse side (Plate X, fig. 5) there are four columns of low, wide, nearly rhombic plates, all showing strong adapical and lateral imbrication and all with secondary tubercles only. The plates of the third column from the right are narrower than the others and imbricate on one side to the right, and on the other side to the left, over the plates of the next adjacent columns. This indicates that this column of narrower plates is the median column of the interambulacral area.

Associated with the more complete specimen just described and under the same catalogue number 64, I. G. 3440, are a few separate plates, Plate X, fig. 4 a.-c. The 4 c is an ambulacral plate considered above. The 4 a consists of two interambulacral plates in contact, the upper plate, probably from an adradial column, has a perforate primary tubercle with scrobicule and secondary tubercles. The lower plate, in part hidden, shows only secondary tubercles. The two plates in contact, fig 4 b, bear secondary tubercles only, and show a strongly beveled edge on the upper side. On the main specimen, Plate X, fig. 3, 5, there is a primary spine, quite stout, swollen at the base, tapering, incomplete distally, but measuring 6 mm. in length. There are also three fragmentary primary spines. A number of fine secondary spines exist, the longest measuring 3.5 mm. in length.

In another lot at the Brussels Museum, n° 65, I. G. 8353, also from Tournai, there are ten primary spines mounted on a card, Plate V, fig. 7, that I would unquestionably refer to *Pholidocidaris tornacensis*. These spines are quite stout, swollen at the base, tapering to the distal end, longitudinally finely striate. The longest of these spines comes to a fine point distally and is evidently complete. It measures 9 mm. in length. They are quite similar to the primary spines on the holotype and to the spines of *Pholidocidaris irregularis* Meek and Worthen.

In the British Museum, n° E 9335 from the Tournaisian, Tournai, A. S. Piret Collection, there is again a series of ten spines relatively stout, swollen at the base, tapering to the distal end, longitudinally finely striate. The longest of these spines comes to a fine point distally and is evidently complete. It measures 9 mm. in length. These spines are similar to those of Plate V, fig. 7, and are doubtless referable to *Pholidocidaris tornacensis* as paratypes. They were labeled «*Oligoporus radioles*». *Oligoporus* is not known from Europe; they certainly do not belong to that genus or any other in the family of the Palaeochinidae.

The holotype of *Pholidocidaris tornacensis* is certainly very distinct from any other species known. While very incompletely known it is referred to the genus *Pholidocidaris* because there are both large and small ambulacral plates similar to those known in *Pholidocidaris*. Also because the strongly imbricating interambulacral plates in median columns bear secondary tubercles only and plates of an apparently lateral column bear both a perforate primary tubercle and secondary tubercles.

**Pholidocidaris sp.**

Plate V, fig. 6a-6b.

In the Brussels Museum, n° 78, I. G. 3440, from the Lower Carboniferous, Viséen, Visé, coll. de Ryckholt, there are two ambulacral plates, Plate V, fig. 6a-6b. These plates are relatively large, rounded, more or less elongate in outline. The plate 6a measures 6.5 mm. in width and height. The pores are large with the peculiar elevated ridge between them which is very characteristic of *Pholidocidaris*. These plates differ from any of those shown in *P. tornacensis* so that they are not definitely referred to that species, though quite likely they belong to it. As I have shown in *Pholidocidaris irregularis* (Phylogeny, Plate LXXIII, fig. 6; Plate LXXIV, fig. 1), ambulacral plates of the ventral side are larger than those of the dorsal side. The two ambulacral plates here shown from Visé are probably ventral plates of *Pholidocidaris*. They are of interest chiefly as showing the occurrence of the genus at Visé.

**Genus FOURNIERECHINUS gen. nov.**

Test of gigantic size, measuring over 300 mm. in diameter, subspheroidal or lower in life, pentagonally lobed in outline, the lobes corresponding with ambulacral areas and the intermediate sinuses with the interambulacral areas. ambulacra broad, with numerous series of ambulacral plates in each area, interambulacra broad with many columns of small imbricating plates, numerous small spines, there is a powerful lantern.

*Fournierechinus*, on account of its imbricate plates and many columns of ambulacral plates, is referable to the *Lepidesthidae*. It differs from other genera of the family in having a large number of columns of interambulacral as well as of ambulacral plates. In its gigantic proportions it surpasses all known sea-urchins, living or fossil, and in fossil forms is approached only by *Proterocidaris gigantea*. In its lobed margin it differs from all known regular Echini.

It gives me great pleasure to name this remarkable and superb sea-urchin in honour of my friend, Dom Grégoire Fournier, O. S. B., who through his devoted enthusiasm and skill has amassed such a splendid collection of Palaeozoic Echini from Denée.

**Fournierechinus deneensis sp. nov.**

Plate IX; Plate X, fig. 1-2.

Gigantic sea-urchins, two of the three known specimens measuring over 300 mm. in diameter. Test apparently low, probably about as in the Recent

Phormosoma, pentamerously lobed in outline, the lobes corresponding to the ambulacral areas and the intermediate sinuses to the interambulacral areas. These lobes exist only on the periphery of the test, and are not produced adapically or adorally as plications of the surface. Ambulacra about the same width as the interambulacra, with many vertical series of small polygonal plates, uniform in character throughout. The two median columns not differentiated from other plates of the area as they are in many of the Palaeochinidae. Ambulacral plates measure about 3 mm. across. Interambulacra are broad, with fourteen columns of relatively small plates in each area. Interambulacral plates polygonal, convex, imbricating adapically. They measure about 5 mm. across both in height and width. No tubercles were seen on the holotype, but the paratypes have spines about 4-6 mm. long. A powerful lantern exists in the three known specimens, in the holotype measuring about 74 mm. across the dorsal face.

The three known specimens of this species are from the « Marbre noir de Dinant » (Viséen inférieur, V 1 a), of Denée, and are all in the Musée Maredsous. The holotype Plate IX is in the Mus. Maredsous, number 140. A small piece representing a fragmentary counterpart, given me by Dom Gregoire Fournier, orig. n° 140', is now in the Mus. Comp. Zoöl., n° 3334. A cast of the whole specimen, made at the Brussels Museum, is in the Mus. Comp. Zoöl., n° 3335. Before taking the photograph of this specimen, also the two others of the same species, the outline was marked and the areas lettered in Chinese white as an aid in differentiating parts. Also a ten centimeter rule was attached to the slab and photographed with the specimens to serve as an aid in verifying measurements.

The outline of the test is strongly lobed on the periphery, practically a unique character for regular Echini. Plates are wanting on a great part of the periphery except in area E, where interambulacral plates extend to the limits of the sinus. This outer portion therefore represents largely an impression of the body from which plates have for the most part disappeared. While plates are wanting on much of the peripheral portion of the holotype, the plates, both ambulacral and interambulacral, extend completely to the periphery of the test in the other two specimens described, Plate X, fig. 1, 2. In all three specimens the test is completely flattened out upon the slabs of rock.

The holotype, Plate IX, though wanting in parts, is not at all distorted and shows every indication of retaining the original form except for its flatness. The lantern is almost exactly in the centre of the test as is shown by the detailed measurements. Fortunately, the specimen shows a little more than one-half of the test, so that from it one can make a fair estimate of the whole. The plane through ambulacral lobe J to the opposite interambulacral sinus E measures 322 mm.

As seen by the accompanying table of measurements, the average length of the three ambulacral radii, J, B, and D, from the centre of the lantern to the periphery, is 180 mm. The average measurement of the interambulacral radii A, C and E, from the centre of the lantern to the limits of the reëntrant sinuses is 141 mm. An average plane through an ambulacrum and opposite interambulacrum would measure 321 mm. The diameter of a circle that would fit around the periphery of the specimen would be about 360 mm. Certainly an astonishing size, far beyond anything known in any other sea-urchin, living or fossil. The figure of the type, Plate IX, is reduced to about 76 % life-size.

From centre of lantern to limit of ambulacral lobe J . . .	measures :	182 mm.
— — interambulacral sinus A	—	140 —
— — ambulacral lobe B . .	—	175 —
— — interambulacral sinus C	—	139 —
— — ambulacral lobe D . .	—	183 —
— — interambulacral sinus E	—	145 —

The ambulacral plates are preserved in part in areas J, B and D, but area B is the clearest (Plate IX). In this area B, twenty vertical series of plates exist between interambulacra A and C. The ambulacral plates are small, about 3 mm. in diameter and imbricate adorally. The pores are about in the middle of each plate (as shown in specimen n° 142, Plate X, fig. 1). The ambulacral plates are polygonal in form, and no median or other columns stand out as markedly different from the others as in many of the Palaeochinidae. Interambulacral plates are seen in areas A, C and E, but are best preserved in area A. The individual plates are polygonal, convex, imbricate adapically and are small, being about 5 mm. in height and width. The width of interambulacrum A as far as preserved peripherally is 57 mm. which is about the width of ambulacrum B in the same zone.

The Aristotle's lantern is one of the most striking features of this specimen (Plate IX). It is almost exactly in the centre of the test and is represented by the dorsal limits of the half-pyramids, all ten of which are more or less clearly recognizable. The diameter across the lantern is 74 mm. which, as all the parts are so nearly in place, must be quite close to the original size in life. The dorsal borders of the half-pyramids from the proximal to the distal or peripheral limits of the same, measure about 27 mm. There is no trace of the epiphyses capping the half-pyramids, but a plate in area D is very probably a misplaced epiphysis. The outer limits of the half-pyramids measure about 20 mm. apart as seen especially well in areas A to G.

A second specimen of *Fournierechinus deneensis* from Denée, Mus. Maredsous, n° 142, is shown in Plate X, fig. 1. It also is seen in dorsal view and while incomplete and not very clear in details, shows important points. The specimen is perfectly flat, but is somewhat distorted, so that measurements are not as

close as in the holotype. The width across the base of the specimen as figured is about 240 mm. From the centre of the lantern to the limits of ambulacral lobes B measures about 128 mm. and to D measures about 132 mm. and to the limit of ambulacral lobe F about 116 mm. From the centre of the lantern to the limit of interambulacral sinus A measures about 125 mm. and to interambulacral sinuses C about 122 mm. and to E about 112 mm. The average measurement of an ambulacral radius is therefore about 125 mm. and an interambulacral radius about 120 mm. The specimen, if complete, would therefore measure through an ambulacrum and opposite interambulacrum an average of about 245 mm. It is distinctly smaller, and the lobes and sinuses are not as strongly marked as in the holotype. This degree of lobing may be a feature developed with age or it may be a matter of individual difference. In all the areas the ambulacral and interambulacral plates extend from near the centre to the limits of the test, whereas they are lacking peripherally in the holotype. In ambulacral areas B, D and F, as indicated by arrows, the ambulacral plates reach to the limits of the lobes. The ambulacral plates are small, with pores in about the middle of the plates and there are at least twenty columns in an area. The interambulacral plates are also small and extend to the limits of the sinuses in areas A, C and E. Many small but rather stout spines, measuring up to 4.5 or 5 mm. in length, are scattered over the surface in both ambulacral and interambulacral areas. The spines of both areas are apparently alike. Indications of the lantern are obvious, though obscure in details.

Still a third specimen of *Fournierechinus deneensis* from Denée is in the Musée Maredsous number 141 (Plate X, fig. 2, reduced to about one-third life-size). It is quite flat on the rock, is apparently seen in ventral view, and while not very clear in details it is a very large and complete specimen. It is quite free from distortion. The ambulacral lobes and interambulacral sinuses are clearly defined but are not as greatly developed as in the holotype. The width of the test through ambulacrum B and the opposite interambulacrum G is 310 mm. From a point in the centre of the lantern to the limits of the test in the several areas the measurements are as follows :

From centre of lantern to limits of interambulacral sinus A		measures about :	150 mm.
—	—	ambulacral lobe B . .	163 --
—	—	interambulacral sinus C	143 --
—	—	ambulacral lobe D . .	160 —
—	—	interambulacral sinus E	140 —
—	—	ambulacral lobe F . .	160 —
—	—	interambulacral sinus G	138 —
—	—	ambulacral lobe H . .	158 —
—	—	interambulacral sinus I	136 —
—	—	ambulacral lobe J . .	150 —

From these measurements it is seen how very little distortion exists for such a huge specimen with all the areas in place and with the character of imbricating plates. There is less distortion indeed than would often be found in specimens of Recent Echinothurids which also have large tests and imbricating plates. It is seen from the measurements given that the average length of the several ambulacral radii from the centre of the lantern to the limits of the test is about 158 mm. and the average length of the several interambulacral radii is about 141 mm. From these measurements it results that the diameter of an enclosing circle would be about 316 mm. The specimen is therefore not as large as the holotype but is practically perfectly preserved as regards its outline and freedom from distortion. The specimen is not very clear and little structure can be made out, but the plates of the test extend from near the centre to the periphery in all areas. A considerable number of spines exist on both ambulacral and interambulacral areas. They measure up to about 5-7 mm. in length. The ventral aspect of the lantern protrudes from the middle of the test but no structure can be made out.

*Fournierechinus deneensis* from the « Marbre noir de Dinant », at Deneé is certainly a most remarkable echinoid, and unique for the whole group in several respects. The holotype, Plate IX, as estimated, would fill an enclosing circle measuring 360 mm. in diameter, and a smaller specimen, Plate X, fig. 2, would fill an enclosing circle measuring about 316 mm. in diameter. This species in its great size thus reaches greater proportions than any other known sea-urchin, either fossil or living. The largest fossil sea-urchin of which I have record is the *Proterocidaris gigantea* described in this paper, which measures up to 295 mm. in diameter. Of recent forms, Dr. H. L. Clark <sup>(1)</sup> records an *Echinus esculentus* Linn. from Plymouth, England, that measures 176 mm. in diameter, and he says that this is larger than any other regular sea-urchin excepting only the largest of the flexible Echinothurids. A. Agassiz <sup>(2)</sup> records an Echinothurid, *Phormosoma (Echinoma) hoplacantha* Wyv. Thomson that measures no less than 312 mm. in diameter, and he says that it is the largest sea-urchin known to him. Later, however, A. Agassiz and Clark <sup>(3)</sup> record an Echinothurid *Sperosoma giganteum* A. Ag and Clark, from Japan, in which the type and unique specimen measures 320 mm. in diameter. This is doubtless the largest sea-urchin previously recorded. *Fournierechinus deneensis* therefore by far exceeds all previous records for size. As regards having marginal ambulacral lobes and interambulacral sinuses, this species

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(1) 1925, Catalogue of the recent sea-urchins in the collections of the *British Museum*, p. 111.

(2) 1881, *Challenger Echini*, p. 101.

(3) 1909, *Mem. Mus. Comp. Zoöl.*, vol. XXXIV, Plates 83-85.



stands unique for all regular Echini. In this respect, however, it can be compared with many Recent Clypeasters in which also to a more or less marked degree the ambulacral areas are extended as peripheral lobes, and the interambulacra extend to the intermediate sinuses. This character is especially developed in *Clypeaster europacificus* H. L. Clark (<sup>1</sup>), from the Eastern Pacific. In *Fournierechinus deneensis* the ambulacra with twenty columns of plates in an area is only equalled in this character by *Meekechinus elegans* Jackson, from the base of the Permian, of Kansas. This extreme type, however, has only three columns of plates in the interambulacra, and the test is relatively small, the holotype measuring 54 mm. in diameter (Phylogeny). *Fournierechinus deneensis* is extreme also in having fourteen columns of plates in an interambulacral area. This is the highest number known in a sea-urchin and is equalled only by *Hyattechinus pentagonus* Jackson, from the Lower Carboniferous of Pennsylvania. This type, however, has only two columns of plates in an ambulacral area. *Fournierechinus deneensis* has a lantern which in the holotype measures 74 mm. across, which is apparently close to what it measured in life, by far the largest lantern known in any echinoid.

Altogether *Fournierechinus deneensis* with its great size, lobed margin, maximum known number of columns of plates in both the ambulacra and the interambulacra, stands unique in all Echini as a specialized and highly evolved form.

The possession of this extraordinary *Fournierechinus*, with the splendid series of *Proterocidaris gigantea* and many other Echini from the single locality Denée, should make the Musée Marcussous a Mecca for all lovers of Echini.

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(<sup>1</sup>) 1914, *Mem. Mus. Comp. Zoöl.*, vol. XLVI, p. 27, Plates 120-131.

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## DESCRIPTIONS OF PLATES

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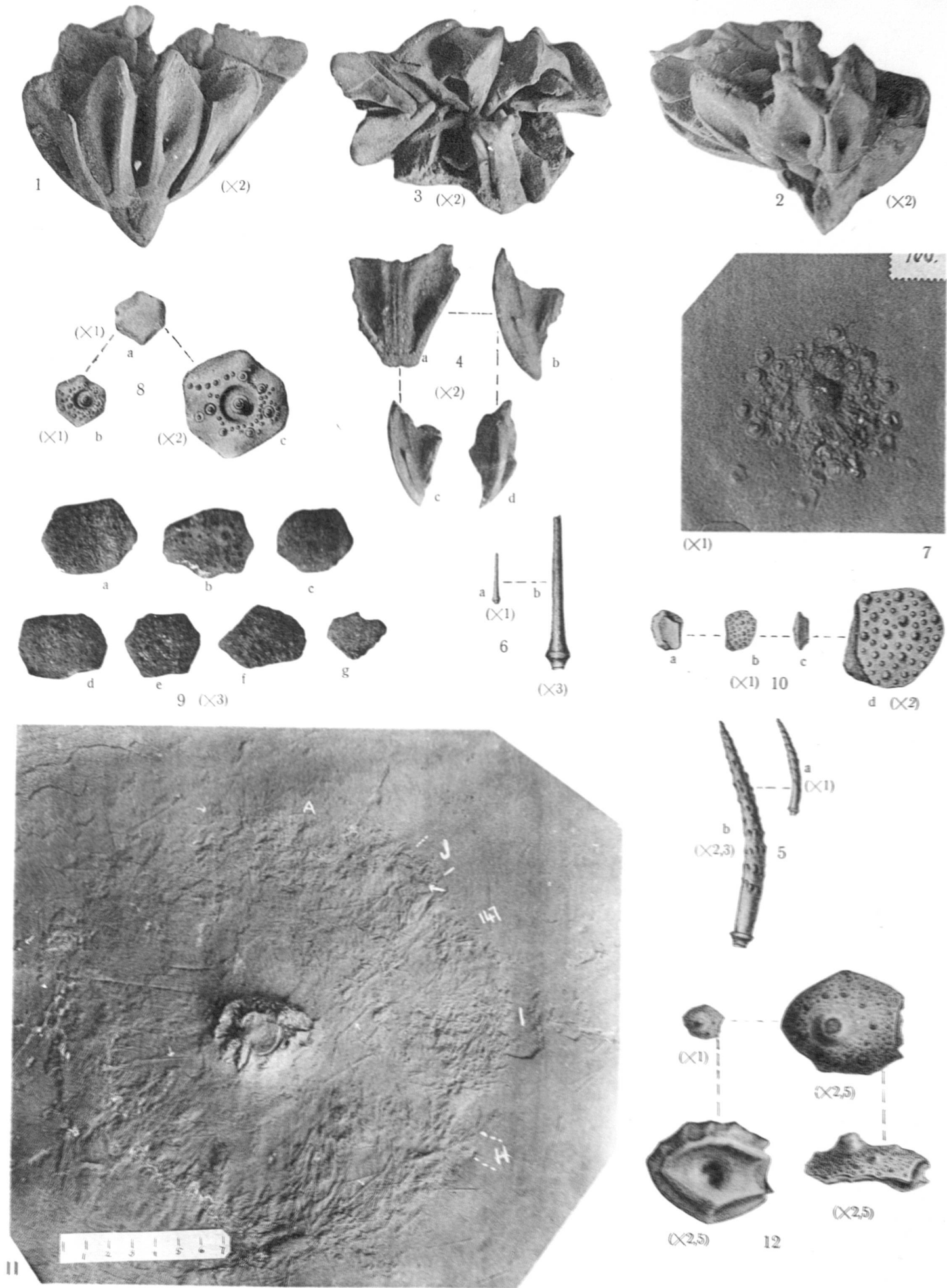
The drawings of figures illustrating the text as insert-cuts, excepting text-fig. 5, were made by Mr. J. Henry Blake. The drawings reproduced in the plates were made by an artist for the late Professor de Koninck. The photographs reproduced in the plates were made by Dom Henri Mariage, O. S. B., of the Abbaye de Maredsous, by the photographer at the « Musée royal d'Histoire naturelle de Belgique », by D. J. Johnson, of Tunbridge Wells, or by Miss Solutia M. Taylor of Boston.

In the lettering of areas, where shown, the sequence is from left to right, or clockwise, the specimen being viewed from above, or dorsally, Plate VII. If viewed from below, or ventrally, then the lettering of areas is from right to left, or anticlockwise, Plate III, fig. 3. The lettering of areas, from A to J, is purely a matter of convenience for description and has no relation to true axes.

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### PLATE I

- FIG. 1-3. *Archaeocidaris Urvii* (FLEMING) . . . . . 15  
Aristotlès lantern, Calcaire Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 49, I. G., 3440.)  
FIG. 1. Side view, × 2.  
FIG. 2. Seen from the opposite side, × 2.  
FIG. 3. Seen from dorsal view, × 2.
- FIG. 4. *Archaeocidaris Nerei* (MÜNSTER) . . . . . 12  
Calcaire Tournaisien, Pont-à-Rieu, carrière Delwart. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 51, I. G., 6938, *a, b, c, d*. Dental pyramids seen from face view, internal side view and external side view, × 2.)
- FIG. 5. *Archaeocidaris propinqua* sp. nov. . . . . 17  
Calcaire Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 86, I. G., 3031.)  
Drawing of spine, life size and enlarged.
- FIG. 6. *Archaeocidaris setosa* sp. nov. . . . . 11  
Calcaire Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 87, I. G., 3031.)  
Drawing of spine life size and enlarged.

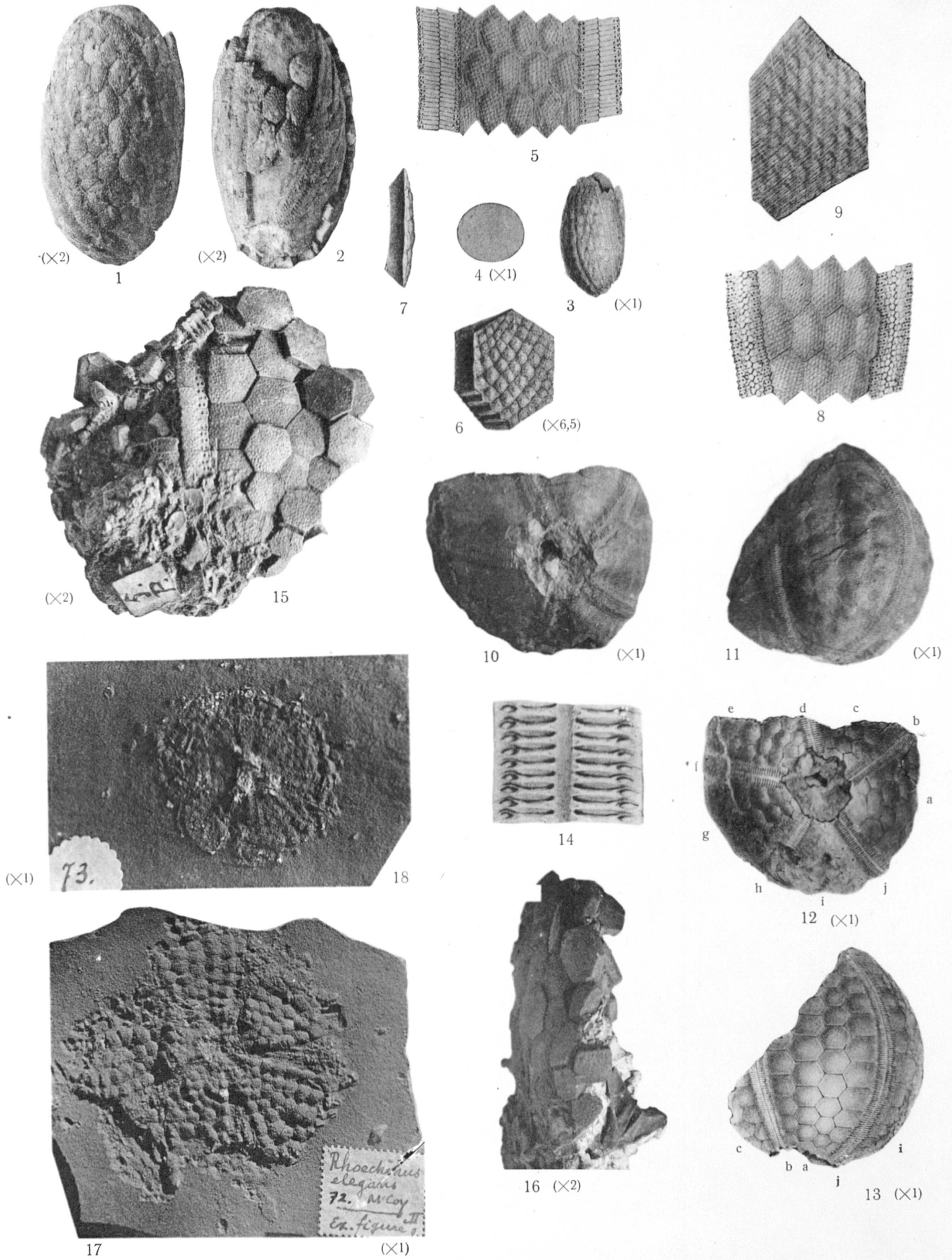


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PLATE II

- FIG. 1-9. *Palaeechinus visetensis* sp. nov. . . . . 33  
 Viséen, Visé. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 38, I. G.,  
 3440.)  
 FIG. 1-2. Holotype in side view and reverse, × 2.  
 FIG. 3. Drawing of same, nat. size.  
 FIG. 4. Cross section of same, nat. size.  
 FIG. 5 and 8. Drawing showing enlargements of ambulacral and  
 interambulacral structure.  
 FIG. 6-7. Interambulacral plate in surface and side view much  
 enlarged.  
 FIG. 9. Interambulacral plate much enlarged.
- FIG. 10-14. *Palaeechinus globulus* sp. nov. . . . . 30  
 Calcaire de Celles (Tournaisien, assise de Celles, facies Waulsortien),  
 Celles near Dinant. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 21,  
 I. G., 2739.)  
 FIG. 10 and 12. Photograph and drawing of holotype seen from ven-  
 tral view, × 1.  
 FIG. 11 and 13. Photograph and drawing of same, seen from side  
 view, × 1; *a, c, e, g, i* interambulacral areas, *b, d, f, h, j* ambula-  
 cral areas.  
 FIG. 14. Ambulacral detail from mould of the interior, much enlar-  
 ged.
- FIG. 15-16. *Palaeechinus ellipticus* M' COY . . . . . 36  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 63,  
 I. G., 3031.) See also Plate III, fig. 5.  
 FIG. 15. Face view showing a half-ambulacrum and an associated  
 interambulacrum, × 2.  
 FIG. 16. The same in side view showing the same interambulacrum,  
 and part of an Aristotle's lantern in place, × 2.
- FIG. 17. *Palaeechinus elegans* M' COY . . . . . 37  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye  
 de Maredsous, n° 72.)  
 Seen from dorsal view, × 1. Figured by Fraipont, 1904, Plate II,  
 fig. 9, under name *Rhoechinus elegans* (M' COY).
- FIG. 18. *Palaeechinus elegans* M' COY. . . . . 37  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye  
 de Maredsous, n° 73, × 1.)
- FIG. 1, 2, 10, 11, 15 16 from photographs by photographer of Mus. roy. d'Hist. nat.  
 de Belg.; FIG. 17, 18 from photographs by Dom Henri Mariage.





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PLATE III

- FIG. 1. *Maccoya sphaerica* (M' COY) . . . . . 39  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye  
 de Maredsous, n° 94.) Dorsal view, × 1.
- FIG. 2-4. *Lovenechinus Lacazei* (JULIEN) . . . . . 40  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée.  
 FIG. 2, 3. Drawing and photograph of same specimen in ventral  
 view, × 1. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 5, I. G.,  
 6938.)  
 FIG. 2a. Drawing of interambulacral plate of same much enlarged.  
 FIG. 4. Very large specimen, × 1. (Coll. Abbaye de Maredsous,  
 n° 123.)
- FIG. 5. *Palaeochinus ellipticus* M' COY . . . . . 36  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 63,  
 I. G., 3031.)  
*a-f.* Isolated interambulacral plates of the individual shown in  
 Plate II, fig. 15, × 2. See also Plate II, fig. 15, 16.
- FIG. 1, 4 from photographs by Dom Henri Mariage; FIG. 3, 5 from photographs by  
 photographer of Mus. roy. d'Hist. nat. de Belgique.

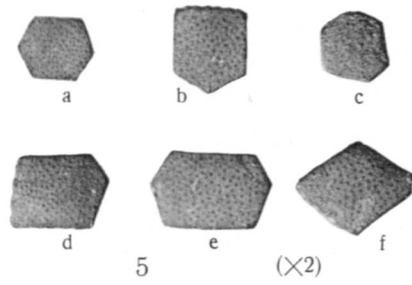
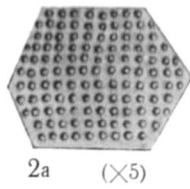
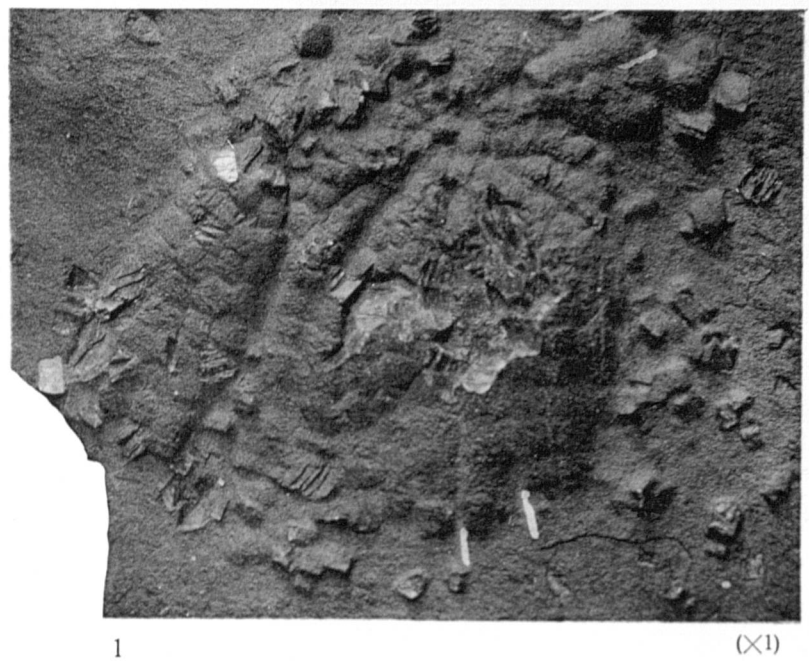
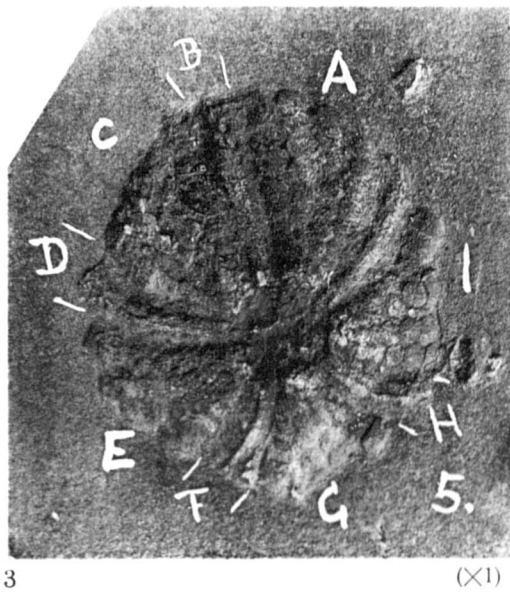


PLATE IV

- FIG. 1 *Lovenechinus anglicus* JACKSON . . . . . 45  
Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye de Maredsous, n° 138.)  
In side view, the ambulacral areas are lettered B, D, F, H and J, the interambulacral areas are lettered A, C, E, G, and I. Reduced to about 78 % natural size.
- FIG. 2-3. *Hyattechinus elegans* sp. nov. . . . . 24  
Tournaisien, Tournai. (Coll. Institut de Géologie, Louvain.)  
FIG. 2, natural size.  
FIG. 3, × 2.  
See also Plate V, fig. 5a-r and text-fig. 5, p. 25.
- FIG. 1, from photograph by Miss Solatia M. Taylor, of Boston, Mass., and fig. 2, 3 from photographs by photographer of Mus. roy. d'Hist. nat. de Belgique.
- FIG. 4a-g. *Hyattechinus elegans* sp. nov. . . . . 24  
Tournaisien, Tournai. (Coll. Abbaye de Maredsous, n° T, 211.) Dissociated plates and spines, × 2. From photographs by D. J. Johnson.  
a-d. Interambulacral plates with secondary tubercles only (a); or with perforate primary and secondary tubercles (b-d).  
e. Spines apparently associated with primary tubercles.  
f. Ambulacral plate seen from outside.  
g. Ambulacral plate seen from inside, showing spinose projection between pores and perradial border of plate.
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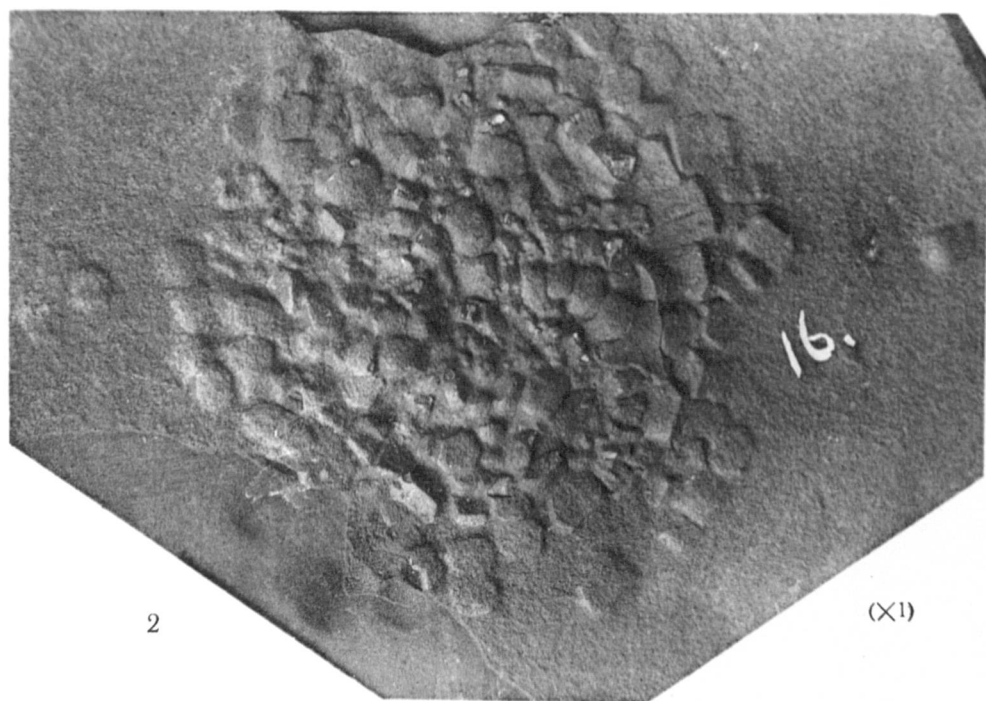
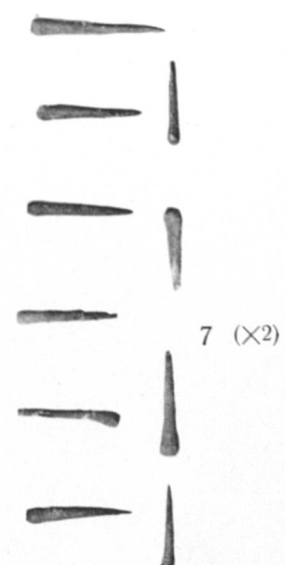
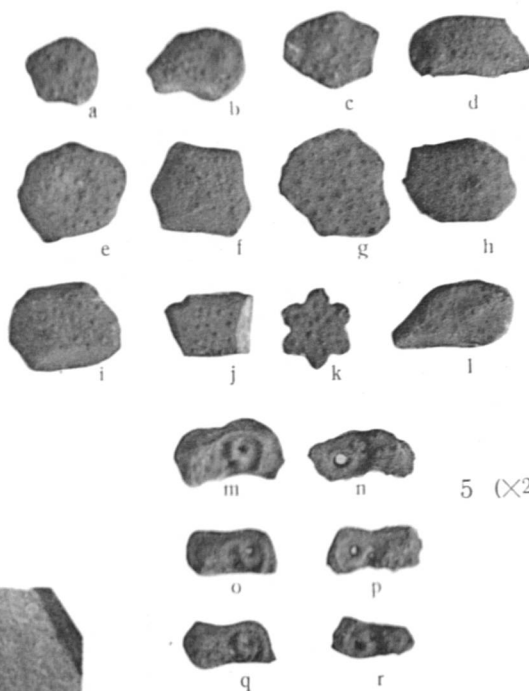
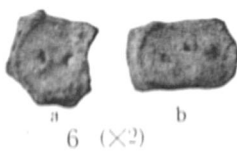
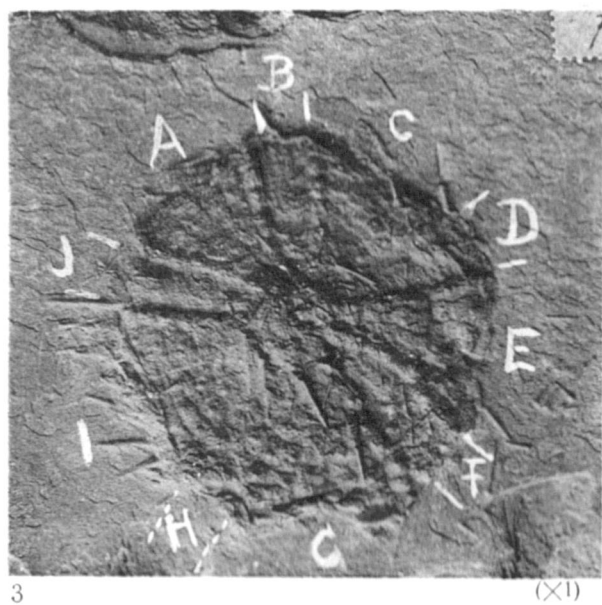
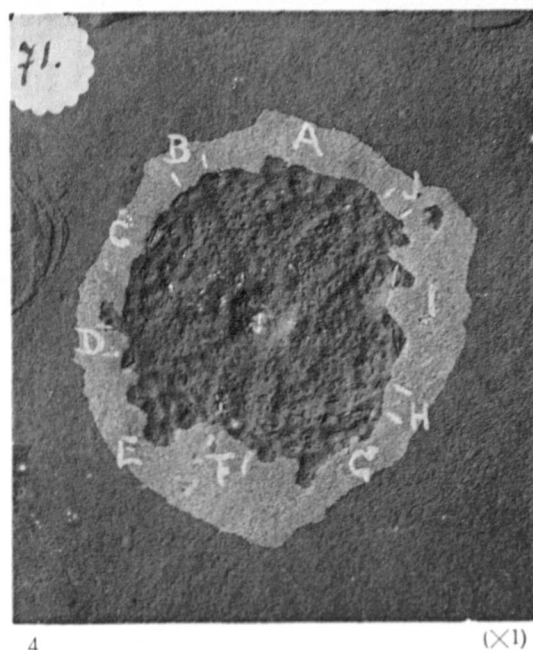
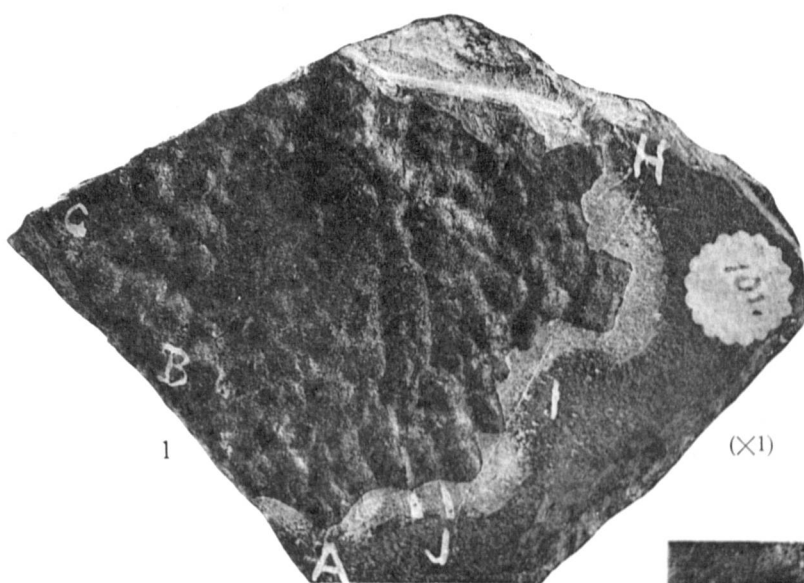




PLATE V

- FIG. 1-2. *Lepidechinus belgicus* sp. nov. . . . . 46  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée.  
 FIG.1. Holotype seen in side view, × 1. (Coll. Abbaye de Maredsous, n° 101.)  
 FIG. 2. Paratype seen in dorsal view, × 1. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 16, I. G., 8391.)
- FIG. 3-4. *Perischodomus Fraiponti* sp. nov. . . . . 48  
 Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye de Maredsous, nos 78 and 71.)  
 FIG. 3. Holotype (n° 78) in dorsal view, × 1.  
 FIG. 4. Another and smaller specimen (n° 71), paratype, seen in ventral view, × 1.
- FIG. 5. *Hyattechinus elegans* sp. nov. . . . . 28  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 71, I. G., 8353.)  
*a-j*, and *l*. Isolated interambulacral plates, × 2.  
*k*. Isolated, star-shaped plate, × 2.  
*m-r*. Isolated ambulacral plates, × 2.  
 See also Plate IV, fig. 2-4 and text-fig. 5, p. 25.
- FIG. 6. *Pholidocidaris* sp. . . . . 67  
 Viséen, Visé. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 78, I. G., 3440.)  
*a-b*. Isolated ambulacral plates, × 2.
- FIG. 7. *Pholidocidaris tornacensis* sp. nov. . . . . 64  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 65, I. G., 8353.)  
 Paratypes, primary spines, × 2.  
 See also Plate X, fig. 3-6.
- FIG. 8-9. *Archaeocidaris Urvii* (FLEMING) . . . . . 17  
 Nouvelle carrière Mutsaarts à Bioul. Houiller, Namurien inférieur, assise de Chokier, base. (Coll. Mus. roy. d'Hist. nat. de Belg., nos 106 and 107, I. G., 9083.)  
 FIG. 8. Photograph of cast of external mould of interambulacral plate, n° 106, × 2.  
 FIG. 9. Photograph of cast of external mould of interambulacral plate, n° 107, × 2.
- FIG. 1, 3, 4 from photographs by Dom Henri Mariage; FIG. 2 and 5-9 from photographs by photographer of Mus. roy. d'Hist. nat. de Belgique.





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PLATE VI

*Proterocidaris gigantea* KONINCK . . . . . 51

Marbre noir de Dinant. (Viséen inférieur, V 1a). Loyers, carrière à carreaux, 5 kilomètres N. E. of Dinant. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 1, I. G., 2739.)

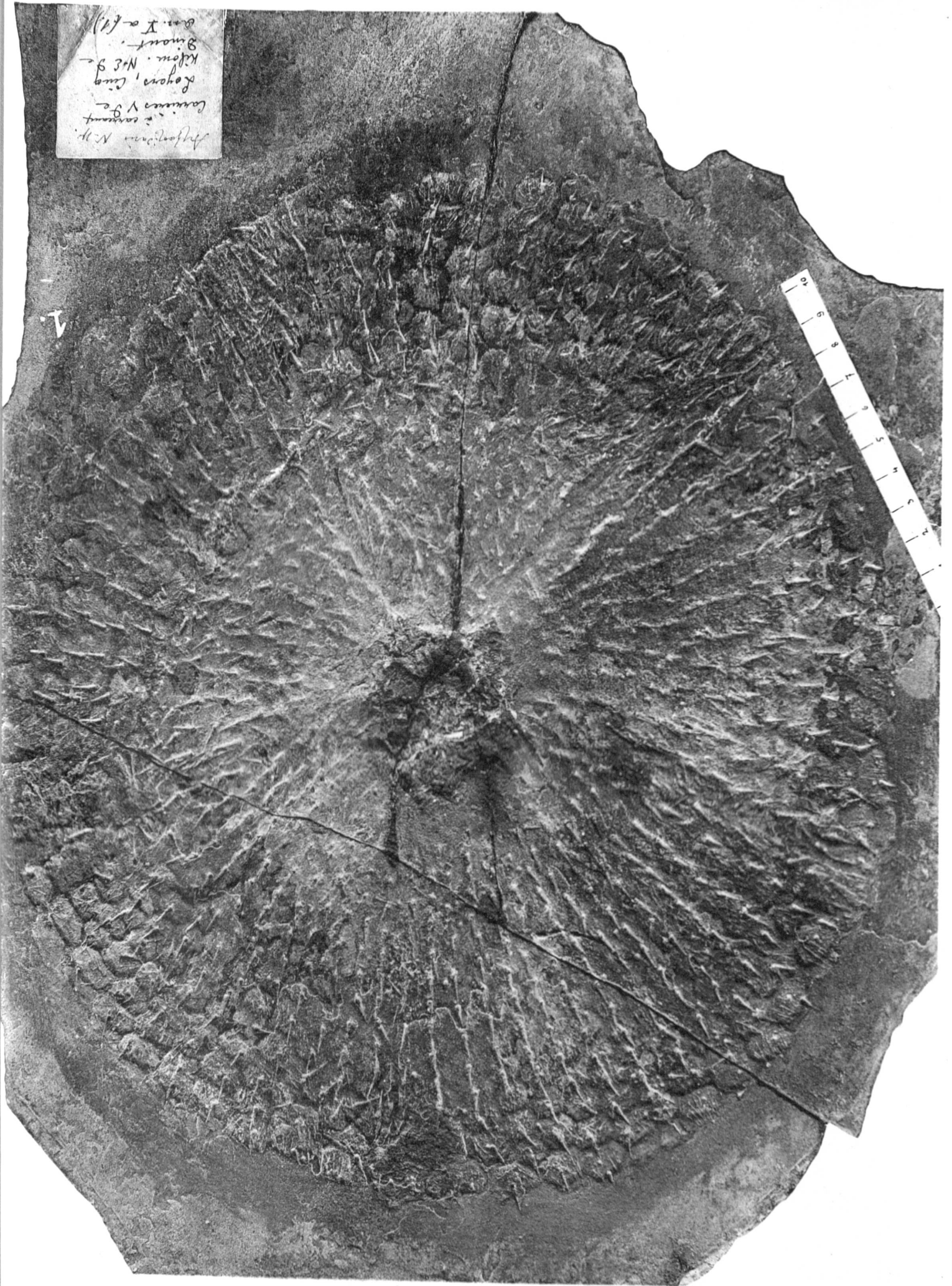
Holotype of genus and species (DE KONINCK, Assoc. franç. pour l'avancement des Sc., 10<sup>e</sup> Session, 1882, p. 514, pl. VIII.)

External mould of dorsal side reduced to about 78%, or a trifle more than three-fourths natural size.

A centimeter rule photographed with the specimen shows the relative size. In this figure, as here shown, it looks as though the plates were in place. If, however, the figure is reversed, then it looks like external moulds of the plates, which is the actual condition.

From photograph by photographer of Mus. roy. d'Hist. nat. de Belgique.





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PLATE VII

*Proterocidaris gigantea* KONINCK . . . . . 53

Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye de Maredsous, n° 127.)

Specimen seen in dorsal view. The outline of the distended gut is seen through the flexible test. Primary spines mostly radiate from point of attachment outward.

A, C, E, G, I, interambulacral areas; B, D, F, H, J, ambulacral areas.

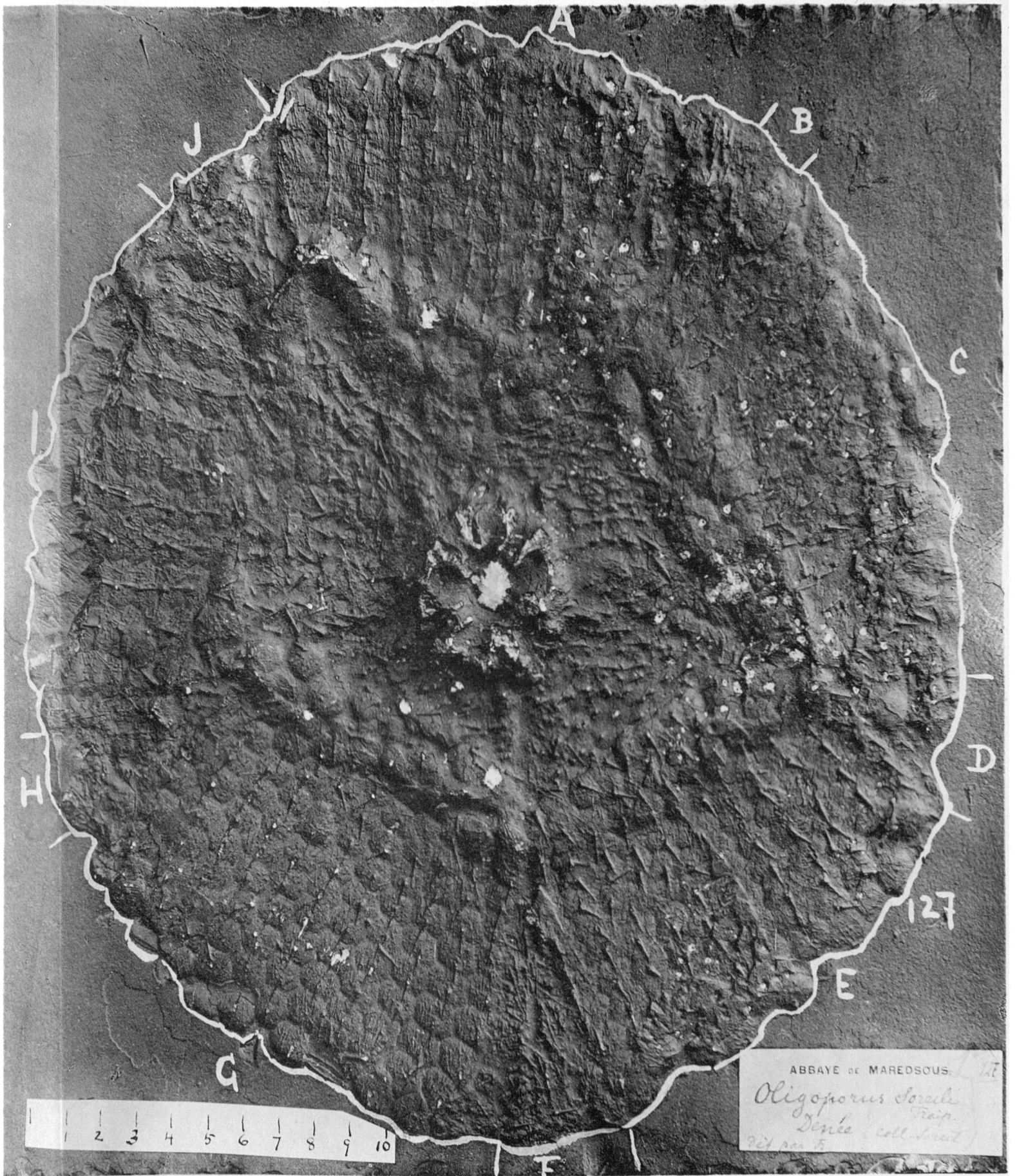
Aristotle's lantern in centre.

The specimen which measures 260 mm. in diameter is slightly reduced in the figure, to about 90 % natural size.

A centimeter rule photographed with the specimen shows the relative size.

From photograph by Dom Henri Mariage, enlarged by D.J. Johnson.





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PLATE VIII

FIG. 1. *Proterocidaris gigantea* KONINCK. . . . . 54

Marbre noir de Dinant. (Viséen inférieur, V 1a), Denée. (Coll. Abbaye de Maredsous, n° 151.)

An immature individual seen from dorsal side.

B, D, F, H, J, ambulacral areas obscurely seen; A, C, E, G, I, interambulacral areas. Remains of Aristotle's lantern in centre, slightly reduced, to about 88 % natural size.

FIG. 2. *Proterocidaris gigantea* KONINCK. . . . . 54

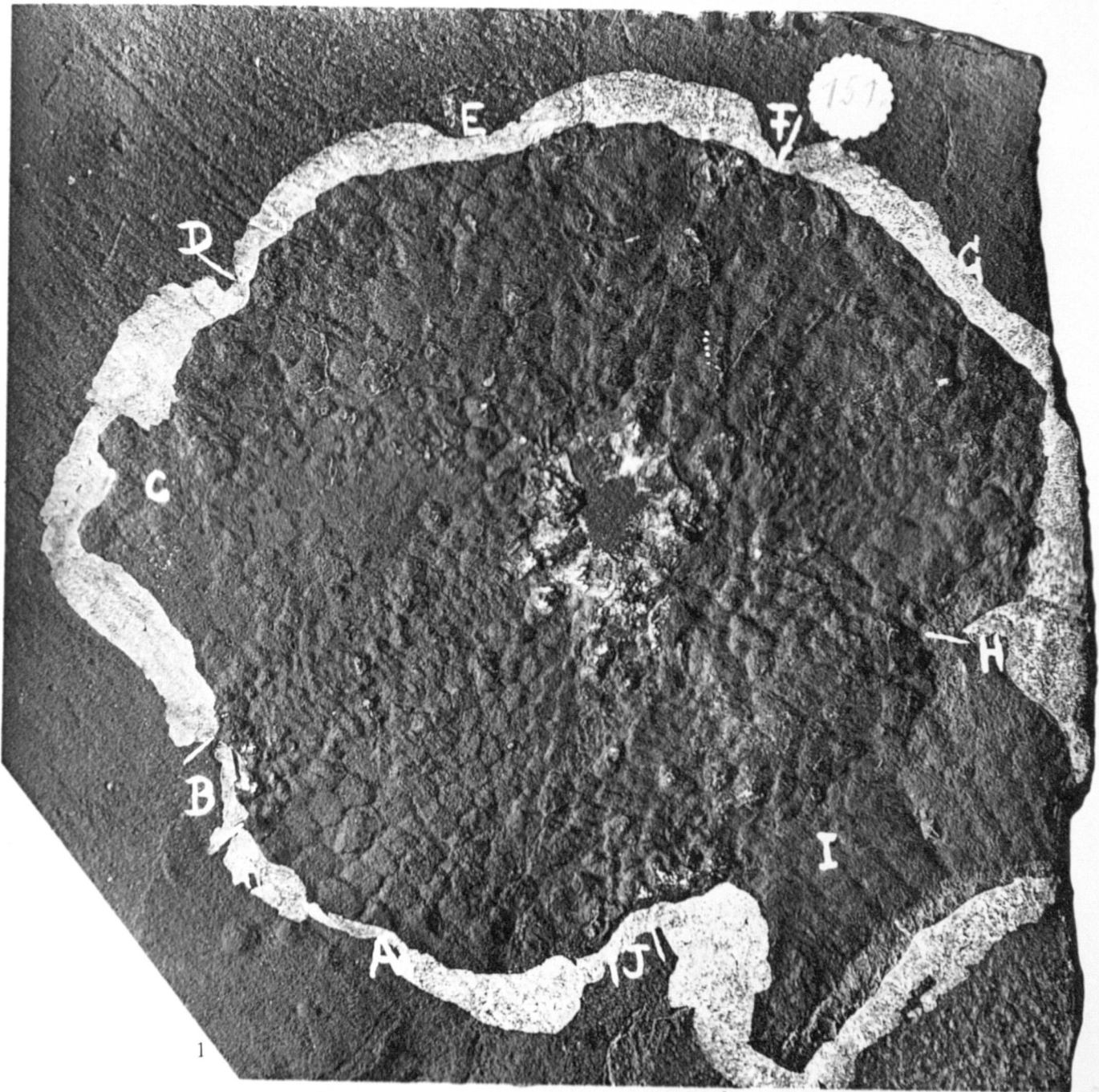
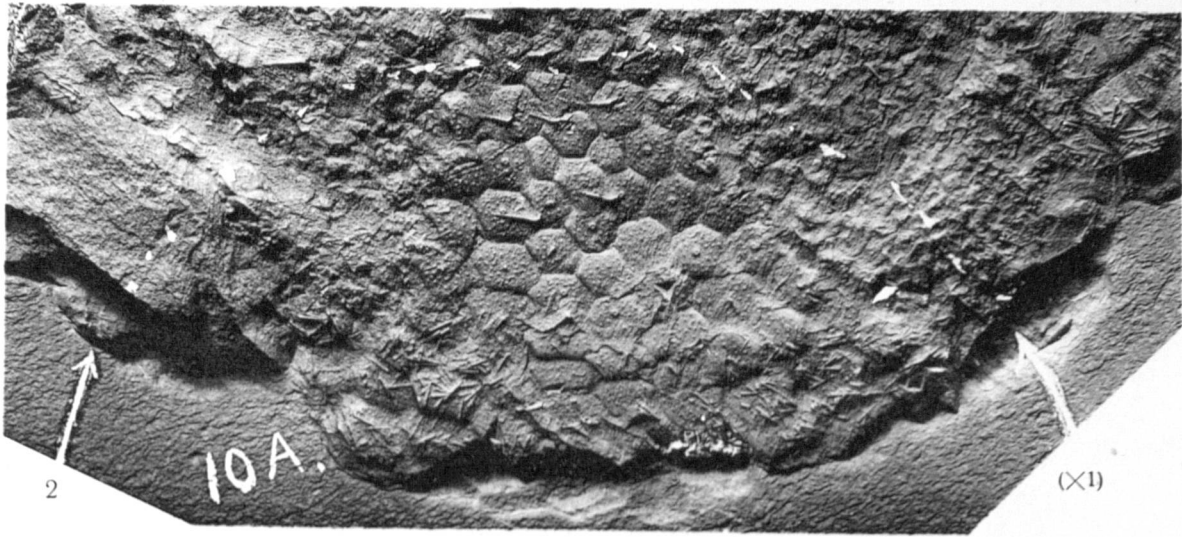
Marbre noir de Dinant. (Viséen inférieur, V 1a), Denée, Carrière Piètte. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 10 A, I. G., 8391.)

Portion of interambulacrum in dorsal view to show structure, natural size.

FIG. 1, from photograph by Miss Solatia M. Taylor, of Boston, Mass.; FIG. 2, from photograph by photographer of Mus. roy. d'Hist. nat. de Belgique.







R. T. JACKSON. — PALAEOZOIC ECHINI OF BELGIUM.

## PLATE IX

*Fournierechinus deneensis* gen. et sp. nov. . . . . 67

Marbre noir de Dinant (Viséen inférieur, V 1a), Denée. (Coll. Abbaye de Maredsous, n° 140.)

Holotype seen in dorsal view.

Outline and areas marked in Chinese white.

B, D, J, lobed ambulacral areas; A, C, E, interambulacral areas.

The plates of test are largely wanting on the peripheral portion, but are seen in place to the periphery in other specimens (Plate X, fig. 1-2).

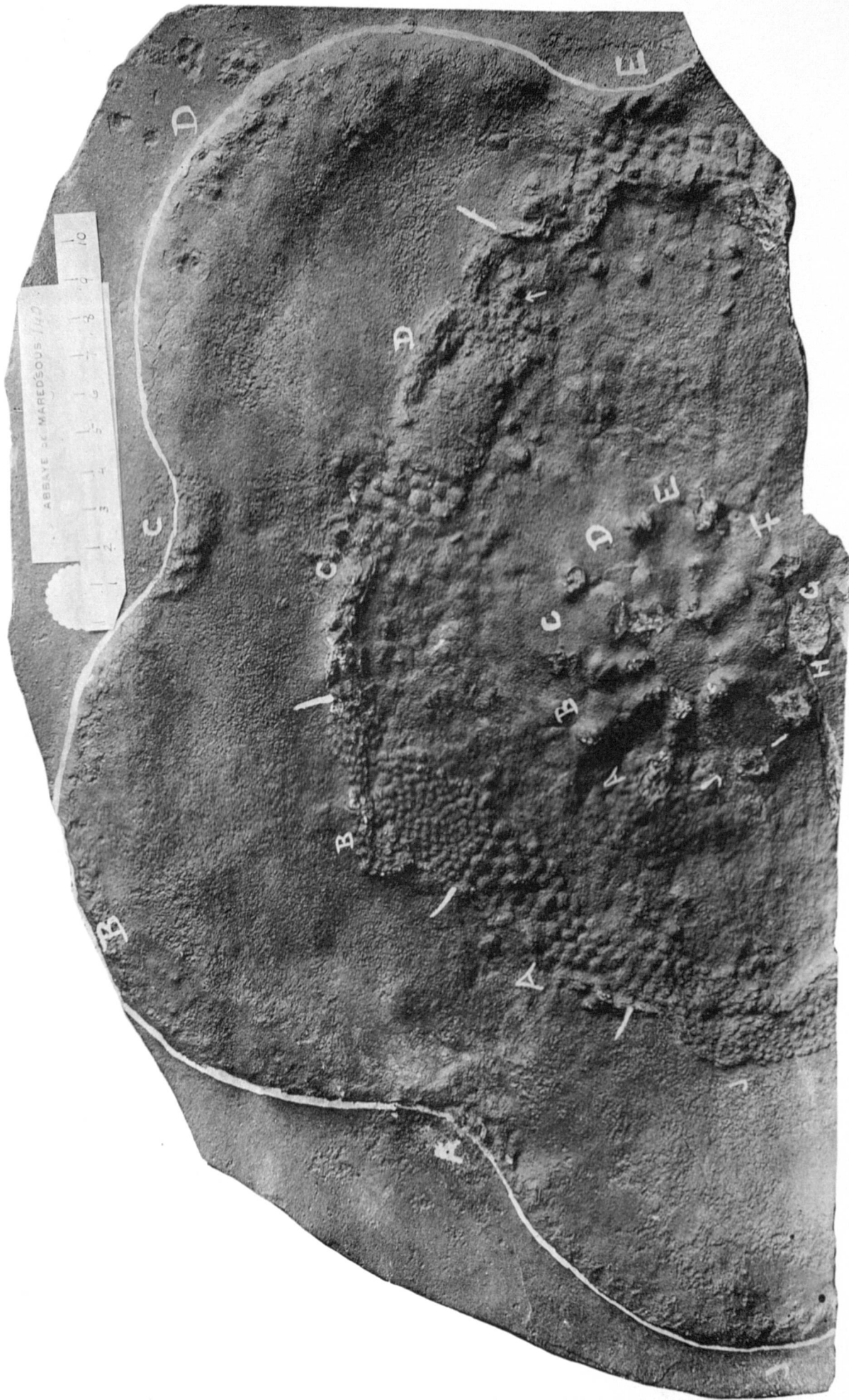
An Aristotle's lantern is in the centre.

This, the largest known sea-urchin, in the figure, is reduced to about 76 %, or practically three-fourths natural size.

A centimeter rule photographed with the specimen shows relative size.

From photograph by Dom Henri Mariage, enlarged by D. J. Johnson.

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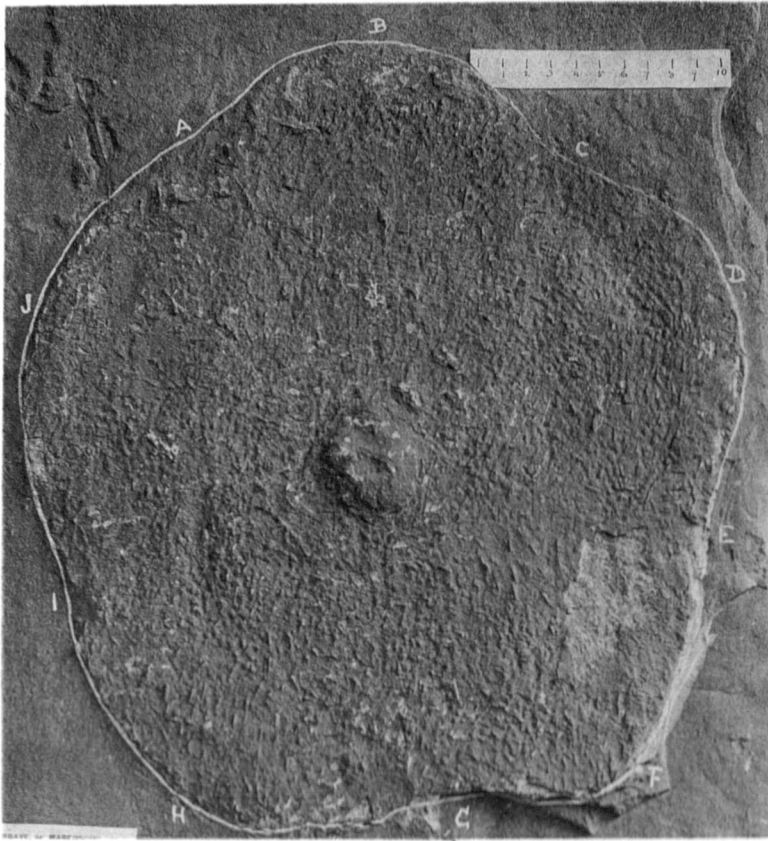
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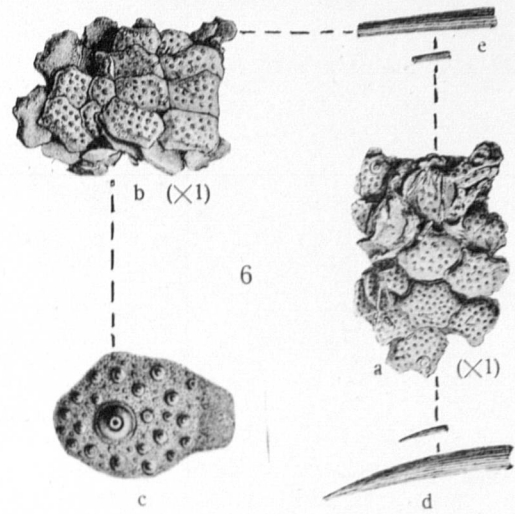
PLATE X

- FIG. 1-2 *Fourniechinus deneensis* gen. et sp. nov. . . . . 69  
 Marbre noir de Dinant. (Viséen inférieur, V 1a), Denée. (Coll. Abbaye  
 de Maredsous, fig. 1, n° 142 and fig. 2, n° 141.)  
 FIG. 1. Paratype.  
 Seen in dorsal view, ambulacral and interambulacral plates extend  
 to periphery of test. Some spines in place.  
 B, D, F, ambulacral areas; A, C, E, interambulacral areas, reduced  
 to about 62 % natural size.  
 A centimeter rule photographed with the specimen shows relative  
 size.  
 FIG. 2. Paratype.  
 A very complete specimen seen in ventral view.  
 Ambulacral and interambulacral plates extend to periphery. Some  
 spines are preserved. Lantern protrudes in centre.  
 Lobes and sinuses less marked than on holotype (Plate IX).  
 B, D, F, H, J, ambulacral areas; A, C, E, G, I, interambulacral  
 areas, reduced to about 34 % or practically one-third natural size.  
 A centimeter rule photographed with the specimen shows relative  
 size.
- FIG. 3-6. *Pholidocidaris tornacensis* sp. nov. . . . . 64  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 64,  
 I. G., 3440.)  
 FIG. 3. Holotype, enlarged a little more than twice, showing inter-  
 ambulacral plates in place and a few ambulacral plates and  
 spines.  
 FIG. 4a-c. Four interambulacral plates associated in twos (a, b) and  
 an ambulacral plate (c) enlarged nearly twice.  
 FIG. 5. Reverse side of same specimen as fig. 3.  
 The right hand side of this view corresponds with the top of fig. 3;  
 enlarged nearly twice.  
 FIG. 6. Drawings representing the same specimen.  
 a. Same view as in fig. 3, × 1.  
 b. Same view as in fig. 5, × 1.  
 c. An interambulacral plate with primary and secondary tubercles  
 much enlarged.  
 d-e. Spines enlarged.  
 See also Plate V, fig. 7.
- FIG. 7. *Lepidocentrus eifelianus* MÜLLER. . . . . 20  
 Tournaisien, Tournai. (Coll. Mus. roy. d'Hist. nat. de Belg., n° 76,  
 I. G., 3440.)  
 a. Drawing of seven interambulacral plates in connection.  
 Natural size.  
 b. One of these plates enlarged, × 4 1/2.  
 See also Plate I, fig. 9.
- FIG. 1, 2, from photographs by Dom Henri Mariage; FIG. 3-5 from photographs by  
 photographer of Mus. roy. d'Hist. nat. de Belgique.

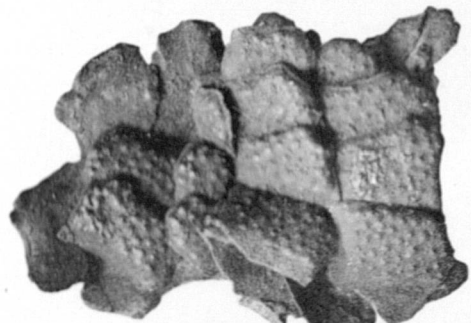




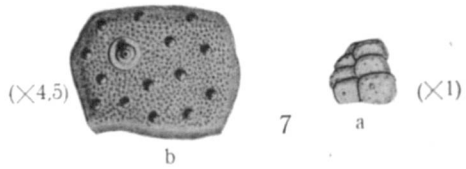
2



6



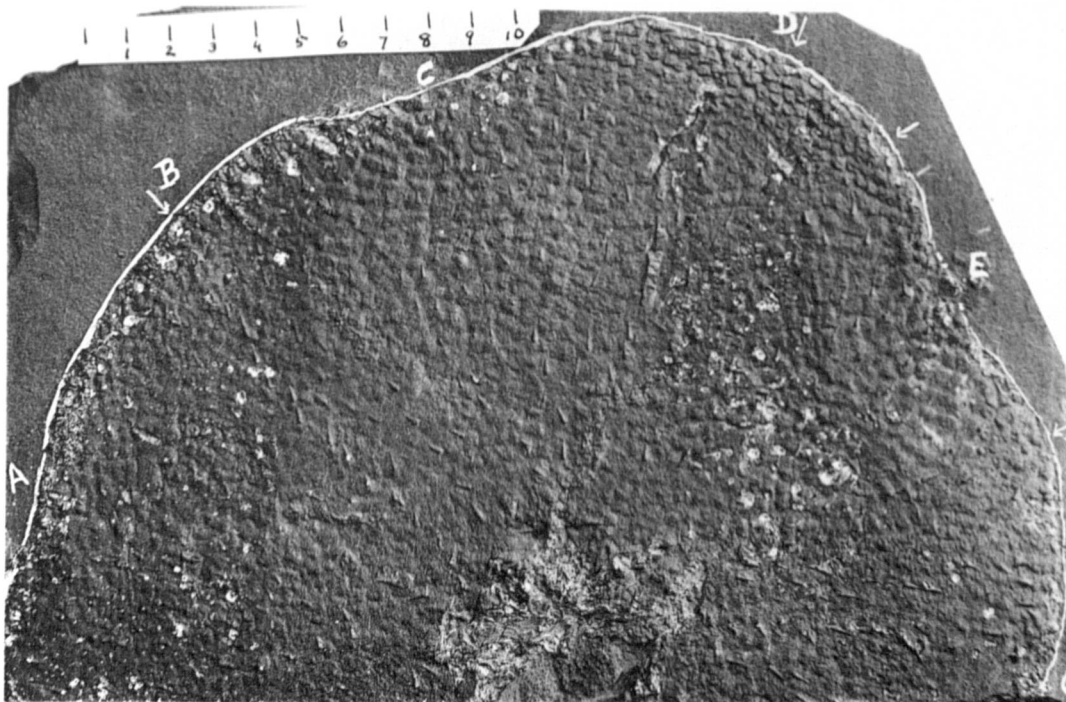
5 (X1,9)



7



4 (X1,9)



1



3 (X2,1)

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