THE TAXONOMY, DISTRIBUTION, AND EVOLUTION OF THE UPPER CRETACEOUS ECHINOID MICRASTER.

by

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ABSTRACT

On the basis of spatangoid echinoids the Cretaceous seas of the American, European and North African continents are divided into two Faunal Realms - the North African and the European Realm. Contemporary allopatric species of the genus Micraster enable distinct Faunal Provinces to be established within the European Realm. These Provinces are called : Northern Faunal Province, Anglo - Paris Basin Province, Touraine - Aquitaine Province and Pyrenean Province. The Provinces are interpreted as reflecting Cretaceous water masses. They are shown to extend further southward with time, particularly during the Coniacian and Campanian periods.

Sympatric species of the genus Micraster, restricted to any Province, are demonstrated to be most easily distinguished by the relative height of their periprocts.

The present system of classifying spatangoid echinoids, based essentially on the presence or absence of various fascioles, is rejected.

Systematic descriptions are given of most of the species of the genera Micraster and Diplodetus, and some species of Epiaster. Two new species (Micraster westlakei and M. solignaci) and one new variety (M. coranguinum var. simpsoni) are established.

On the basis of the genus Micraster an attempt is made to correlate the Turonian and Senonian strata of the different European Provinces.

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INTRODUCTION

HISTORICAL

Micrasters are more or less common in the Upper Cretaceous throughout northern and western Europe. They have been collected since the times of bronze age men and figured by seventeenth and eighteenth century naturalists. The great morphological variations shown by Micrasters attracted the attention of variety hunting systematists, the latter surviving to the present day. Micrasters became of scientific value in the nineteenth century due to their usefulness in the fields of stratigraphy and evolution.

PROBLEM AND METHODS

The confussion caused by mistaken identifications of *Micraster* species, and an unsound basis for the generic classification of Cretaceous spatangoids, has led to many errors regarding their geographical and stratigraphical distribution.

In 1967, at the suggestion of Dr. J.M.Hancock, I began collecting and examining specimens of the genus *Micraster* in order to study their geographical variations in northern and western Europe. During the following years I visited France, Spain, Switzerland, Belgium, Germany, Denmark, Sweden and Poland working mainly in the field, but also examining some important collections containing Micrasters.

Statistical methods were not found necessary in this study. As Hawkins (1936) pointed out "A prectised eye can tell "by a general look at a Micraster its correct zonal position, "whereas laborious analysis of each character separately often "leads to contradictory and confusing results." The same may be said regarding the identification of a species, and the faunal province from which it comes. Simple graphs are used to illustrate certain features which are easily observable with the naked eye. Lack of sufficient well localised material prevents more such graphs being given.

NOMENCLATURE

In this thesis only the nomenclature of species of Micraster, Diplodetus, some "Epiaster" and a Proraster is revised. The generic and trivial names of all other echinoids mentioned are those used by the previous workers quoted, and are not necessarily valid.

PART I

THE BIOLOGY AND TAXONOMY OF MICRASTER INTERPRETED IN RELATION TO LIVING SPATANGOIDS.

CHAPTER I MODE OF LIFE

In 1959 Nichols published his classic work on the mode of life of Micraster interpreted in relation to living forms. The progressive morphological changes described by Rowe (1899) were interpreted by Nichols as showing adaptation to a deep burrowing mode of life. The sympatric and contemporaneous gibbose Micrasters he interpreted, like Kermack (1954), as being surface dwellers which ploughed through the sediment with their respiratory regions exposed.

More recently Chesher has carried out extensive work on modern West Indian spatangoids. He discusses the concept of sympatric species pairs in 1968. In each of the cases of sympatric species pairs which he describes, the two species of a single genus both occupy the same ecological niche. Thus the Gause Hypothesis - that two closely related species can not share the same ecological niche - is not valid with reference to these spatangoids.

The chalk holasteroid Echinocorys is usually represented by two morphologically distinct forms in many horizons (personal communication N.B.Peake), but both forms must be interpreted as surface dwellers.

The species pairs described by Chesher show a high form and a low form, as in the genus Micraster and modern Spatangus from European waters. The difference between the sympatric forms of Micraster and Spatangus is most clearly shown by the ratio of the height of the periproct to the total height of the test. This does not appear to be the case in the West Indian pairs.

The depth of burrowing varies greatly within any species. Chesher (1969) shows that it depends on size, gonadal condition, rate of movement, nature of the sediment, wave action and possibly water temperature.

The nature of the substrate appears to be very important with regard to depth of burrowing. Nichols burrowing material and that described by Chesher (with the exception of Brissopsis alta) all came from localities of sands or shell gravel. In such coarse grained sediments it is relatively easy for a spatangoid to maintain a respiratory funnel and to force out the waste water into the interstices of the surrounding sediment. The latter is an equally essential function of the respiratory system. This process becomes increasingly difficult with depth (Chesher 1969), and presumably in homogeneous fine muds. The chalk,in which Micrasters of deep burrowing aspect occur, is a very fine grained homogeneous deposit. It seems questionable whether Micrasters would be capable of disposing of their waste water if deeply burrowed in such a sediment.

Depth of burrowing may also be related to chemical conditions within the substrate. Nichols (1959) suggests that the low rH value of a bed of blue muddy sand may have prevented Echinocardium cordatum from burrowing more deeply than the upper layers of this bed. This chemical interphase may be much closer to the surface in deep water, and may thus account for the observation of Ursin (1960) that _E. cordatum_ lives within a few centimetres of the surface in the central North Sea, as opposed to its usual depth of burial of up to 25 centimetres in littoral regions.

Did _Micraster_ burrow ?

This question is now being raised by Goldring and Stevenson (in press). I am not yet familiar with all the evidence they put forward to suggest that it did not.

The tests of _Micraster_ are often broken, oriented in various positions, sometimes abraded due to rolling on the sea floor. Many are covered with an epifauna, including their lower surfaces, and more rarely they show signs of having been attacked by fish. These facts are used by Goldring and Stephenson to suggest a non-burrowing mode of life. However, as Gislen (1924) pointed out, diseased and moribund spatangoids come up to the surface, presumably to facilitate respiration. Thus the features quoted above are more likely to have been produced after the death of the Micrasters.

Another line of evidence used by these authors is the lack of preserved burrows attributable to _Micraster_ in the _Micraster_ chalk. This is, unfortunately, negative evidence.

Fossil spatangoid burrows are well known from Cenozoic strata, but in the cases with which I am familiar, the lithology and infered environment can not be regarded as comparable to that of the chalk. I have examined _Echinocardium_ burrows in the shelly foreset sands of the Red Crag, shown to me by my friend Mr. Shepherd. In these sands the burrows are obvious from the way in which the shell débris was moulded around the posterior of the urchin. Such structures can not be expected to occur in a lithology such as the chalk. The sediments in which fossil spatangoid burrows are preserved seem restricted to those deposited in shallow water high energy environments, in which thick sequences of sediment may be deposited in a very short period of time. Thus the burrows could be preserved before being obliterated by reworking or long periods of bioturbation.

The calk, however, was deposited very slowly, and thus any spatangoid burrows would have been subjected to reworking and bioturbation for considerable periods of time. Assuming that Micraster could burrow to depths comparable to that of Echinocardium (about 25 cms), and assuming that evidence of their burrows could be preserved in the chalk, it is most unlikely that the latter would survive the continual reworking of the sediment by marine worms. Marine worms of the present day are recorded burrowing to depths of 60 cms (Davidson 1891). Such worms in the chalk seas could have carried on removing evidence of spatangoid burrows for an immence period of time after any particular horizon was in reach of a Micraster. Kennedy (1967) has shown that the Lower Chalk has been intensely burrowed many times over. It is not unreasonable to assume that this is equally true of the Upper Chalk.

From the evidence presented above it is concluded that the lack of direct evidence of Micraster burrows in the chalk presents no basis for saying that Micraster did not burrow. Equally, comparisons with the mode of life of modern spatangoids do not prove that it did. From the evidence of modern sympatric species pairs one would expect *Micraster* to occupy the same niche as the gibbose Micrasters. The problem appears to be insoluble. For convenience in the following chapters, it is assumed that the main *Micraster* lineage did burrow in the manner described by Nichols (1959).

CHAPTER II GEOGRAPHICAL DISTRIBUTION OF SPATANGOIDS

The geographical distribution of marine invertebrates is often regarded as being dependent upon any one, or any combination of such factors as the nature of the substrate, depth of water, water temperature, salinity or water masses.

Nature of the substrate.

Chesher (1963) has shown that *Moira atropos* inhabits substrates ranging from the finest silt to heavy coral gravel in the West Indies. In 1968 he showed that *Brissopsis alta* burrows in a variety of silty muds with great variation in mean grain size, sorting, and the percentage of clay and silt fraction. In the summary of his 1968 work on West Indian spatangoids he states "that the characters of these genera ... indicate a strong genetic control which is not greatly influenced by substrate changes or geographic distance.".

The wide variety of lithologies from which *Micraster glyphus* has been collected shows that it is tolerant of considerably variable facies. It is found in exceedingly soft pure white chalks in Belgium, in very marly chalk round Krakow, and in glauconitic marly sandstones in Scania and the Munster Basin.

M. glyphus is absent outside the Northern Faunal Province despite the fact that similar facies of the same age are present elsewhere.

Likewise *M. turonensis* is not restricted to the fine grained glauconitic sandstones of Touraine and Aquitaine proper, but is also found in the chalk facies as far north as Caudebec.

These two examples taken from the genus *Micraster* should suffice to show that lithology is of little or no importance in controlling the distribution of this fossil spatangoid.

It is easy to appreciate how the concept of facies control was developed with regard to faunal provinces. In many cases faunal provinces are restricted to certain structurally controlled sedimentary basins which show peculiar lithological types, often with the convenient absence of evidence between the basins due to erosion. The super ficial association of faunal provinces with certain facies realms does not of necessity lead to the conclusion that lithology is the causal factor of faunal distribution.

Other factors

Ursin (1960) published the only account of the distribution of modern echinoderms which also analysed in detail the controlling factors. In the summary of this paper on North Sea echinoderms, Ursin states that "The distribution of individual species is only slightly tied up with temperature, salinity, and grade of soil. It seems more dependent upon the distribution of plankton assemblages which, again, are indicators of distinct water masses."

Younge (1949) related the distribution of *Echinus esculentus* and other invertebrates to these water masses. Orthamalus stellatus has a distribution which corresponds to that of Atlantic water "and one is driven to the conclusion that this barnacle is dependent on some obscure but essential constituent of such water." (Younge 1949, p. 307 of 1970 ed.)

Attempts to identify the obscure and essential constituents of the water masses, and the differences between water masses have been made. The problem, however, remains unsolved.

Accepting the doctrine of uniformitarianism one feels justified in interpreting the Upper Cretaceous faunal provinces, described in the following chapters, as being a reflection of ancient water masses.

CHAPTER III TAXONOMY OF SPATANGOIDS

The classification of modern and fossil spatangoids is based mainly on the presence or absence of various fascioles. Despite the fact that inconsistencies in the development of fascioles in spatangoids have long been observed, echinologists have continued to attribute an exaggerated importance to these ephemeral features. The most recent classification of spatangoids (Fisher 1966) divides what is here regarded as one genus - Micraster - into three genera - Isomicraster, Plesiaster and Micraster - and two subgenera - M. Micraster and M. Gibbaster - which are placed in three different families and two separate suborders, mainly on the basis of fascioles. This situation is regarded as untenable.

Chesher (1968) has shown that fascioles may be resorbed during ontogeny. The "genus Isomicraster" shows that they may be lost during phylogeny. With regard to fascioles, "Isomicrasters" are degenerate Micrasters. They are not, as Fisher suggests, a link between the Toxasterids and the Micrasterids. Chesher (1968) states that the exact path of the fasciole, if developed, over the plates of the test is constant and is a valuable character in spatangoid classification. He suggests that inhibitor genes prevent the phenotypic expression of epidermal characters such as fascioles and pedicellariae.

Amongst Micrasters the development of conjugate pores in the unpaired petal, typical of a respiratory region, is regarded as a character of subgeneric importance. It is used to distinguish the gibbose forms from normal Micrasters. As is shown elsewhere in this work, this character is clearly seen in certain true Micrasters such as M. glyphus.

The two criteria for the subdivisions of the Micrasters, fascioles and pores of the unpaired petal, are here rejected.

The only satisfactory method for distinguishing between the gibbose and normal Micrasters is by their shape. The gibbose forms have a more or less conical shape, associated with which is a low periproct. As the gibbose Micrasters are polyphyletic all subgenera are rejected. The term "gibbose" is used informally. The only alternative being to erect new subgenera for each separate lineage - a course which has nothing to commend it.

Thus, as in the case of modern spatangoids, sympatric species pairs are not split into different subgenera.

Chesher (1968) points out that meristic characters are of great taxonomic interest. He found that "the number of plates from the peristome to the petalloid portion of the ambulacra ...(is)..of specific importance. The number of interambulacral plates from the peristome to the fasciolar systems is amazingly constant and, in some groups of familial importance. The stability of the subanal fasciole in relation to the interambulacral plates is such that it is of super-familial importance."

Application of Chesher's system of measurements to fossil material would doubtless prove most valuable.

As long ago as 1889 Lambert showed the stability of certain meristic characters in the species Echinospatangus neocomiensis. This would appear to be the first and last such work concerning fossil spatangoids.

Classifications, ideally, should be based on phylogeny. Phylogenies can only be reconstructed by detailed work starting at the species level and working up to the higher taxa. With regard to Cretaceous forms, the present system of classifying spatangoids is in great need of revision. Completely unrelated forms are placed in the same genus (eg. Plesiaster and Periaster), conversely closely related forms may be separated into different families and suborders (eg. the case of Micraster quoted above). Time ranges of such unnatural taxa may lead stratigraphers,who are not specialists in the group, into basing far reaching conclusions upon them.

PART II

THE DISTRIBUTION AND EVOLUTION OF *MICRASTER* AND OBSERVATIONS ON THE DISTRIBUTION OF SOME OTHER CRETACEOUS SPATANGOIDS.

CHAPTER I INTRODUCTION TO EUROPEAN AND NORTH AFRICAN REALMS

The European Realm is most easily defined in Upper Cretaceous times, when it is characterised by the presence of certain holasteroid echinoids and the genus *Micraster*. *Holaster*, *Cardiaster*, *Echinocorys*, *Hagenowia*, *Infulaster*, and *Offaster* are holasteroids which are almost completely confined to this Realm. In Lower Cretaceous times the distinction between a European and North African Realm is more difficult to detect. It is not until Albian times that a distinctly European Realm spatangoid manifests itself in the form of *Hemiaster minimus* and *H. baylei*. In pre Albian times the region destined to become the European Realm is characterised by a sparce spatangoid fauna. Those forms which do occur are of North African Realm type, but in greatly reduced numbers. Indeed the holotype of the type species of the typically North African genus *Enallaster* (*E. greenovii*)is a specimen from southern England.

Zoeke (1951) was able to divide the genus *Hemiaster* into two major groups, one typical of Europe and the other of Africa. Zoeke's divisions are based mainly on the shape of the plates in the pre-petaloid portions of the ambulacra, and the shape of the interambulacral plates near the ambitus. These features are not usually accurately figured. In the following chapters European and North African spatangoids are distinguished on the basis of their general shape and the development of their petals.

The European spatangoids, as noted by Zoeke concerning the Hemiasters, have, in general, a globular shape and relatively short posterior petals, usually up to two thirds of the length of the anterior pair.

North African spatangoids are depressed, with a broad flat posterior face sloping such that the periproct is visible from above. The petals are broad with numerous elongate pores. The posterior pair of petals being about the same length as the anterior pair.

The echinoid genera Tetragamma, Codiopsis, Orthopsis, Diplopodia and Polydiadema appear to be restricted to the North African Realm. Of the spatangoids, Toxaster, Miotoxaster, Pliotoxaster, Enallaster, Heteraster, Palhemiaster, Macraster, Enallopneustes, Douvillaster and Polydesmaster are diagnostic of this Realm. The so-called Periasters from North Africa are merely variations of the North African Hemiaster stock. They are in no way connected with the true Periasters of the Touraine-Aquitaine region. The same may be said of the North African Epiasters.

Mortensen (1950) and Fisher (1966) state that Polydesmaster is restricted to France. Lambert (1920a) states quite clearly that his new genus is found at Lambèse and Medina (Aurès), localities in the high plateau region of Algeria.

CHAPTER II TYPICAL NORTH AFRICAN REALM REGIONS

THE NORTH AFRICAN *HEMIASTER* STOCK

Lambert (1933a) revised the 56 Cretaceous species of the genus *Hemiaster* which occur in Algeria and Tunisia. He divided them into 11 groups, the first of which he called typical *Hemiaster*. This is the European type, represented by *H. bufo* and *H. punctatus* . As Lambert pointed out, the very rare occurances of these species, in the Cenomanian and Campanian respectively, represent southward migrations of the European fauna.

Lambert's *Leymeriaster* and *Holanthus* groups do not appear to be typical of either the European or North African Realms.

All the members of the other groups appear to be typical of the North African Realm, the number of species per stage being as follows : Albian 1, Cenomanian 19, Turonian 12, Santonian 9, Campanian 7, and Maastrichtian 3. The Coniacian is noticeably absent in all the classic works on North African echinoids.

Several species within Lambert's Algero-Tunisian *Hemiaster* stock are refered to the genus *Periaster*. According to Mortensen this genus is restricted to circum - mediterranean regions. This statement is reiterated by Fisher (1966). The North African Periasters of which I have seen figures are typical Hemiasters of this region which have developed a latero-anal fasciole. They bear no resemblance to the Cenomanian - Turonian stock of Touraine - Aquitaine, from whence the type species (P. elatus) and other early known species of Periaster come.

MAROCCO

The Cretaceous echinoids of Marocco have been studied by Lambert (1931, 1933, 1937), Petitot (1961-2) and Devriès (1965).

A toxasterid fauna is found from the Berriasian to the Aptian. Devriès records Heteraster oblongus from Hauterivian to Aptian. Palhemiaster and the North African Epiaster appear in the Aptian, the latter continuing into the Albian. The Cenomanian yields typical North African Hemiasters, as does the Turonian. This stock must continue through into the Campanian, from which H. messai is recorded, although Santonian examples are lacking.

Lambert (1937) records Gibbaster gibbus from the Rif region, comparing it with the Upper Campanian gibbose form from Nice. There is no evidence as to the exact age of the strata from which the sole specimen was collected. This specimen does not have the appearance of a typical European gibbose Micraster (only the upper surface is figured). Assuming that the figure is life size, it is possible that this specimen is related to M. peini - a species restricted to the Santonian, and best known from Tunisia.

ALGERIA

Fossil echinoids from this country have been studies by Cotteau, Peron and Gauthier (18 -188), Lambert (1931-32) and Devriès (1957).

Toxasters and Heteraster continue up to the Aptian, when Macraster and Palhemiaster also occur. The Albian yields Heteraster and "Epiaster". Typical North African Hemiasters persist from the Albian to the Maastrichtian.

Along with Polydesmaster and typical Hemiasters in the Cenomanian, Lambert (1931) records Micraster numidicus Gauthier MS in Lambert and Thierry (1924). The figures given in this latter work show that this is a member of the North African Hemiaster stock which has developed a subanal fasciole only.

There would appear to be an incursion of European forms in the Santonian, from which rare Echinocorys and Micraster are recorded (Lambert 1931). Lambert identifies the Micraster as M. corbaricus (= brevis) - a species diagnostic of the Pyrenean Province. Whether this determination is accurate, or whether the species is M. peini is impossible to say, not having seen the specimens.

TUNISIA

The Cretaceous spatangoid fauna of Tunisia is directly comparable to that of Algeria (Lambert 1931-32) in that it yields typical North African elements throughout the Cretaceous.

A southern migration of Pyrenean Province Micraster brevis is here regarded as the origin of M. peini. The age of this incursion is uncertain. Conventionally M; peini is regarded as a Santonian species, the term Coniacian being lacking in literature on North Africa. M. peini gave rise to M. solignaci in the Campanian. The M. peini - solignaci stock is regarded as being endemic to this region of the North African Realm.

A later temporary southward migration of European elements is seen in the Upper Campanian, from which a single specimen of a gibbose Micraster is known. This poorly preserved specimen (= Isomicraster Brueti Lambert 1931) represents the most southern influence of the Northern Faunal Province Micrasters, showing a continued migration southward from the Nice region.

EGYPT

The Cretaceous echinoids of this country have been described by Faurtau (1914) and Lambert (1932).

The earliest spatangoids recorded, Toxaster, Heteraster and Epiaster, are from Aptian deposits. No Albian forms are mentioned. All the Cenomanian spatangoids are typical of the North African Hemiaster stock. This stock continues into the Turonian, and two species of it are known from the Santonian. No mention is made of the Campanian.

The Maastrichtian shows a change to the European Realm. Holasteroids appear here (Echinocorys Fakhryi) and the spatangoids (Schizaster Dowsoni and Linthia chargensis) are of European aspect.

THE MIDDLE EAST

Cotteau (1869) described several typical North African Hemiasters from Syria and Idumée (Palestine). The most abundant ones (H. fourneli and H. saulcyanus) are presumably from the Cenomanian. A single specimen of H. orbignyanus is recorded from a locality between Suf and Jerash. This is a typically European spatangoid . Its occurance in this region may indicate that the European Realm extended almost as far south as Syria during the Cenomanian. At Martigues (Bouche du Rhône) the same spatangoid occurs with the North African echinoid Heterodiadema libycum, suggesting a mixing of the two Realms.

I have a specimen from Jebel Tannur, Jordan which is a typical North African Hemiaster. From the arrangement of the fascioles it could be regarded as a Palhemiaster - a genus known only from the Aptian.

SOUTH AMERICA

All the Cretaceous spatangoids of which I have seen figures are typical of the North African Realm. Termier and Termier (1952) show Enallaster occuring in the very south of Argentina. Basse (1928) figures Heteraster tscudii from the Upper Albian of Peru, and Hemiaster teilhardi from the Senonian of the same country. Cooke (1949) figures Hemiaster (Macraster) cascajalensis from the Albian near Lima.

Cooke (1955) figures Hemiaster texanus from El Napo in Ecuador. This species occurs in the Senonian of Texas.

Colombia yields Cretaceous echinoids which have been described by Noeth (1935) and Cooke (1955). The latter figures Toxaster colombianus, which occurs in abundance in the Hauterivian; Heteraster caesarensis from the late Neocomian; and Enallaster (Washitaster) bravoensis from the Albian.

Enallaster bravoensis from the ?late Albian, Enallaster sp. from an uncertain horizon, Hemiaster sp. from the "early Cretaceous", and Epiaster whitei from the ?Albian are all typical North African forms from Venezuela described by Cooke (1961).

CONGO AND ANGOLA

The two Cretaceous spatangoids from this region figured by Dartevelle (1953) are both typical of the North African Realm. These are :- Epiaster catumbellensis (Middle-Upper Albian) and E. carvalhoi (?Senonian). Douvillaster benguellensis (Upper Albian) belongs to a genus unknown outside this Realm. Epiaster angolensis (?Senonian) and Hemiaster reineckei (Upper Albian) are not figured. The fact that the former is refered to the section Mecaster, and the latter is characterised by elongate rows of closely spaced pores in the petals, suggests that they are also North African types.

It is most difficult to account for the presence of typical European holasteroids (Holaster dombeensis, H. lerichei, and Cardiaster kelleri) in the Upper Albian of this region.

PORTUGAL

The echinoid horizons of this country range in age from Lower Neocomian to Upper Cenomanian. De Loriol (1887) notes four species of Toxaster and two of Enallaster from beds of pre - Cenomanian age. Enallaster delgadoi is fairly abundant in the Lower Cenomanian - a late occurance for this genus. Hemiaster is very abundant at certain horizons of the

Cenomanian. De Loriol creates nine new species, all of which, as well as H. scutiger (Forbes), belong to the group Mecaster, as do most of the Algerian species of this age.

IBIZA

Jeannet (1935) figures two typically North African spatangoids from the Urgo-Aptian of this island. These are Palhemiaster ibericus and Macraster ibizaensis.

AUSTRIA

Pliotoxaster cf. brunneri is recorded from the Barremian and Barremian/Hauterivian of the Province of Verarlberg by Jeannet (1933).

SERBIA

Mitrovic (1963) described Heteraster oblongus from the Hauterivian of eastern Serbia.

CHAPTER II A   NORTH AMERICA (fig. 2)

The Cretaceous of North America is divided into three major regions by Gignoux (1954). These are the Pacific Geosyncline (which is not dealt with here), the epicontinental seas of the Central States (including the Western Interior), and the Atlantic slopes of the Appalachians.

I THE ATLANTIC SLOPES OF THE APPALACHIANS

Lower Cretaceous rocks in this region consist of non-marine deposits similar to the Wealden facies of Europe.

The Upper Cretaceous was a period of marine transgression. Echinoids yielded by rocks of this age are of European Realm type.

The earliest echinoids come from the Matawan Group in New Jersey. Hemiaster welleri is a typical European form, but H. kuemmeli is too poorly preserved and deformed to be interpreted from the figures of Clark (1915).

The Vincetown Sands of the Rancocas Group yield a rich echinoid fauna in New Jersey. Ananchytes ovatus Clark appears to be very similar to Echinocorys sulcatus which I have from the Upper Danian of Limhamn, Sweden. Cardiaster cinctus from the Vincetown Sands, and C. smocki from the Matawan Group, show that the New Jersey faunas are typical of the European Realm. The spatangoids Hemiaster stella, H. ungula and H. parastatus are typical European forms. The latter species is also known from the Ripley Formation of Mississippi and Alabama, and thus, along with the occurance of H. lacunosus

Slocum (non Goldfuss), shows an extention of the European Realm into the Eastern Gulf area in Ripley times at least.

II THE CENTRAL STATES AND MEXICO

The succession in these regions is marine throughout the Cretaceous.

Echinoids are abundant in the Comanche Series. From the Trans-Pecos region of Mexico and Texas, Smiser (1936) figures 23 species of spatangoids from this Series. All his species are typical of the North African Realm. They belong to the genera Pliotoxaster, Heteraster, Lambertiaster, Leiotomaster, Macraster, Palhemiaster and Hemiaster.

Spatangoids from all the Formations of the Comanche Series are all of North African Realm type. Holasteroids (Holaster simplex and Pseudananchytes completa) appear in the Washita Formation at the top of the Comanche Series. The occurance of Holasteroids with North African spatangoids may indicate that the Washita Formation is of Aptian age.

The influence of the North African Realm continues into the Turonian and Senonian in Texas. The following species of Hemiaster, figured by Cooke (1955), are typical of this Realm. H. jacksoni occurs in the Turonian of Texas and is also known from the Sergipe province of Brazil and Sierra Santa Ana in Mexico. H. texanus is found in the Anacacho Limestone and the Taylor Marl of the Austin Chalk. H. sabinal comes from an horizon which may be Coniacian or Santonian.

The Gulf States of the U.S.A. were certainly within the European Realm in Campanian times, and later. Proraster dalli, Linthia variabilis, Hemiaster wetherbyi and H. humphreyanus are all European type spatangoids.

Cooke (1953) described and figured several species of Micraster. None of them bear any close relationship to the European Micrasters, but they are all of European Realm type. Isomicraster rossi appears, from the advanced state of its interporiferous zones, its projecting labrum and coarsely granular periplastronal areas, to be younger than the stated Turonian horizon of the Terlingua region in Texas. Isomicraster danei has exceedingly long paired petals which, like those of I. rossi almost reach the ambitus. In these species there are over 50 pairs of pores in one row of petal II. Micraster uddeni from the Austin Chalk has exceptionally long anterior paired petals, but very short posterior ones. Micraster americanus, like the Tunisian Micrasters, developed a peripetalous fasciole.

III THE WESTERN INTERIOR

Echinoids are known from the Montana Group of Montana and South Dakota. These appear to be of European Realm type. Hemiaster humphreysanus and Cardiaster curtus from the Pierre Shale in Montana are obviously so, but the poorly preserved H. beecheri from the same horizon in South Dakota is difficult to interpret.

This chapter is based entirely on the liturature. Clark (in Clark & Twitchell 1915) is the most comprehensive work on North American Cretaceous echinoids, and was thus used most.

CHAPTER III LOWER CRETACEOUS SPATANGOIDS OF BOREAL EUROPE

The marine Neocomian of Yorkshire yields echinoids in Bed C of the Speeton Clay (= Hauterivian). These were first described and figured by Phillips (1835) under the name Spatangus argilaceus. It was placed in the genus Echinospatangus by d'Orbigny (1853) and became the type species of the genus Hypsaster Pomel 1869 (not Hypsaster Pomel 1883). It is commonly known as Echinospatangus cordiformis.

Dr.P.F.Rawson has kindly lent me his specimens of this species. They appear much more elementary than the Toxaster amplus which I have collected from the Upper Hauterivian in the Drôme. They resemble the figures of primitive Echinospatangus from south east France given by d'Orbigny 1853 (eg. pls. 844 and 845), but I have not yet compared them to actual specimens. It is not certain that the Speeton material is truely spatangoid. Due to the poor preservation I have not been able to confirm that the plastron is amphisternous, and therefore spatangoid. It may possibly be meridosternous, and therefore holasteroid.

The only other record of spatangoids from the Boreal Neocomian, of which I know, is d'Orbigny's (1853) reference to Hills (Hanover) as a locality for Echinospatangus cordiformis.

These Boreal occurances of spatangoids, apparently identical to southern European forms, suggests a marine connection with the Mediterranean region during the Neocomian. This connection could not have been via the Paris Basin, because marine conditions were not continuous until the Aptian here. One must conclude that there was a connection via an ancestral Atlantic and north of Scotland,or via the Moscow region of Russia following a route north of Scandinavia into the North Sea region. A connection around the eastern end of the Mid European Island seems unlikely. Such long migration routes will no longer be necessary if the Boreal "spatangoids" are later shown to be holasteroids.

THE NORTHERN FAUNAL PROVINCE

This Province was named by C.W.Wright (in Kermack 1954) who recognised differences between the echinoderm faunas of northern and southern England.

The Northern Faunal Province is the most widespread of all the Upper Cretaceous faunal provinces. It extends from Northern Ireland, including Yorkshire, Lincolnshire and Norfolk in England, through Belgium, north Germany, southern Scandinavia, Poland, Ukraine, Donetz Basin, Russian Platform, Caucasus, Crimea, and into the Koppeh Dagh. In Lower Campanian times it spread southward to include the eastern part of the Paris Basin. In Upper Campanian times it spread further, covering the Touraine, Aquitaine, and south east France. One specimen of a Northern Faunal Province *Micraster* is known from Tunisia.

The evolution of the genus *Micraster* in this Province is best demonstrated by reference to nothern Germany, where Upper Cretaceous stratigraphy is known in detail.

CHAPTER IV NORTHERN GERMANY (figs. 2A - 9)

THE MAIN MICRASTER LINEAGE

Micrasters first appear in the lower Middle Turonian (Lamarcki Zone) the dominant form being M. borchardi. I have collected this species at Wüllen near ,haus, where it is not uncommon above the hardgrounds of the Lamarcki Zone (Ernst 1967). I do not know the exact age of the dark blue grey marls exposed at Oelinghausen near Bielefeld, but here I have collected a thin tested Micraster resembling the M. cobovis from the English Lata Zone. These specimens may well be slightly older than the Wüllen material. Specimens of M. borchardi in the collections of Münster University come from the following localities :- Iburg, Lengerich, Altenbeken, Halle, Dreigrund, Laer-burg near Rothenfelde and Hilter. The specimens from the Staffhorst mine-shaft are from the Deformis Zone. Specimens from Hoppenstedt (Hartzforland) come from the Lamarcki Zone (Tröger Collection). Heinz (1926) records M. leskei from the Scaphites geinitzi Zone of Zeltberg (Luneburg), probably refering to M. borchardi. Elbert (1901) describes the species,under the name of M. breviporus, from the Teuteburger Waldes.

M. borchardi evolves into M. bucailli . The evidence from the Staffhorst mine-shaft shows that the change occurs roughly half way through the Upper Turonian based on Inoceramus stratigraphy, and that all the intermediates occur within the Upper Turonian. Intermediates occur earlier at other localities. At Söhlde, Kleine Flötte and Nettlingen in the region south of Braunschweig, they occur in the Vancouverensis Zone. The distribution of M. bucailli is exclusive of the Münster Basin (personal communication G. Ernst 1968). I only have a few poorly preserved specimens of this species, collected from the chalk just above the Mid-Vancouverensis Marl Band at Dorstadt and Kl. Flötte.

M. coranguinum evolved from M. bucailli in the uppermost Turonian. Evidence from the Staffhorst mine-shaft shows that typical M. coranguinum was present in the lowest Coniacian. As with M. bucailli, broad flat forms are absent. M. coranguinum continues through the Coniacian and into the Santonian. The succession exposed in the quarries around Lägerdorf overlaps with that of the Staffhorst mine-shaft and continues upwards to the Maastrichtian (Ernst 1963, 1966). From the Middle Santonian of the Breitenburg Quarry Ernst has collected specimens of M. coranguinum which I regard as being equivalent to those from the lowest Uintacrinus Zone of southern England. The Middle and Upper Santonian of Breitenburg has yielded to Ernst specimens of most advanced M. coranguinum, most of which I regard as intermediates to M. schroederi (= Micraster sp. from the Upper Santonian and lowest Campanianof Tab. 5, Ernst 1963).

M. schroederi evolved from M. coranguinum in the period ranging from Middle Santonian to lowest Campanian. M. schroederi itself gave rise to the broad flat M. glyphus, both species survive until the end of the lower Upper Campanian.

IN general it may be said that M. schroederi is more typical of the Lower Campanian, and M. glyphus of the Upper Campanian. Juvenille specimens of M. glyphus from the Upper Campanian are indistinguishable from small M. schroederi suggesting ontogenetic recapitulation. Large specimens of M. schroederi do occur in the Upper Campanian. I have examined examples of such from Hamm and Porta-Westfalica (south east Münster Basin) in the collections of Münster University.

The lineage M. borchardi - bucailli - coranguinum - schroederi is interpreted, following Nichols (1959), as showing a progressive adaptation to a deep burrowing mode of life. M. glyphus, extreme examples of which have conjugate pores in the unpaired petal and a slightly conical upper surface, are regarded as very shallow burrowers occupying the niche between that of M. schroederi and M. stolleyi.

MICRASTER ROGALAE

M. rogalae occurs in the Middle and Upper Santonian chalk in the Breitenburg Quarry at Lägerdorf (Ernst 1963a). I have seen no specimens which I would regard as intermediate between this species and the M. coranguinum - schroederi stock. The morphology of this species suggests that it was a very shallow burrowing form. The ancestor of M. rogalae remains unknown. If the stratigraphy of Russian authors is correct it occurs much earlier in eastern Europe. Its occurance in Germany an Belgium (see below) may thus represent a western migration of a very conservative stock.

MICRASTER GRIMMENSIS

In Germany this species is only known from the Mucronata Chalk in the Rostock region (Nietsch 1921) and the lower part of the Bostrychoceras Beds (= middle part of the Mucronata Zone) in the Luneburg area (Heinz 1926). As with M. rogalae, the occurance of M. grimmensis may indicate the influence of eastern faunal elements of the Northern Faunal Province.

THE GIBBOSE MICRASTERS

In the Münster Basin M. borchardi gave rise to the gibbose form M. cortestudinarium (= M. brevis auct.) in the upper part of the Vancouverensis Zone. Material from a section at Zeche Preussen near Dortmund, ranging in age from the upper part of the Middle Turonian to the Upper Turonian, shows the transition. M. cortestudinarium is very abundant in the Deformis Zone throughout the southern part of the Münster Basin. I have collected it at Erwitte, Paderborn, Kohlstadt and Schlangen. Dr. Ernst (personal communication 1968) regards it as being restricted to the Münster Basin, with M. bucailli occupying the same horizon in the other parts of Germany (such as the Hannover-Braunschweig region, Staffhorst, Lüneburg and Lägerdorf.).

South of Braunschweig are many old workings in the Turonian, usually exposing the Vancouverensis Zone. The Mid Vancouverensis Marl is a useful marker horizon in this region. Immediately above this marl echinoids are not uncommon. AT Kl. Flötte and Dorstadt M. bucailli is found at this horizon. Only 12 Kms north west of Kl. Flötte Middle Turonian to Lower Coniacian rocks are exposed at Salder bei Saltzgitter. Here M. cortestudinarium is abundant immediately above a thick marl band in the lowest Deformis Zone. Thus gibbose Micrasters are not restricted to the Münster Basin in Upper Turonian times.

The distinction between the contemporary species M. cortestudinarium and M. bucailli is easily seen by the relative height of their periprocts. The periproctal height of the Salder material is the same as material from the Münster Basin (Paderborn), and is distinctly lower than in typical M. bucailli . As I only have few, and poor specimens of M. bucailli from Germany, material from Yorkshire is used to provide a contrast with M. cortestudinarium (see fig. 6). M. cortestudinarium died out at the end of the Turonian.

Gibbose Micrasters appear again in the uppermost Santonian and lowest Campanian of the south west Münster Basin. All specimens of this form come from glauconitic marls or marly sandstones. Dr. Ernst, who first recognised this new species, has collected it from the upper part of the Marsupites Zone at Ridderbusch/Dorsten, the Granulata-Quadrata Zone at Lippe-Seiterkanal near Dorsten, and the Lingula-Quadrata Zone at Hiermann/Bottrop. Similar material in the old German collections is labelled "Emscher" only. This material, from glauconitic marls at Essen and Mulheim, is presumably of the same age. This new species is broad, but not very high for a gibbose form, it lacks a fasciole and is very conservative in appearance, the interporiferous zones of the paired petals are subdivided. This species is presumably evolved from M. cortestudinarium, but there is no evidence of gibbose forms in the Coniacian, nor in most of the Santonian.

Outside the Münster Basin advanced gibbose forms appear in the Lingula-Quadrata Zone and continue up to the top of the Langei Zone (personal communication Dr. Ernst). These belong to the M. fastigatus - stolleyi stock. M. fastigatus is typical of the Lower Campanian and M. stolleyi of the Upper Campanian, the differences between the two being but slight. This stock probably evolved from a pre-existing form known only from one specimen coming from the Bavnodde Greensand (Lower Santonian) of Bornholm. The M. fastigatus - stolleyi stock is not found in the Münster Basin. The holotype of M. stolleyi is stated to come from Coesfeld (Schlüter 1869). Schlüter also records it (as Epiaster gibbus) from Halden and Aachen. I have seen no specimens of this stock from the Münster Basin in any of the German collections which I have examined, including the Schlüter Collection. Dr. Ernst (personal communication 1968) knows of no such specimen. Schlüter's specimen from Coesfeld (? which has been lost) indicates a temporary migration of this stock into the into the Münster Basin in Upper Campanian times.

The distinction between the M. schroederi - glyphus and M. fastigatus - stolleyi lineages is easily seen by reference to the relative height of their periprocts (see figs. 7 and 8) . The frequency distributions of the periproctal height ratios (fig. 9) shows that the distinction between the two stocks increases with time. I know of no intermediates between the two lineages.

CHAPTER V BELGIUM (fig. 10)

With the exception of Campanian forms, the genus Micraster is very rare in Belgium. This chapter is based mainly on the material examined in the Musée Royal d'Histoire Naturelle in Bruxelles.

SPECIMENS OF DUBIOUS ORIGIN

There are some specimens in the Bruxelles Museum, stated to have been collected in Belgium, which I believe to have come from other countries.

Three specimens numbered I.G.9694 were bought from a dealer called Piret in the 1890's. A manuscript label of Meijer (1957) identifies the form as M. coranguinum var. schroederi and states that they probably came from the Craie d'Obourg. Another label states that they are from the Craie Phosphatée (Campanian Cp4b) of Ciply. No informatioh is given on Piret's original label. The specimens are M. decipiens from the zone of that name, and probably come from southern England or the north west Paris Basin. THe nodular white chalk facies noted on these specimens being typical of these regions.

One specimen numbered I.G.4285 from the Bosquet Collection, is stated to come from the Middle Campanian (Craie Marneuse) Assise de Nouvelles of Slenaken. This is a typical M. turonensis from a glauconitic facies typical of the Craie de Villedieu. The specimen is most probably from the Upper Coniacian of the Villedieu region. Lambert (MS label) identified the specimen as M. turonensis.

Two specimens numbered I.G.10511 are stated to be from the Campanian of Ciply. Meijer (MS 1957) regards the horizon as being probably Craie d'Obourg and identifies them as M. coranguinum var. schroederi. These are specimens of M; turonensis var. intermedius from the Santonian. They are probably from the Elbeuf region.

MICRASTER LESKEI

I have not examined any Belgian examples of this species. The only specimen of definitely known locality and horizon is from the Fortes Toises at Harchies, pit no. 1 (Mons Coll.), which is described and figured by Smiser (1935). Smiser states that it is from the lower part of the M. leskei Zone (= Planus Zone). Smiser's figure (Pl. 7, fig. 3) suggests that it is an Anglo-Paris Basin form.

MICRASTER DECIPIENS

Smiser (1935) refers a young specimen from the Craie de St. Vaast to this species, previously refered to

M. coranguinum by Lambert (1911). Idid not notice this specimen in the Bruxelles Museum. The identification of Lamert is more probably correct considering the Santonian age of the Craie de St. Vaast.

MICRASTER CORANGUINUM

One specimen numbered I.G.12710, collected between Mons and Eugies, is stated to;be from the Middle Campanian (Craie de Nouvelles). Determined by Meijer (MS 1957) as M. coranguinum var. schroederi. This is a typical M. coranguinum s.s. from the Coranguinum Zone. If it is impossible for the Santonian to outcrop in this region, one must conclude that the given locality is wrong.

MICRASTER ROGALAE

The holotype of M. belgicus represents this species in the Craie de St. Vaast at Frameries. The paratype of M. belgicus is a distinctly gibbose form possibly derived from M. rogalae . The occurance of M. rogalae correlates the Craie de St. Vaast with the upper Middle Santonian of Lägerdorf. Smiser (1935) states that he knew of "about six" specimens of M. belgicus, but I have only noted the two specimens figured by Lambert (1911) in the Bruxelles Museum.

MICRASTER GLYPHUS / SCHROEDERI STOCK

I) Craie de Trivières

Lambert (1911) records one specimen of M. schroederi, numbered I.G.6312, from this horizon at Harmignies.

II) Craie d'Obourg

This is, according to the labels, the horizon from which the majority of Belgian Micrasters have come. Specimens of this stock are relatively abundant at Obourg, and more so at Harmignies. I have only seen single specimens from this horizon at Nimy and Cuesmes. The _M. glyphus_ / _schroederi_ stock consists of interbreeding populations of both end members, in which intermediate forms predominate. Although adult forms of _M. glyphus_ are easily identified, it is difficult to distinguish the young forms which have a typical _M, schroederi_ shape. In general it can be said that _M. glyphus_ is relatively more abundant than _M. schroederi_ at Harmignies than at Obourg, a fact that may indicate that the horizon exposed at Harmignies is somewhat younger than that at Obourg.

III) Craie de Nouvelles

In these beds most of the specimens are of _M. schroederi_ type, although one specimen of _M. glyphus_ is known from each of the localities of Harmignies and Hallembaye. I have seen specimens of the _M. glyphus_ / _schroederi_ stock from this horizon at Orp-le-Grand, Harmignies, Hallembaye and Schalsberg. Three specimens from Heure-le-Romain are distinctly flattened forms of _M. schroederi_ belonging to the variety _planus_ of Maczynska.

I have seen no specimens which I would regard as _M. brogniarti_ from Belgium., although Lambert (1911) records this species from the Craie de Nouvelles at

Orp-le-Grand, and Cotteau (1874) from the same horizon at Harmignies.

GIBBOSE FORMS FROM THE CAMPANIAN

MICRASTER STOLLEYI

Lambert (1911) records this species from the Craie de Trivières at Harmignies. I have not noticed the two specimens to which he refered.

I only know of one typical specimen of this species (I.G.8261) from the Craie d'Obourg at Obourg.

MICRASTER GIBBUS

Eleven specimens, numbered I.G.6435 and I.G.6312, plus the one figured by Lambert (1911, pl. II, figs. 1-3) as M. stolleyi, belong to Lamarck's species. They all come from the Craie d'Obourg at Harmignies.

The specific difference of the gibbose Micrasters from the Craie d'Obourg at Harmignies and Obourg supports the suggestion (see above) that the Craie d'Obourg is of different ages at these two localities.

MICRASTER CIPLYENSIS

This is the name given to the gibbose form from the Craie de Spiennes at Spiennes and the flint casts from Ciply. I have only examined one specimen of this form from Spiennes, this specimen was figured by Lambert (1911). It is perhaps best regarded as a variety of M. stolleyi.

CHAPTER VI SCANDINAVIA

DENMARK

This section is based on the specimens examined in the Mineralogisk Museum, Copenhagen.

I) Specimens from the Danian of Faxse and Saltholm

Mortensen (1924) and Ravn (1927) record two specimens of Micraster from Faxse and one from Saltholm. These specimens appear to have been lost (personal communication Prof.H.W.-Rasmussen 1968). Ravn described the poor state of preservation of these specimens. I regard them as mis-identified Cyclaster, Brissopneustes or possibly a large undescribrd species of Hemiaster of which I have a specimen from the Upper Danian of Limhamn, Sweden.

II) Proraster oedumi sp. nov.

syn. Micraster sp. Brunnich-Nielsen 1910, p. 466.

Micraster Desori Ødum 1926, p. 162, pl. II,fig. 1a-c.

Proraster desori (Ødum), Poslavskaia 1964, p. 188, text fig. 231b, pl. 37, fig. 7;

non Micraster Desori Hébert 1856, pl. 29, fig. 17.

This new species is erected, by kind permission of Dr. Ødum, as a replacement name for his primary junior homonym. The holotype is the specimen figured by Ødum 1926, pl. II, fig. 1a, from Kjabenhavns Havn, Knippelsbro, Copenhagen, a manuscript label of Wind (1953) identifies it as Washitaster ? sp. ind.. The specimen from Purhus, figured by Ødum pl. II, figs 1b-c, is lost.

III) Micraster sp. from the Bavnodde Greensand.

Only one specimen of this form is known. It was collected from the Lower Santonian between Horsemyreodde and Forchhammers Klint on the island of Bornholm, and is mentioned by Ravn (1921 and 1927). The specimen is poorly preserved, the oral surface is completely missing, the remaining test is somewhat distorted due to its relative thinness. It is a typically gibbose form, the periproct being situated at about 51% of the total height. The interporiferous zones of the paired petals are almost divided. The number of pore pairs in one row of petal II of this specimen (length 40.9 mms) was estimated to be about 32. The outer rows of pores in the unpaired petal are slightly oval, but the individual pores of each pair are still separated by a granule.

This specimen is probably a representative of the stock from which the abundant Campanian gibbose Micrasters (the M. fastigatus - stolleyi stock) evolved.

SWEDEN

The Micraster sp. from the Danian of Scania (Lundgren 1888) was shown by Schlüter (1897a) to be a Brissopneustes.

Micraster Idae from the Köpinge Sandstone is here transfered to the genus Diplodetus (see chapter on Diplodetus).

True Micraster occurs in Sweden only in the form of small specimens of M. glyphus in the Köpinge Sandstone. All the seven specimens, of which I know, come from the Köpinge - Herrestad region north east of Ystad. They are almost identical to specimens which I have collected from the quarry at Poskwitow near Cracow. My Echinocorys from the later locality are regarded as being from an horizon equivalent to the Eaton Chalk of Norfolk by Mr. Peake.

CHAPTER VII POLAND

TURONIAN SPECIMENS

Kongiel (1936) figured two Turonian specimens from Krasne Siolo near Wodkowyska under the name M. leskei. The smaller specimen (MZW Ee 634 (3); Kongiel pl. I, fig. 4) has every appearance of a M. leskei excepting that it has a very thin test. The larger specimen (MZW Ee 634 (4); pl.II,fig.5) has an equally thin test and resembles M. corbovis from the Planus Zone of southern England. Both specimens have smooth interporiferous zones in their paired petals and only a few scattered granules in their periplastronal areas. Kongiel, following English and French workers, regards these as Upper Turonian specimens. They are equivalent to Lamarki Zone material of Germany.

Similar material from the Upper Turonian of Kzemieniec shows sutured interporiferous zones and finely granular periplastronal areas (Makowski Coll., MZW Ee 633 and 632).

A specimen from the Turonian of Opole (MZW Ee 649) resembles M. corbovis.

MICRASTERS FROM THE CRACOW - MIECHOW REGION

This region exposes horizons yielding abundant Micrasters which have been studied by Nowak (1909b) and Maczynska (1968).

The stratigraphy of the chalk in this region is not known in great detail.

The earliest Micrasters present in this region are those refered by Maczynska to M. cortestudinarium. She records this species from the Turonian glauconitic marly chalk of Trojanowice, and the Santonian green marls of Uline Wielka, Giebultow and Tomaszowice. Recent quarrying (1969) at Korzkiew has exposed reworked glauconitic marly sandstones rich in this form. This is the only locality for this form which I have visited. The Micrasters, as is shown by the sediment they contain, originally came from a hard glauconitic limestone, but have been redeposited in the marly sandstone.

This slightly gibbose form, which warrants a new name, is characterised by being broad but not high. The peristome is some way from the anterior border, which shows only a slight notch. The anterior third is very broad and it tapers greatly towards the posterior. The petals are deeply excavated with subdivided to divided interporiferous zones.

The material which I have collected from Korzkiew appears to be from the Upper Turonian in the German sense. Specimens from other localities in the Muzeum Ziemi, particularly those from Ulina Wielka,could well have come from higher horizons.

All the other Micrasters which I have examined and collected from this region I regard as being Campanian.

Maczynska's work (1968) splits the Campanian forms into a large number of species. Not being able to compare her Polish material with western European specimens, she had only the poor descriptions and figures of the classical echinologists for guidance.

I would regard the following as *M. glyphus* from the Campanian :- *M. coranguinum* (stated to be from the Santonian), *M. bibicensis*, *M*, (*Paramicraster*) *cracoviensis*, *M.*(*P.*) *latior*, and *M.*(*P.*) sp.. Maczynska's *M. brongniarti* are juvenile *M. schroederi*. Her *M*, *belgicus*, *M. dallonii* and *M. senonensis* are all typical of the *M. fastigatus* - *stolleyi* stock.

Although it is obvious that all these Micrasters are Campanian, it is difficult to subdivide the Campanian on the basis of *Micraster*. Mr. N.B.Peake has examined the *Echinocorys* which I collected. On the basis of these forms he suggests that the horizons exposed at Pielgrzymowice, Witkowice, Rzerzusnia, Poskwitow, Iwanowice and Bibice correlate with the Eaton Chalk of Norfolk.

Micrasters were previously unknown from Gnatowice, a locality generally regarded as Maastrichtian by Polish workers on the basis of the occurance of *Galerites*. Here I found two crushed specimens of *M. stolleyi* which suggests an Upper Campanian age. The presence of *Galerites* is not diagnostic of the Maastrichtian, it is fairly common in the Upper Campanian at Lägerdorf (Ernst 1963a), it is known from the Beeston Chalk of Norfolk (Peake and Hancock 1961)also.

The chalk of Michalowice, Mlodziejowice and Rzerzusnia may correlate with the Craie de Nouvelles of Heure-le-Romain in Belgium by the common occurance of M. schroederi var. planus.

I have seen no evidence to suggest that the Santonian is present in the Cracow region. The determination of the strata exposed at Bonarka, Tomasowice, Giebultow and Poreba Dzierna seems to be based on the occurance of Gonioteuthis granulata and the rough textured glauconitic nature of the chalk. The latter characteristic is typical of chalks deposited in transgressive seas, and is no basis for stratigraphical determination. G. granulata is typical of the Lower Campanian at Lägerdorf, Hannover and Braunschweig (Ernst 1963a,b; 1968). In the Hannover - Braunschweig region the thin development of uppermost Santonian is often overstepped by transgressive Lower Campanian, and itself rest on the Upper Turonian with slight unconformity (Ernst 1963b, 1968). On the echinoid evidence, it appears to me that this thin development of Santonian is lacking in the Cracow region. Maczynska's stratigraphy of this area is probably based on unpublished work of Kongiel, who regarded G. granulata as a typical Santonian species (Kongiel 1962). Elsewhere in the Northern Faunal Province it is regarded as a typical Lower Campanian form (Jeletzky, quoted in Kongiel 1962).

CHAPTER VIII U.S.S.R.

THE UKRAINE (fig. 11)

Nowak (1909a) and Pasternak et. al. (1968) have studied Cretaceous echinoids from this region.

Pasternak et. al. record the following species of Micraster -

M. corbovis and M. leskei from the region to the north of Loziv, central Kremencia and the Ternopilskoi area; M. cortestudinarium from Kotova, Kremencia, Ternopilskoi area, Baluchina and the Lvivskoi region; M. coranguinum from the Lower Coniacian of Beregan (Kremencia) and the Ternopilskoi area, and from the Upper Coniacian at Kozini in the Ivano-Frankiskoi region; M. rogalae from the Dubivic and Kozini areas of the Ivano-Frankivskoi region; M. cf. schroederi fragments from the Stavchan - Lvivskoi region.

The region studied by Pasternak et. al. is to the north east of the Carpathian Mountain Belt and includes the towns of Chernovtsy, Ivano-Frankovsk, Lvov and Lutsk. It is that which includes the Lvov Basin of the Polish - Lithuanian synclise and links the latter with the Black Sea Depression (Naidin 1960).

The stratigraphical ranges of the Micrasters given by Pasternak et. al. are not usual for the Northern Faunal Province. By comparison with occurances in north Germany,one would suspect that their Upper Turonian = Middle Turonian, their Lower Coniacian = Upper Turonian, and that their Upper Coniacian is more likely to be Santonian. The occurance of M. cortestudinarium and M. coranguinum together during half of one stage is most dubious. The identification of the figured specimens of Pasternak et. al. seems accurate with the exception of plate XLIX figures 5-9. These figures are stated to be of M. cortestudinarium from the Lower Coniacian of the Kremencia area. Its overall appearance is that of a M. glyphus from the Campanian, except for the poorly developed anterior notch and labrum.

Nowak (1909a) worked on the stratigraphy of the chalk around Halicz in the Lvov region. The list of species given by Nowak coming from any one bed cover a wide range of stages. It seems probable that his Bed I, with M. cf. decipiens (? = M. bucailli) is Upper Turonian in the German sense; his Bed II, with M. rogalae, is probably Upper Santonian, although a manuscript label of Prof. Kongiel states that the holotype of this species comes from the Turonian; and Nowak's Bed III is probably Lower Campanian.

THE DONETZ BASIN (fig. 12)

Savchinskaya (1967) gave the ranges of Micrasters in this region. The species are not figured in this work.

The record of M. grimmensis from the Maastrichtian is most dubious. Elsewhere this species is typical of the Upper Campanian. Many species of Echinocorys and Galeola senonensis are recorded from the Upper Campanian. No Lower Campanian echinoids are recorded. G. senonensis is regarded as a Lower Campanian species in Germany (Ernst 1963a,b). No Santonian forms are recorded, their absence is a feature shared by other regions immediately north of the major fold belts of eastern Europe (eg. the Cracow region).

THE NORTHEAST RUSSIAN PLATFORM

Echinoids are rare in the northeast of the Russian Platform (Pechora, Moscow, Caspian and Ukrainian Synclises). This change in the abundance of echinoids corresponds to a major change in facies and the belemnite fauna (Naidin 1960). Naidin interprets the change in the belemnite fauna as being climatically controlled.

THE SOUTHWEST RUSSIAN PLATFORM

In the southeast part of the Ukrainian Synclise _M. corbovis_ occurs in the lamarcki Zone (Upper Turonian) and _M. coranguinum_ in the Involutus Zone (Upper Coniacian). The same species are found at the same horizons in the northern part of the Black Sea Depression (Naidin 1960). _M. corbovis_ is also found in the Upper Turonian of the Saratov region (Naidin 1959). _M. grimmensis_ is recorded by Naidin (1960) from the Langei Zone of the Volsk area.

In Germany the Lamarcki Zone is regarded as lower Middle Turonian, and the Involutus Zone as Middle Coniacian.

THE NORTHERN FLANKS OF THE CAUCASUS AND CRIMEA (fig. 13)

Moskvin and Poslavskaia (1959) published figures of the Micrasters from this, and other regions. This section is based on these figures.

M. corbovis and _M. leskei_ appear similar to those from the Planus Zone of southern England. _M. subglobosus_ is here regarded as synonymous with _M. corbovis_. The specimens of _M. cortestudinarium_ (= _M. bucailli_) and _M. coranguinum_ show the characteristic side profile of the Northern Faunal Province. The _M. rostratus_ is a _M. schroederi_ with a well developed rostrum. The specimen figured as _M. brongniarti_ is an intermediate between M. schroederi and M. glyphus. The Isomicraster faasi is a M. stolleyi, Poslavskaia herself used the same figures in 1964 to illustrate M. stolleyi. The so-called I. gibbus is M. fastigatus. The specimen figured as M. heberti is in no way related to this Pyrenean species. It appears to be a broad, not very high, gibbose form. The so-called I. ciplyensis is not the same as the Belgian species. The extremely poor state of preservation makes an accurate determination difficult. The side profile is distinctive, and separates it from the other species. M. glyphus is notably absent, at least in the published figures.

I cannot accept the stratigraphical distribution given by Moskvin and Poslavskaia for these forms. On the evidence available I would place the Santonian / Campanian boundary in the middle of their Lower Santonian. However M. heberti of these authors must be Campanian because plates 1a1 and 1a2 are clearly separated (op. cit. textfig. 105).

The Turonian forms (M. corbovis and M. leskei) appear to be very close to the Anglo-Paris Basin stock, and not to the contemporary North German material. M. cortestudinarium (= M. bucailli) and all subsequent species are typical of the Northern Faunal Province.

Although M. rogalae is described and figured in this work it is only recorded from Mangûshlaka in central Europe.

THE KOPPEH DAGH (fig. 14)

This section is based on the figures published by Dzabarov (1964). From these figures one can say :-

1) the specimen of *M. corbovis*,with its relatively thick test, appears to be the Northern Faunal Province form *M. borchardi*.
2) *M. leskei* cannot be distinguished from specimens of Anglo-Paris Basin origin.
3) the so-called *M. cortestudinarium* does not show Northern Faunal Province characteristics
4) nor does the *M. coranguinum*.
5) the Lower Campanian *M. schroederi* shows afinities with typical Santonian *M. coranguinum*, but the advanced projection of the labrum is characteristic of the Campanian.
6) *M. pseudorostratus* is a *M. schroederi* with a well developed rostrum.
7) the Upper Campanian *M. glyphus* is absolutely typical of its species.
8) the *Isomicraster gibbus* is an advanced *M. fastigatus*.
9) *M. carinatus* is close to, though not typical of *M. bucailli*.

No comments can be made on the other species and subspecies mentioned by Dzabarov,because he does not figure them. Assuming that the stratigraphy of the Koppet Dagh sections adopted by Dzabarov is correct, the rate of evolution of the genus *Micraster* is much slower here than in more western regions of the Northern Faunal Province. During the

Turonian, Coniacian and Santonian the rate of evolution is the same as that in the Anglo-Paris Basin. With the exception of M. borchardi none of the Micrasters from these stages are typical of the Northern Faunal Province. Indeed, the so-called M. cortestudinarium appears close to M. decipiens. The Koppet Dagh may have formed a sub-region of the Northern Faunal Province in which evolution was retarded during these stages. It could be argued that the region was influenced by the Anglo-Paris Basin fauna from Turonian to Santonian times. The great distance of the Koppet Dagh from the Anglo-Paris Basin and, save for the Turonian evidence from Czechoslovakia, no records of the Anglo-Paris Basin fauna between these regions, makes the latter hypothesis difficult to accept. In Campanian times typical Northern Faunal Province Micrasters appear at their "correct" horizons, although the Lower Campanian M. schroederi is retarded in some features.

CHAPTER IX

THE BAKONY MOUNTAINS OF HUNGARY

Sorenyi (1955) monographed the Cretaceous echinoids of this region. The stratigraphical determination of the various horizons is open to doubt. The succession given by Sorenyi is as follows :-

SENONIAN	(	Marne à Inoceramus Calcaires à Hippurites Marne à Gryphées
CENOMANIAN	(	Marne à Turrilites Marne Glauconitieuses
ALBIAN	(	Calcaire lamelles gris Calcaire à Orbitolines
APTIAN / ALBIAN		Calcaire à Requienies
APTIAN		Marnes argilleuses

The Senonian beds are only found in the southern part of the Bakony Mountains, where the Marne à Gryphées is but locally developed. The Aptian to Cenomanian succession is restricted to the northern part of these mountains.

The Marnes argilleuses yield abundant <u>Heteraster</u> typical of the North African Realm.

In the Calcaire lamelles gris and the Marne Glauconitieuses there is a numerical predominance of European spatangoids. From the latter horizon <u>Hemiaster bufo</u> (European) is known from 280 specimens. From both these horizons <u>H. baconicus</u> (North African) is known from only 45 specimens. Small numbers of the typical North African forms <u>Douvillaster subtrigonalis</u>, <u>Epiaster pseudodistinctus</u> and <u>E. hemiastriformis</u> are also recorded from these beds, the latter two forms are also found in the overlying Marne à Turrilites.

In the Marne à Turrilites all the spatangoids are of North Afriwan type.

There would thus appear to be ossilations between the

North African and European Realms in pre-Senonian times, indicating that this region was situated near the boundary of these Realms. Sorenyi also describes species of Holaster from the Calcaire à Orbitolines to the Marne à Turrilites inclusive, indicating that the European Realm was very close.

The Senonian rocks yield distinctly European Realm echinoids.

From the Marne à Gryphées Sorenyi figures a so-called *M*. cf. *decipiens* . This appears, from the poor figures of a poor specimen, to be a Northern Faunal Province *M*. *schroederi* from the Campanian.

M. *corbaricus* and *Hemiaster pulcher* are recorded from the Calcaires à Hippurites. From the figures given, no attempt can be made to interpret the former species.

The Marne à Inoceramus yields *Echinocorys* and, according to Sorenyi, *M*. *fastigatus*. The latter appears to be a Santonian *M*. *brevis* from the Pyrenean Province

From my identifications of the figures of Sorenyi's Micrasters, it would appear that the superpositional relationships of the echinoid horizons in the southern part of the Bakony Mountains have been misinterpreted, or that the sequence is inverted. It would also seem that the Bakony Mountains were part of an eastward extension of the Pyrenean Province in Santonian times, this being replaced by a southward migration of the Northern Faunal Province during the Campanian.

CHAPTER X THE NORTHERN FAUNAL PROVINCE IN THE BRITISH ISLES

YORKSHIRE , LINCOLNSHIRE AND NORFOLK

This Province was first recognised by C.W.Wright (in Kermack 1954) and its southern boundary is somewhere north of Swaffham (Peake and Hancock 1961). Wright defines the province on the stratigraphical and geographical distribution of various echinoderms. The genus Micraster is known (Kermack 1954) to evolve more rapidly here than in southern England, even on the basis of a southern England inspired zonal system. From this fact, and the distribution and stratigraphical occurances of other echinoderms, Wright suggests (personal communication) that there may have been a north-east to south-west dispersion of echinoderms over England.

TURONIAN MICRASTERS

The two specimens of M. corbovis from the Planus Zone of Kiplingcotes with strongly projecting labrums (Wrights' Collection) are peculiar to this locality. They are not typical of the Northern Faunal Province nor the Anglo-Paris Basin Province.

C.J.Wood has recently collected well preserved Micrasters from the Turonian at Ulceby (Lincs.). On comparison I found them indistinguishable from the Northern Faunal Province form M. borchardi which I have collected from the Lamarcki Zone at Wüllen. The Ulceby horizon is at present regarded as Upper Turonian, the Wüllen horizon is lower Middle Turonian.

CONIACIAN MICRASTERS

M. bucailli is abundant in the "Cortestudinarium" Zone at Little Weighton, Yorkshire (locality 18 of Wright and Wright 1942). Mr.C.W.Wright has demonstrated to me that this form is easily distinguished from the southern English form (*M. decipiens*)by its more advanced labrum and its characteristic side profile.

The evolutionary stage reached by the Micrasters in this zone of Yorkshire is equivalent to that reached in the Upper Coniacian of southern England, and the top of the Middle and Upper Turonian of north Germany.

SANTONIAN MICRASTERS

The *Hagenowia rostrata* Zone of Yorkshire yields rare specimens of *Micraster*. I have only seen one such specimen from South Landing, Flamborough (Wrights' Collection). This incomplete specimen is difficult to interpret, but one has the impression that the pores of the paired petals are more compact than in typical *M. coranguinum*.

Aberrant forms of *M. coranguinum* occur in the Coranguinum Zone of Norfolk at South Creake and Litcham (I.G.S. R 250 and HBW 560 respectively). These specimens were regarded by Nichols (1959) as coming from the Mucronata Zone. Other unlocalised material from the Woodward Collection (I.G.S.), with numbers in the range HBW 556-561, may well be from Litcham.

LOWER CAMPANIAN MICRASTERS

M. aff. *glyphus* occurs in the lower part of the Lingula

Zone at Sewerby, Yorkshire. The only specimen which I have seen is from Wrights' Collection. The specimen is not quite typical of the species in that the peristome is situated relatively far from the anterior border.

M. coranguinum is stated by Wright and Wright (1942) to be not uncommon in the Discoscaphites Subzone at Bessingby, Yorkshire. I have only seen three specimens from Bessingby Hill (I.G.S. 90432-4) all of which are very narrow elongate forms being intermediates between *M. coranguinum* and *M. schroederi*.

Peake and Hancock (1970) record *M.* cf. *schroederi* and *M.* cf. *faasi* from the upper part of the Gonioteuthis Zone at Skiffky, Norfolk. The occurance of the latter form is the earliest record of the *M. fastigatus* - *stolleyi* stock in the British Isles.

UPPER CAMPANIAN MICRASTERS

Micrasters become relatively abundant in the Mucronata Zone of Norfolk. These Micrasters have recently been discussed by Kermack (1954) and Nichols (1959). Kermack recognised three forms in this zone :- *M. glyphus*, *M. stolleyi* and "some aberrant forms, resembling in some ways *M. coranguinum*." The latter presumably refers to *M. schroederi* or true aberrant *M. coranguinum* of which the horizon has been mistaken. Nichols recognised *M. glyphus* and *M. stolleyi* and states, contrary to the conclusion of Kermack, that intermediates between these two species occur. Although Nichols states that he has seen no specimens resembling

M. coranguinum from the Mucronata Zone, he includes in his list of specimens from this zone an aberrant M. coranguinum from the Coranguinum Zone of South Creake (I.G.S. R 250).

Regarding the Mucronata Zone Micrasters as one population, as done by both Kermack and Nichols, is a great oversimplification. Figure 15 shows that when this is done there is no large gap between the two groups present in this zone (ie; M. glyphus - schroederi stock and M. stolleyi). Equally, a frequency distribution of the periproct height ratio (fig. 16) shows no distinct break between the groups.

The Mucronata Zone forms must be regarded as a succession of populations. They come from over 400 feet of chalk (Peake and Hancock 1961). Any statistical study must deal with specimens from more narrowly defined horizons. Unfortunately much of the museum material is not sufficiently well localised to be of use in this study. The horizons of the specimens utilised are infered from the museum labels and the maps of Peake and Hancock (1961 & 1970). When the periproct height ratio is plotted for more limited horizons (fig. 17) the distinction between the groups becomes much clearer. Another important fact shown by this figure is that the periproct height of the gibbose forms is very variable throughout the Mucronata Zone as a whole, but of limited variability within certain horizons, such that this ratio can be used to define the horizon at localities such as Catton and Thorpe. The very low periproct height of the gibbose form from Catton may be a reflection of ecological conditions. The Catton Sponge Bed and associated horizons may have stimulated exceedingly shallow ploughing forms with unusually low periprocts. When the chalk at Thorpe was deposited conditions had probably changed such that the gibbose forms ploughed deeper into the sediment, allowing the periproct to become situated higher.

Micrasters occur throughout the Mucronata Zone of Norfolk, but are rare in the Basal Mucronata, Eaton and Beeston Chalks. Gibbose forms appear to be absent in these named Chalks.

Maastrichtian Micrasters

Micrasters have recently been found in the Lower Maastrichtian of the Norfolk coast (personal communication N.B.Peake). I have not seen any of these specimens.

The evolution of Micrasters in northern England parallels that in north Germany, but at a slower rate. The Micrasters from Bessingby Hill have not yet reached the typical M. schroederi which is present at this age in Germany. The M. cf. glyphus from Sewerby is readily recognisable as a Campanian form. The occurance of this form at such a low horizon is remarkable in that contemporary material from Germany does not yield forms so far advanced, except for the peristome, towards the typical M. glyphus. It is even more remarkable that it occurs before the M. cf. schroederi from the Discoscaphites Subzone.

The Mucronata Zone Micrasters from Norfolk are the same as those from the same zones in Belgium, Germany and

Poland. This increase in homogeneity of the Northern Faunal Province Micrasters is probably connected with an extension of the Upper Cretaceous transgression beginning at the end of the Lower Campanian. Kongiel (1962) suggests this hypothesis to explain the decrease in provincialism in Upper Campanian belemnites.

NORTHERN IRELAND

Micrasters are rare, and poorly preserved usually, in Northern Ireland.

Specimens from pre-Mucronata Zone horizons are exceedingly difficult to interpret. I have seen the following examples :-

1) A specimen from Whitepark Bay (I.G.S. Zr 5595), which appears to be a small form of M. bucilli, corresponding to those from the "Cortestudinarium" Zone of Yorkshire. Mr. Wood insists, on other evidence, that the horizon must be Uintacrinus Zone.

2) One from Kilcoan Quarry (Kilcoan Greensand) is equally typical of the Yorkshire "Cortestudinarium" Zone.

3) Two specimens recorded by Hancock (1961) from the Hibernian Greensands in County Derry, 2'2" above the base of the Upper Glauconitic Beds at Tricreven Burn. (Hancock Coll. C 1365A & B). Both these specimens are gibbose forms with numerous compact pores in their paired petals. They are probably related to the Micraster sp. nov. of Ernst from the Santonian / Campanian boundary of the south west Münster Basin.

The four specimens mentioned above show affinities with typical Northern Faunal Province regions.

4) Hancock's specimens from the Sponge Bed of the Island Magee (= Crinoid Zones, Hancock 1961) are matched by a specimen in the BM(NH) from the Kilcoan Greensand. The latter specimen is from a different bed from specimen 2), above, within this Greensand (personal communication C.J.Wood). Their very low narrowish form is characteristic. In some ways they resemble M. coranguinum var simpsoni var. nov. from the top Marsupites and Pilula Zones of southern England.

The Mucronata Zone specimens are typical of the widespread Northern Faunal Province Upper campanian Micrasters. Hancock (1961) records M. glyphus from the Basement Beds of the White Limestone in Derry. The Wood Collection contains a M. glyphus from the Basal Mucronata Chalk at Benbradagh, (I.G.S. CJW 2774). Wood's specimen (I.G.S. CJW 1370) of M. stolleyi from Port Braddon is the only one of this species which I know from Northern Ireland.

CHAPTER XI

SOUTHERN ENGLAND (figs. 18 - 21)

LOWER CRETACEOUS

Lower Cretaceous echinoid faunas are restricted to the Aptian and Albian, the Neocomian being represented by non-marine deposits. The Aptian and Albian echinoid faunas, although sparce, are varied and in much need of study.

The section of this chapter on Lower Cretaceous and Cenomanian echinoids is based on the literature, I have not yet examined museum material.

The North African Realm fauna is represented by Enallaster fittoni in the Lower Greensand (Aptian) of Shanklin, Atherfield and Hythe, and by E. greenovi in the Upper Greensand (Albian) of Blackdown (Wright 1878).

Hemiaster murchisoniae is also found in the Greensand at Blackdown, but this appears to be a European type spatangoid, possibly an early member of the Touraine-Aquitaine "Epiaster" stock. The Echinospatangus quenstedtii Wright 1878 from the Upper Greensand of Wiltshire equally appears to be a European form. Epiaster deloriolii Wright 1878,of the same location as the latter, appears, from a brief examination of Wright's specimens in the BM(NH), to be closely related to Diplodetus and may possibly represent the ancestral stock of this genus. The Gault Clay facies of the Albian yields only typical European spatangoids in the form of Hemiaster asterias, H. bailyi.

Holasteroids, indicative of the European Realm, are present from Aptian times onwards in southern England. _Cardiaster bedstedi_ is known from the Lower Greensand of Shanklin and Atherfield. The Upper Greensand yields _C. perezii_, _C. fossarius_ and _C. latissimus_.

The Lower Cretaceous echinoid faunas of southern England thus show a mixing of North African and European Realm elements, assuming that the literature portrays the fossils accurately.

UPPER CRETACEOUS

CENOMANIAN

In Cenomanian times only European Realm elements are represented in the form of Holasteroids (_Holaster trecensis_, _H. subglobosus_) and the spatangoid _Hemiaster morrisii_. Wright's figures of the latter (1878) appear very close to the Touraine-Aquitaine "_Epiaster_" stock.

TURONIAN TO CAMPANIAN SPATANGOIDS

The classic work of Rowe (1899) on the evolution of the genus _Micraster_ was based on the material which he collected in southern England. Unfortunately his collecting was not as rigid as the title of his paper would suggest. Many of his correlations are inaccurate (personal communication C.J.Wood).

A succession from the Lata Zone to the lower part of the Coranguinum Zone is well exposed on the East Cliffs of Dover and is easily accessible at Langdon Stairs. Mr. Wood's bed by bed collection from the East Cliffs has proved invaluable in elucidating the stratigraphical distribution of the southern English Micrasters. For this reason, this region is here used as a standard for the Anglo-Paris Basin Province fauna. The succession at Langdon Stairs is given (fig; 19) with the ranges of the spatangoids along side. Most of the Micrasters in the Wood Collection were collected from the East Cliffs, but the beds are easily traced through Langdon Stairs.

THE TOURAINE - AQUITAINE "EPIASTER" STOCK

The earliest occurance of Micraster-like echinoids is the form collected from the Labiatus Zone at Beer, Devon. I have only seen one such specimen from the Wrights' Collection, which was recorded as M. leskei by Kermack (1954). This is an "Epiaster" as is all Rowe's material from the south Devon "Cuvieri" Zone, which Rowe labelled M. corbovis. This stock continues into the Lata Zone. At this time it became more widespread and more abundant. Specimens from this Zone in the Rowe Collection come from Hooken, South Down Common, Compton Bay and White Cliff to Hooken. Rowe's Collection also contains specimens from the Planus Zone of Westerham (Kent), Pinhay Bay and east of Dover. I have collected a typical "E." michelini 0.2 m below the base of the Chalk Rock at Kensworth, Herts. The specimen recorded by Rowe (1899) from 20 feet above the base of the Cortestudinarium Zone (on the same page that he states that M. corbovis is not found above the Planus Zone) he identifies as *M. corbovis*. This is a member of the "*Epiaster*" stock. This stock probably continues higher up the succession. I have noted afragment of a thin tested spatangoid between beds Z and Y on Langdon Stairs, which is presumably an "*Epiaster*."

In the Wood Collection from Dover, this stock ranges up into the lower part of the Chalk Rock (beds I to J of Wood) where it occurs with intermediates to *M. leskei*.

LATA ZONE TYPE OF *MICRASTER CORBOVIS*

This form is found in the Lata and lower part of the Planus Zones. In the Wood Collection it is first found about one metre above the Four Foot Band. Its last known occurance is in the Basal Complex of the Planus Zone. Immediately below the Basal Complex intermediates between this form and the "*Epiaster*" stock occur.

PLANUS ZONE TYPE OF *MICRASTER CORBOVIS*

I know of no accurately collected specimens of this form.

MICRASTER LESKEI

This species may have evolved from the "*Epiaster*" stock during lowest Chalk Rock times, intermediates between the two being found in beds Ito J of Wood. The typical small *M. leskei* is not represented in the specimens from the East Cliffs. It is abundant in the Chalk Rock complex in the cliffs west of St. Margarets Bay. I have collected 6 specimens from the top of the Chalk Rock at Kensworth, Herts. The typical *M. leskei* appears to be restricted to the Chalk Rock.

At Kensworth another hard ground occurs about 0.70 m above the Chalk Rock. This horizons yields a distinctive large variety of *M. leskei* which is distinguished by its broader anterior and more inflated form. Inbetween these two hard grounds at Kensworth fragments of an exceedingly large *Micraster* occur. The Wood collection from Dover contains two specimens from beds I to J of Wood which appear to be large *M. leskei* but with short petals

MICRASTERS OCCURING BETWEEN THE CHALK ROCK AND THE TOP ROCK

These Micrasters are difficult to interpret due to the diversity of forms present.

A group of specimens found resting on the top of hard ground L at Dover by Mr. Wood are forms of large *M. leskei*. Higher up the succession, below the Top Rock, are specimens which have affinities with the previous group and, to a certain extent, *M. decipiens*.Within the Top Rock are specimens which are perhaps best called advanced *M. leskei* (? = Planus Zone *M. praecursor* of Rowe). A specimen from the top of the Top Rock could be said to have affinities with a great variety of Micrasters, such as *leskei*, *normanniae* and even *decipiens*. Rare examples of intermediates between *M. leskei* and *M. normanniae* occur between the Chalk Rock and the Top Rock.

MICRASTER NORMANNIAE

Typical *M. normanniae* is found resting on the Top Rock. This distinctive species is known to occur up to bed M2.

A specimen attributable to this species, from beds 8-9 of Wood, varies in that it is less flattened and has a deeply sunken mouth region situated further back than usual.

MICRASTER DECIPIENS

M. decipiens of an early type appear at M2 and continue up to E2. As in the case of M. normanniae, odd forms with regressive peristomal regions occur, such specimens coming from beds 12-13 and 14-15. Certain of the early M; decipiens have a shape somewhat like that of M. coranguinum in that they are narrower and higher than the typical form.

The typical form of M. decipiens is found in beds 21-24 of Wood. Some of Wood's specimens compare in almost every respect with the figures of Bayle (1878). In these beds occurs a specimen showing general shape affinities with broad M. coranguinum, and a distorted specimen which could possibly be an early M. coranguinum.

Bed 25-26 has yielded to Wood an intermediate between M. decipiens and M. coranguinum, as has the chalk just below bed 29. M. coranguinum first appears in bed 27-29.

MICRASTER CORANGUINUM

Shepherd-Thorne & Wood (in press) take the marl band numbered 29 as the base of the Coranguinum Zone. Above this marl band all the main lineage Micrasters are M. coranguinum. Broad forms of this species occur early, Wood has a specimen collected between my beds S and T.

Above these lowest Coranguinum Zone horizons the zone fossil becomes uncommon, and does not appear in any abundance again until the level of Whitaker's 3-inch Band. The succeeding horizons are best studied on the Thanet Coast, where Micrasters are not uncommon from the 3-inch Band to a level about 1.50 m above the Barrois Sponge Bed. This bed marks the top of the Coranguinum Zone in this region. M. coranguinum from the upper Coranguinum and lower Uintacrinus Zones are the advanced forms with a well arched carina. It is this form which is usually figured (eg. Forbes 1850a). There is a tendency for the periplastronal areas of the Uintacrinus Zone forms to become ornamented with small discrete granules.

MICRASTER ANGLICUS

This gibbose species occurs in the Coranguinum Zone of southern England. Its earliest accurately recorded occurance is between my beds S and T in the East Cliffs of Dover (Wood Coll. 688). I know of no occurances of this form in the Decipiens Zone, material labelled as such in the museum collections are M. decipiens in my opinion. Mr. Wood has demonstrated to me a change in the ornamentation of the periplastronal areas of this species. A specimen collected below Whitaker's 3-inch Band shows very fine granules with small scattered tubercles in depressed areas (CJW 814), as does the specimen from the East Cliffs mentioned above. A specimen (I.G.S. Zr 4166) collected 0.90 m below the Barrois Sponge Bed has well developed granules in these areas. An intermediary stage is shown by a specimen (CJW 545) from 0.50 m below Whitakre's 3-inch Band. From this evidence Wood concludes that there is a change in this lineage at the level of Whitaker's 3-inch Band, corresponding to a change in other elements of the fauna. I have seen no specimens of *M. anglicus* coming from above the Barrois Sponge Bed.

POST - CORANGUINUM ZONE MICRASTERS

Micrasters are rare in the upper part of the Uintacrinus Zone of this country. I have seen no such examples.

The Marsupites Zone yields *M. coranguinum* var. *rostratus*. I only know this variety from museum material which is labelled "Marsupites Zone" only.

In the upper part of the Marsupites Zone the earliest specimens of *M. coranguinum* var. *simpsoni* var. nov. occur. I have this variety from the Echinocorys Band on Thanet (collected loose). Mr. Simpson has found it in the top of the Marsupites Zone at Friars Bay.

M. coranguinum var. *simpsoni* var. nov. is abundant in the Pilula Zone of Sussex. The holotype (Simpson Collection) comes from the lower part of this Zone at Saltdean. I have seven specimens from this horizon at Saltdean and one from Newhaven.

In the remainder of the Lower Campanian Micrasters are apparently absent in southern England.

MICRASTER WESTLAKEI

The only three specimens of Mucronata Zone Micrasters which I have seen are attributed to this new species. They come from Tichbourne Farm, Hampshire (Westlake Collection). Kermack (1954) records a specimen from this Zone of the Isle of Wight (Hawkins Collection) as *M. glyphus*. Not having seen this specimen I cannot comment upon this identification, although it is most improbable that M. glyphus occurs in southern England.

STRATIGRAPHICAL CONSIDERATIONS ON THE DOVER MICRASTER SEQUENCE

THE LATA / PLANUS ZONE BOUNDARY has been drawn at various horizons. Rowe (1900) placed it at the lower marl of the Basal Complex. The Geological Survey place it at the base of Wood's group E. There is no major change in the spatangoid fauna at either of these horizons. Typical "Epiaster" continues throughout. Although the last typical Lata Zone type M. corbovis in the Wood Collection are below Rowe's boundary, it would be unwise to assume that they occur no higher. The appearance of M. leskei (both typical and large forms) in the lowest Chalk Rock marks an important change in the spatangoid fauna. This horizon is much higher than any conventional Lata - Planus Zone boundary.

THE PLANUS / CORTESTUDINARIUM ZONE BOUNDARY is marked by the Top Rock.

In the succeeding zone M. decipiens predominates and ought to give its name to the zone. This zone is habitually called the Certestudinarium Zone by English authors despite the fact that this species was known not to occur in this country (Lambert 1895) and that de Grossouvre (1896) correctly refers to this zone as the "craie à M. decipiens." Although M. decipiens ranges from M2 to Y in the East Cliffs, it is more abundant and of the more typical form in the upper part of its range. *M.normanniae* is diagnostic of the lowermost part of the Decipiens Zone. The 2 metres of chalk above the Top Rock which yield *M. normanniae* could be regarded as the Normanniae Subzone of the Decipiens Zone.

THE BASE OF THE CORANGUINUM ZONE is taken by Shephard-Thorn and Wood (in press) at the upper and more conspicuous of two marl seams 2.10 m above the 'basal *coranguinum* tabular' of Rowe at St. Margaret's Bay. From my identification of the specimens in the Wood Collection, it is seen that *M. coranguinum* first appears between these two marls. Logically the boundary should be drawn at the lower marl.

OTHER LOCALITIES IN SOUTHERN ENGLAND

The Micrasters from the rest of southern England can be fitted into the Dover-Thanet sequence.

The *M. normanniae* horizon is of limited occurance. Other than Dover material I have only seen one specimen of this species coming from Hampshire. *M. decipiens* has been collected from the chalk at Eastbourne over greater thickness than at Dover. The facies here is less nodular (personal communications C.J.Wood). One could thus conclude that the succession becomes thicker, and perhaps more complete west of Dover. The Top Rock must represent a relatively major break in the succession at Dover, where no Lower Coniacian Bed A facies of Cayeux (1967) is present. This latter horizon may well be present at Eastbourne, Mr. Hollis having shown me a specimen of chalk rich in club-shaped *Cidaris* spines and starfish débris from Beachy Head. The exact horizon from which this specimen came is uncertain.

Mr. Wood has shown that the typical high Decipiens Zone M. decipiens, representative of beds B2 to Y of Dover, is found resting directly on the Top Rock in the Chilterns. Thus the Normanniae horizon and much of the Decipiens Zone proper is missing here. My own collecting at Charnage Limeworks suggests that the same situation occurs here.

The Micrasters from the Cortestudinarium Zone at Swaffham (I.G.S. 84480-84505 from Swaffam Limekiln Pit) are of southern English type (as stated by Peake & Hancock 1961) but are tending to become gibbose forms, seven of the twenty six specimens having lost their fascioles. The northern limit of the Anglo-Paris Basin Province is thus somewhere north of Swaffham in Coniacian times.

THE DISTINCTION BETWEEN THE SYMPATRIC SPECIES M. CORANGUINUM AND M. ANGLICUS

This has presented problems to many workers. Kermack (1954) studied a collection of 516 specimens, comprising these two species, from the upper part of the Coranguinum Zone of Northfleet, Kent (Rowe Collection). He concluded that the only character upon which the species could be distinguished was the development of the subanal fasciole. This contention is rejected, and the relative height of the periproct is regarded as the most reliable criterion for their distinction. The Northfleet population was measured to confirm this. The results are shown in figures 20 and 21 . The height of the top of the periproct was measured to an accuracy of 0.005 inches. Kermack's measurements (1950) for the maximum height of the test were accepted as accurate. Figure 20 shows the height of the top of the Periproct plotted against the maximum height of the test for the 390 specimens on which both measurements could be taken. By counting the number of specimens in two offset 1.0 mm grid systems and taking the means of the overlapping quarters one arrives at figure 21 . This method diminishes the difference between the groups, but it may be an indication of the situation in a much larger population. The figure shows clearly the concentration of the individuals on two trend lines. The two groups were arbitarily divided along the low concentration areas seen in fig. 21 . The fact that such an area of low concentration exists between these two groups is significant in view of the fact that Kermack (1954) showed that Rowe's Collection is biased in favour of intermediary forms. The regression lines for the two groups thus separated were calculated on a computer and plotted on fig. 20 . The agreement of this biometric character with the manuscript identifications of Rowe is also shown by reference to this figure.

ADDENDUM TO CHAPTER XI SOUTHERN ENGLAND.

I) HALDON FLINT GRAVELS

Micraster coranguinum and *M. decipiens* are not uncommon in these flints. Of the material which I have examined in the I.G.S. and B.M.(N.H.) I have seen only one specimen which is attributable, with some uncertainty, to *M. leskei*. The apparent absence of *M. normanniae*, and the extreme rarity of *M. leskei* does not necessarily lead to the conclusion that their respective horizons were not deposited or only thinly represented here. These facts are more probably a reflection of the association of Micrasters with flints. My collecting experience in other parts of southern England leads me to believe that Micrasters are rarely invaded or enclosed by flints until the Decipiens Zone above the horizon of *M. normanniae*.

II) MUCRONATA ZONE

Micrasters are not uncommon in this Zone at Studland Bay. I have not been able to determine to which species my crushed fragments belong.

CHAPTER XII THE NORTH-WEST OF THE PARIS BASIN

THE COAST SECTIONS FROM LE HAVRE TO DIEPPE

The magnificent sections along the Normandy coast are easily accessible, and being fossiliferous, have received a certain amount of attention.

L. Cayeux is in the process of publishing a series of papers on the stratigraphical distribution of the Cretaceous echinoids of this region of the Bec de Caux. The succession here is easily matched with that at Dover.

The oldest chalk from which I have collected spatangoids is probably that exposed at Senneville. I have an "Epiaster" showing affinities with the Lata Zone type M. corbovis from 1.80 m beneath a prominent marl band exposed beside the lower part of the steps leading to the beach. At Dover this specimen would be typical of the chalk immediately below the Basal Complex.

The Planus Zone (sensu anglais) is well exposed in the cliffs south-west of Etretat. Here it shows a succession of marly chalks and nodular beds with well developed burrowed horizons, and a pebble bed. The only fossils I have come from a hard nodular chalk with sponges which is exposed immediately south-west of the promenade. I was unable to correlate this horizon with the well developed unfossiliferous sequence further south-west. It yielded M. leskei and Holaster planus in relative abundance.

The Normanniae Zone is exposed high in the cliffs at the north end of Etretat promenade. Here a very distinct marl band (2.5 - 15 mms) is exposed in the old gun emplacement. Club-shaped <u>Cidaris</u> spines are common around this horizon, and starfish ossicles are abundant within the marl and just below it. Around this horizon the Micrasters are of early <u>M</u>. <u>normanniae</u> types. The abundance of cidaroid spines and starfish débris correlates these beds with Bed A of the Lower Coniacian (Cayeux 1967) despite the fact that Cayeux regards his Bed A as being devoid of irregular echinoids. French authors have long since recognised that <u>M</u>. <u>normanniae</u> is diagnostic of the lowest Coniacian. Bucaille, in erecting this species, states (1883) that it is found in the lower Senonian "dans les assises en contact avec le Turonien supérieur."

The exposures immediately west of the promenade at Yport yield <u>M</u>. <u>decipiens</u> in white chalk with flints about 2.25 m above a distinct burrowed hard groun which forms the wave cut platform. Whether the latter is the equivalent of our Top Rock, and whether the 2 m of chalk above it represent the Normanniae Zone is impossible to say without palaeontological evidence. The fact that many of the higher beds appear to thicken towards the south-west (ie. towards Etretat) may indicate that the Yport succession is not complete.

Immediately east of Yport promenade broad forms of <u>M</u>. <u>coranguinum</u> occur in white chalk with bands of irregular flint nodules and a thick, massive, zoned cavernous flint bed. The beds are almost horizontal both east and west of

Yport. The facies examined at beach level (in particular the flints) to the east being seen high in the cliffs to the west, one could conclude that Yport is situated on a fault downthrowing to the east.

The cliffs south west of Fécamp yield typical M. decipiens in white chalk with thick (c. 120 mms) flint layers.

M. decipiens is also found in horizons high in the cliffs at Senneville. It is common in fallen blocks.

The Upper Coniacian is also exposed immediately west of Dieppe, where typical M. decipiens can be collected in and around an iron stained sponge bed full of Inoceramus débris.

The cliffs between St. Valery-en-Caux and Dieppe expose almost horizontal Santonian chalks, with the exception of the locality just mentioned.

From the soft white chalk with flints on the foreshore of Pourville I have collected M. coranguinum and M. anglicus typical of the Coranguinum Zone.

Advanced M. coranguinum of the Uintacrinus Zone together with Echinocorys typical of this Zone (determined by Mr. Peake) are not uncommon in the pure white chalk of the foreshore at St. Marguerite. One of the Echinocorys which I collected here is characteristic of an horizon 4.50 m above the Barrois Sponge Bed on Thanet according to Mr. Peake.

Similar M. coranguinum occur in the soft white chalk with numerous flint bands and sponge beds in the cliffs west of the steps to the beach at Sotteville. The abundant

Echinocorys, here associated with the sponge beds, are typical of the top of the Uintacrinus Zone (determined by N.B.Peake). This is the highest horizon from which I have collected on the Normandy coast.

Further east, in the exposures east of Puys, the Planus Zone is richly fossiliferous. *Holaster planus* is not uncommon in marly chalks and sponge beds regarded as Coniacian by Bignot (1964). Bignot's section of the Dieppe cliffs shows a monoclinal flexure bringing up the Turonian to the east. I have seen no evidence to support the steep WSW dips immediately east and west of Dieppe harbour as shown on Bignot's section. The occurance of a major, roughly N-S, fault east of Puys, not shown on Bignot's section, and minor N-S faults in Dieppe harbour, suggest that the sudden change in age of the strata on either side of Dieppe is best explained by a large fault. It is easy to imagine the great fault of the Pays de Bray extending north west along the remarkably straight valley of the Béthune and through Dieppe.

THE BOULONNAIS REGION

Parent (1892) published the most recent work on the Cretaceous echinoids of this region. It is obvious, from the names which he uses, that this is a typical Anglo-Paris Basin fauna, although I have not done any collecting here.

The Craie à *Micraster breviporus* (= *M. leskei*, = Planus Zone) yields Parent's and Hébert's zone fossils in many localities.

The so-called "Craie de Vervins" is a much used but ill defined term. Parent (1892) regards M. corbovis and M. normanniae as being diagnostic of this horizon in the Boulonnais. He also records M. breviporus (=M. leskei) and M. cortestudinarium (=M. decipiens)from this chalk. The fact that this combination of Micrasters can never occur together leads one to suspect the validity of Parent's stratigraphical work.

The Craie à M. cortestudinarium is the equivalent of the Decipiens Zone. Inoceramus involutus being found at Moulin de Coquelles and Elnes. M. gibbus of Parent from the latter locality may be an early M. anglicus, as may be that from Coquelles. The occurance of M. gosseleti (=M. gauthieri of Parent) in this zone at Moulin de Coquelles indicates an influence of the Lille fauna in the Boulonnais.

The Coranguinum Zone outcrops around St. Omer. Localities to the north west of the town yielding M. coranguinum and M. anglicus. The localities to the south of the town, placed in this Zone by Parent, may well be top Coniacian as Parent states that the fossils here are those of the I. involutus chalk of Lille.

THE LILLE REGION

Other than flintless and unfossiliferous hard chalk in temporary sections at Seclin, the only outcrop which I found near Lille is a large quarry at Loos. This may be the locality called Ennequin in the old literature.

The base of this quarry is cut in magnificently developed hard grounds with <u>Thalassinoides</u> burrows. The matrix of loose <u>H</u>. <u>planus</u> and small <u>M</u>. <u>leskei</u> shows that they must have come from these hard grounds, which must therefore be in the Planus Zone. One such specimen of <u>M</u>. <u>leskei</u> shows characters intermediate to "<u>Epiaster</u>" indicating that the Chalk Rock is represented within the 2 metres of hard grounds exposed. I have collected <u>M</u>. <u>decipiens</u> in situ about 3 metres above the hard grounds, and from higher horizons of the white chalk. One concludes that the Planus Zone is very much reduced here, and the Normanniae Zone almost certainly absent.

I am unable to interpret the work of Cayeux (1890) from that which I have observed at Loos. Cayeux and other authors record <u>M</u>. <u>decipiens</u> (as <u>M</u>. <u>cortestudinarium</u>) from the uppermost hardground (called Tun). Polvêche (1957) questions this occurance.

The uppermost part of the Decipiens Zone in the Lille region yields rare specimens of <u>M</u>. <u>gosseleti</u>. This species, from the chalk with <u>I</u>. <u>involutus</u>, is known only from this region and the northern part of the Boulonnais.

OTHER LOCALITIES IN THE NORTH-WEST OF THE PARIS BASIN

LES ANDELYS. I have collected <u>H</u>. <u>planus</u>, <u>M</u>. <u>leskei</u> and abundant Terebratulids from a hard groud exposed beneath Château Gaillard near Les Andelys, and from a similar facies about 500 m south of Amfreville. Mr. Hollis has given me a specimen of <u>M</u>. <u>decipiens</u> from Les Andelys. It remains to be seen whether or not the Normanniae Zone is present in this region.

EVREUX . Typical poorly fossiliferous mid-Coranguinum Zone chalk outcrops west of the city. I have one M. coranguinum from here.

DREUX. High Santonian chalk is exposed in a wotking quarry at Les Osmeaux near Dreux. The uppermost beds of the disused part of the quarry yields Echinocorys, along with which I found a plate of Marsupites. The lower beds of the disused section yield quite common advanced M. coranguinum with Echinocorys which I believe to be typical of the Uintacrinus Zone.

THE MICRASTER SEQUENCE OF THE NORTH-WEST OF THE PARIS BASIN

The Turonian to high Santonian spatangoids of this region show that it was a typical Anglo-Paris Basin Province area during these stages. The Lille region, in upper Coniacian times, shows the development of a distinct local species,sympatric with the Anglo-Paris Basin fauna.

I know of no Campanian Micrasters from this region. It would be unwise to assume that they would be the same as those of southern England had they been present.

CHAPTER XIII THE SOUTH-EAST OF THE PARIS BASIN (figs. 22 & 23)

LOWER CRETACEOUS

VALANGINIAN

The Valanginian transgression extended as far north as the valley of the Seine in the south-east of the Paris Basin. Marine Valanginian deposits are locally developed in the Yonne, Haute Marne and the Aube, resting on the "Portlandian." Lambert (1916) records Holaster cordatus (=H. grasi) from these beds. This is the earliest of all known members of the Holasteridae.

HAUTERIVIAN

This stage is rich in Toxaster retusus which are so abundant at one horizon that the latter is known as the Calcaire à Spatangues. The stage terminates in yellow marls with T. neocomiensis. Holaster intermedius and H. conicus come from the Hauterivian.

BARREMIAN

T. ricordeaui is stated to be typical of this stage. Heteraster oblongus appears in the Upper Hauterivian of the Haute Marne. The latter does not appear until the Lower Aptian in more southern regions (ie. SE France, the Pyrenees and Algeria).

APTIAN

Only the Upper Aptian yields spatangoids. No Aptian holasteroids are known from this region. T. dolosus is recorded from the Upper Aptian at Gurgy. Miotoxaster collegnoi is restricted to the uppermost Aptian, in the Yonne and Aube, and _M. breyniusi_ to the same horizon in the Ardennes at Grandpré.

The earliest of all "Hemiasters" - _H. oriens_ Lambert 1916 - from the Upper Aptian of the Yonne and Aube has been examined by Devriès (1963) and shown to be a _Heteraster_.

ALBIAN

It is in the Albian that the first European Realm spatangoids appear, but these are rare in the south east of the Paris Basin. Cotteau records one specimen of _Hemiaster minimus_ from Seignelay. Valette cites _Epiaster ricordeaui_ from the Gault at the same locality and Saint-Florentin. _Holaster_ is represented by _H. altus_, _H. perezii_ and _H. latissimus_.

CENOMANIAN (UPPER CRETACEOUS)

The Cenomanian fauna of Sancerre includes _Holaster nodulosus_, _H. subglobosus_, _Epiaster distinctus_ and _E. crassissimus_ according to Lambert (1913). Cotteau (1865) records _H. trecensis_, _H. carinatus_ and _H. subglobosus_ from localities in the Aube and Yonne. Cotteau (1857-78) adds _Hemiaster bufo_ and _H. peroni_ (=_H. griepenkerti_ in Valette 1907) to this list.

The above lists of Lower Cretaceous and Cenomanian echinoids is based entirely upon the literature; ie. Cotteau 1865, 1857-78, Lambert 1892, 1913, 1916, Valette 1907.

Although Holasteroids are present from Valanginian times onwards, North African Realm spatangoids exists from

Hauterivian to Aptian times, the latter are not replaced by European Realm spatangoids until the Albian. From Albian times onward there is no trace of the North African Realm forms.

TURONIAN TO CAMPANIAN SPATANGOIDS

THE VALLEY OF THE YONNE

The Upper Cretaceous of this region remains the best documented of all the Paris Basin, despite the fact that most of the work dates from the nineteenth century. At this time the chalk was well exposed in numerous small quarries, many of which have since been infilled, and those which remain are usually very much degraded and overgrown.

Hébert (1863, 1876), Lambert (1878, 1879, 1882, 1887, 1902), and Peron (1887) have contributed the more important works on the stratigraphy of this region. Lambert's lettered zones for the Turonian and Senonian provide the most detailed zonal system of all the Anglo-Paris Basin Chalk.

The exact correlation of this region with southern England is uncertain.

The Turonian strata were studied by Hébert (1876) and Lambert (1879). Their zonal systems, and a possible correlation with southern England, being shown on the next page.

THE TOURAINE - AQUITAINE "Epiaster" STOCK

Records of M. leskei (=M. breviporus in Hébert) from Zones A and B of Lambert, and the lower part of the Labiatus Bed of Hébert most probably refer to "Epiaster." Specimens

POSSIBLE CORRELATION OF THE TURONIAN OF THE YONNE WITH SOUTHERN ENGLAND

TURONIAN OF THE YONNE			SOUTHERN ENGLAND
HEBERT 1876	LAMBERT 1879		
Assise à Holaster planus	Assise à Micraster breviporus	E Holaster planus	Planus Zone
		D Holaster icaunensis	Planus Zone
		C Terebratulina gracilis	Lata Zone
Assise à Inoceramus labiatus	Assise à Inoceramus labiatus	B Echinoconus subrotundus	Labiatus Zone
		A Inoceramus labiatus	Labiatus Zone
		a Belemnites plenus	Plenus Subzone

from slightlynhigher horizons could be either "*Epiaster*" or *M. corbovis* of Lata Zone type. *M. sanctae-maurae* from Sainte-Maure appears from the type material (MHNP) and a specimen in the BM(NH) to be a small crushed "*Epiaster*." Material of this species from Couvrot, although part of the type series is a completely different form of spatangoid. It is the peculiar peristome of the Couvrot fragments which is figured by Gauthier (1887) in his reconstruction of a "*Micraster*."

M. leskei var. *joviniacensis* Lambert (in Lambert & Thiery 1924) from the Lata Zone of Joigny is obviously an "*Epiaster*."

M. micranthus Lambert (in Lambert & Thiery 1924 , the holotype being the specimen figured by Cotteau 1878, pl. 75, fig. 5) may well be a young "*Epiaster*."

MICRASTER CORBOVIS

I have seen no specimens of *M. corbovis* (neither Lata nor Planus Zone types) coming from the south-east of the Paris Basin. This name is used in the literature on this area, but it seems to apply to large inflated forms of *M. renati* from Zones E and F.

MICRASTER LESKEI

M. leskei is recorded (under the name *M. breviporus*) as being abundant in the Planus Zone (sensu Hébert) near Somery, and between Villecien and Villevallier (Hébert 1876). I have collected it from nodular chalk at Côte St. Jaques, Joigny.

MICRASTER RENATI

This species is characteristic of Zones E and F of Lambert.

I have examined three specimens of this species from Zone E in the Lambert Collection. They are labelled M. beonensis from Béon, M. normanniae from St. Julien, and M. tropidotus from Armeau. All the Zone E material has well developed fascioles. The subanal fasciole is inconsistantly developed in Zone F material. I have some 20 specimens of this form from Zone F at St. Julien-du-Sault.

MICRASTER DECIPIENS

This species seems to appear first in Zone G. I only have one specimen of M. decipiens from the Yonne, collected loose at the bottom of the cliff at Rosoy. This is a fairly advanced specimen of the species, but not the typical high Coniacian form. The flint mass from which it was collected would suggest that it comes from Zone G, thus indicating that Zone G is equivalent to the chalk between the Normanniae Horizon and typical M. decipiens beds at Dover. The species becomes less rare in Zone H, according to Lambert, but I have not examined any material from this horizon. At this level it should be the typical M. decipiens.

MICRASTER ANGLICUS

M. anglicus occurs much earlier in the Yonne than in southern England, Lambert giving its range (as M. senonensis) as Zones G to I (Lambert 1895). This species seems to have evolved from the M. renati stock in mid-Coniacian times. M. icaunensis Lambert 1895 is the name given to intermediate forms. M. anglicus does not range higher than the lower half of Lambert's Assise à M. coranguinum (= all the Santonian)

MICRASTER CORANGUINUM

Lambert (1878) ranges this species from Zones I to L. I have examined no specimens of M. coranguinum s.s. from the south-east of the Paris Basin. The specimen of M. coranguinum var. rostratus from St. Martin (Lambert Collection) is the typical Marsupites Zone form. Lambert gives the Zone as K (MS label), but, as he decided (Lambert 1902) that one could not distinguish between Zones K and L, it is reasonable to assume that the horizon may well be higher that the old Zone K.

MICRASTER FASTIGATUS

Raulin's record (1858) of M. cordatus from Chigny, a locality regarded as exposing Zone M (Lambert 1878), presumably refers to this species. Lambert (1878) disputes the occurance of Micrasters in this Zone.

MICRASTER GLYPHUS

This species is recorded from Zone N at Michery and the same horizon at Villethierry (Cotteau 1878).

MICRASTER BRONGNIARTI

Lambert (1879) records this species from Zones O and P. I have seen no specimens typical of this species from the Yonne.

MICRASTER SCHROEDERI

Stolley's species M. schroederi was not known in France until the work of Lambert (1901). This species is probably recorded under the names M. glyphus and M. brongniarti in the works on echinoids from the Yonne, during the last century. I have examined a typical specimen of M. schroederi from Zone O of St. Aignan (Lambert Collection).

CAMPANIAN MICRASTERS OF THE EPERNAY - REIMS REGION

Peron (1887) subdivides the Campanian in this region into three zones, namely M. fastigatus, M. glyphus and Magas pumilus. The two lower zones representing the Lower Campanian, and the upper one the lower part of the Upper Campanian. M. fastigatus and M. glyphus are restricted to their respective zones, and M. brongniarti typifies the brachiopod zone. I have examined a typical M. fastigatus from Muizon (Marne) from Zone M of Lambert (Lambert Coll.), and two specimens of juvenile M. glyphus from Montbré near Reims (Peron Collection no. 530). The latter specimens are labelled M. glyphus var. brongniarti.

PARIS

M. brongniarti was found in the Upper Campanian previously exposed at Meudon and Issey-les-Moulineaux which are now Paris suburbs. Specimens from these localities are the only ones which I have seen which are typical of the species. Lambert (1895) regards the horizon here as Zone P.

THE MICRASTER SEQUENCE IN THE SOUTH-EAST PARIS BASIN

Typical Chalk Rock type M. leskei from Joigny show that at this horizon this region yields an Anglo-Paris Basin fauna. It is doubtful whether M. corbovis occurs in this region. No typical high Planus Zone Micrasters, nor M. normanniae have been seen. Taking Lambert's stratigraphy at face value, these forms are replaced by the M. renati stock here. One can thus establish a Sub-Province of the Anglo-Paris Basin Province based on the distribution of this species. This Sub-Province is of limited duration, because it is invaded by *M. decipiens* in Zone G, and thus becomes part of the Anglo-Paris Basin Province proper once again. The main lineage Micrasters of the Upper Coniacian and the Santonian are typical Anglo-Paris Basin types. *M. anglicus*, evolving from *M. renati*, appears earlier here than in more northern regions of the Province.

The Santonian - Campanian boundary coincides with a major change in the *Micraster* fauna. All the Campanian forms are typical of the Northern Faunal Province, and thus show a southward extension of this Province in lowest Campanian times. *M. brongniarti* is a distinctive form derived from the *M. glyphus/schroederi* stock and one could erect another Sub-Province, this time of the Northern Faunal Province, on the distribution of this species. However, it is by no means certain that it occurs outside the Paris area.

EXTENT OF THE SOUTH-EAST PARIS BASIN SUB-PROVINCE OF UPPER TURONIAN AND LOWER CONIACIAN TIMES

The *Micraster* fauna of the Yonne region extends into the Aube and the Marne. The holotype of *M. renati* comes from Grange-au-Rez in the Aube. Although Cotteau (1865) described the fossil echinoids of the Aube, no Micrasters are figured and the descriptions are inadequate for any accurate interpretation.

According to Peron (1887) *M. renati* (recorded under various names) from the Craie de Vervins (=F Zone) is found in the Yonne, Aube, Marne, Aisne and as far as the Oise.

Lambert (1920b) states that his M. icaunensis of the Upper Turonian is found in the Yonne, Aube, Marne, Ardennes and Aisne.

NOTES ON THE STRATIGRAPHY OF THE TURONIAN AND SENONIAN CHALK IN THE SOUTH-EAST PARIS BASIN

Stratigraphical descriptions of the chalk in this region are of little use in the field because very few bed by bed sections are given.

The most problematical zones are those called Zones D to F by Lambert, and thus include the Turonian - Senonian boundary. The section at St. Julien-du-Sault is given by Hébert (1876) and discussed by Lambert (1878). This is the only locality at which both top and bottom of the Planus Zone (Zone E) are defined. The Planus Zone is always stated to be 10 metres thick. Following the works of Hébert and Lambert at St. Julien one concludes that it is here represented by 4 metres of chalk from which no fossils are recorded at this locality.

It would appear from the fauna of ammonites, gasteropods and sponges recorded by Lambert (1902) that the Chalk Rock is represented in his Zone D at the pit between Villencien and Villevallier.

The only Micrasters which I have examined from Zone E are virtually indistinguishable from those of Zone F. M. renati from these zones are probably equivalent to the advanced M. leskei and M. normanniae in the southern England - Normandy region.

Zone G is interpreted as being higher than the Normanniae Zone of Normandy, and Zone H as the horizon of typical *M. decipiens*.

Zone F yields Turonian ammonites according to Lambert (1902). Thus Lambert moved it down into the Turonian, having previously regarded it as the base of the Senonian. One would therefore suspect that the Turonian - Coniacian boundary in southern England should be drawn higher than the Top Rock.

In 1902 Lambert united certain zones together viz. I to J, K to L, O to P. The fact that this was necessary suggests that his original zonal system was theoretical rather than based on detailed field work.

From Mr. Peake's stratigraphical determinations of the *Echinocorys* which I have collected in this region one can say that :-

I) The lower half of our Coranguinum Zone outcrops in the cliff on the western side of the road south of Villenavotte.

II) The upper part of the Coranguinum Zone, or perhaps Uintacrinus Zone, outcrops in the cliffs immediately south of St. Martin.

III) The typical Uintacrinus Zone *Echinocorys* is found about 800 metres north of Villenavotte.

CHAPTER XIV CZECHOSLOVAKIA

I have only seen five specimens of Micraster from this country. They were collected, by Dr. Nekvasilova, from a grey marly limestone at Cizkowice near Lovosice. They are now in the collections of the Institue of Geological Sciences. Two of them (For 2361-2 appear to be the typical small M. leskei, and another (For 2360) the same species with certain "Epiaster" affinities. These specimens are thus comparable with the forms from the lower part of the Chalk Rock at Dover (beds I - J of Wood). The remaining two specimens (For 2358-9) are not directly comparable with specimens I have examined from the Anglo-Paris Basin. They are large forms with long and narrow paired petals.

The importance of this material is the fact that it shows the occurance of the typical Anglo-Paris Basin Micrasters outside England and France, in Chalk Rock times at least.

CHAPTER XV TOURAINE AND AQUITAINE (figs. 24 & 25)

INTRODUCTION

This section is based on the account given by de Grossouvre (1896-7). Touraine is sparated from the Paris Basin by the Axis of Merlerault. This was a prominent feature throughout the Jurassic, which was not submerged until Inflatum Zone times (Albian). Marine connections between Touraine and Aquitaine were established during the Upper Cenomanian, when sedimentation began in Aquitaine. The southern boundary of this region appears to coincide with a structural line, in that it follows the series of WNW-ESE trending faults which downthrow to the south along the valley of the Gironde.

The pre-Campanian sediments deposited in this region present a marked contrast with those of the Paris Basin. They indicate shallow water environments in an unstable area. The facies include marly chalk, sands, tuffeau, soft chalk often sandy or micaceous, quartz sands, hard limestones, glauconitic marl and nodular chalk. There is considerable lateral variation in facies, in both Touraine and Aquitaine.

Campanian strata, composed of marly chalk with nodular flints, offer great similarities with certain chalks of the Paris Basin.

ECHINOIDS

The rich Turonian echinoid fauna of this region includes many genera unknown, or represented only by rare individuals, in the Paris Basin, eg. Hemiaster, Periaster, Clypeolampas, Nucleolites, Catopygus, Pyrina, Cyphosoma, Goniopygus and Salenia.

THE TOURAINE - AQUITAINE "EPIASTER" STOCK

Many of the species of the so-called genera Epiaster, Periaster, Hemiaster and Micraster in this region show a great similarity in shape and ornamentation, being separated into their respective genera on the basis of fascioles. I have only examined the so-called Micrasters of this group (see Chapter on "Epiaster" in Part III), but future work may reduce all these thin tested and heeled spatangoids to one genus. Until this is done the nomenclature remains uncertain, and the trivial names in Part III may become junior synonyms.

In Cenomanian and Turonian times this group was much more widespread than in the Senonian. Cenomanian species (Epiaster distinctus, E. crassissimus)and E. varusensis) extended over most of France (Calvados, Seine Maritime, Aisne, Cher, Isère, Yonne, Sarthe, Charente Maritime, Maine-et-Loire, Deux Sevres, Orne and Var) and into Switzerland (Vaud). Hemiaster morrisii from southern England appears to belong to this stock.

In Turonian times the group spread into the Pyrenean region and is well represented in southern England.

Other than occurances mentioned in the chapter on southern England, I know of no Senonian representatives of this stock outside the Touraine and Aquitaine regions. In these latter regions the group continues into the Maastrichtian. It is its long stratigraphical range in Touraine and Aquitaine which leads to the name of the stock, but this must not be taken as implying that the stock originated in these regions.

MICRASTER DECIPIENS

The first true Micrasters to appear in Touraine come from the hard limestones (Bed A) at the base of the Craie de Villedieu. Lecointre (1957) states that these beds are of Lower Coniacian age. At Crocq de Marbot and Châteaudun de Grossouvre (1897) identifies specimens from this horizon as *M. decipiens*, those from Lavardin he calls *M.* cf. *decipiens*. Without doubt *M. turonensis*, which is abundant some metres higher in Bed C of the Craie de Villedieu (= Upper Coniacian - Lecointre 1957), evolved from *M. decipiens*. Presumably, the specimens from Bed A, of which I have seen no examples, are intermediary in form between the two species but closer to *M. decipiens*. The Bed A Micrasters show a southern migration of Micrasters from the Anglo-Paris Basin in Lower Coniacian times.

MICRASTER TURONENSIS

This species is stated to be very common in Bed C, a glauconitic marl, of the Craie de Villedieu. It is found no higher than this horizon in Touraine. Further north I have collected it from the chalk facies at Caudebec. The variety intermedius is found in the Santonian chalk at Elbeuf. The form described as M. rostratus by Bucaille (1883) from the Marsupites Zone of the Elbeuf region is probably another variety of this species. I have seen no specimens of this latter form.

In Aquitaine the species is recorded up to the top of the Santonian. Future work may show that the Santonian forms are varieties of the Coniacian species. This is the case in the specimens from the Elbeuf region and the variety coniaciensis (an unfortunate name for a Santonian form) from Cognac and Ile d'Oléron. De Grossouvre (1898) indicates that the Micrasters from N2 are not the typical M. turonensis by recording them as M. cf. turonensis.

MICRASTER REGULARIS

M. regularis is characteristic of the Lower Campanian and is found in a variety of facies. The specimens described by Lambert (1895) from Chaumont come from a horizon of "sandy chalk with flints" which de Grossouvre (1898) points out is not a true chalk, but a siliceous flour full of sponge spicules and other micro-organisms. The specimen which I have from Talvoisin comes from a slightly marly chalk with irregular flint nodules. The specimens from Aquitaine are preserved in fine grained massive flinty limestones.

The ancestor of _M. regularis_ remains problematical. The fact that it shows the same number of pores in the paired petals, and occupied the same geographical region as _M. turonensis_ and its varieties makes these latter the most likely ancestor.

MICRASTER GLYPHUS

The only Upper Campanian _Micraster_ from this region is that which was called _M. marginalis_ by Arnaud in 1888. Schlüter, to whom Arnaud sent a specimen from Caillau-Talmont, regarded it as distinct from his _M. glyphus_ (Zurcher & Arnaud 1888). I am unable to distinguish a specimen from the same locality, labelled _M. regularis_ (Lambert Coll. no. 1535), from _M. glyphus_. The Cotteau Collection contains specimens of typical _M. glyphus_ from Caillau, Talmont, Guillon (P31) and Royan. The Upper Campanian is only preserved in the Aquitaine Basin.

Thus in Upper Campanian times the Northern Faunal Province spread around the northern part of the Massif Central into the Touraine-Aquitaine Province.

CHAPTER XVI THE BOUNDARY BETWEEN THE TOURAINE-AQUITAINE PROVINCE AND THE ANGLO-PARIS BASIN PROVINCE (fig. 26)

Defining the Touraine-Aquitaine Province on the distribution of *M. turonensis* it is seen to extend northwards into the chalk facies of the Anglo-Paris Basin. I have collected *M. turonensis* at Caudebec-en-Caux, where thick (about 230 mms) and continuous bands of flint are present in the chalk. Bucaille (1883) describes the variety *intermedius* from chalk with similar flints at Elbeuf and Orival. This same type of flint occurs in the valley of the Eure north of Chartres. De Grossouvre (1892) records typical Touraine-Aquitaine Micrasters from the latter region (*M. intermedius* from Le Mousseau and *M. turonensis* from St. Prest). I have only been able to find indeterminate fragments of *Micraster*, from chalk with the same flints, at Jouy. Passing north along the Eure valley the thick zoned tabular flint bands disappear in the region of Maintenon, and are replaced by bands of flint nodules.

It would appear that the distribution of *M. turonensis* corresponds to the distribution of the thick and continuous beds of flint, and thus, in the absence of palaeontological evidence the latter could be used to define the boundary between the faunal provinces. Similar flints are typical of the Coniacian of Yorkshire, but the Micrasters here are characteristic of the Northern Faunal Province.

The Touraine-Aquitaine - Anglo-Paris Basin boundary, based on the flint facies, runs in a NW-SE direction from Maintenon to Dreux. At Tréon, SW of Dreux, the thick flint bands occur. At Les Osmeaux, NE of Dreux, bands of flint nodules occur, characteristic of the Anglo-Paris Basin Province. The flint facies boundary is most irregular. Typical Paris Basin flints are found at Evreux, but thick tabulars occur north of here at Louviers, where they are well exposed on the road to St. Etienne.

Thick flint beds also occur on the Normandy coast in Upper Coniacian and Santonian chalk. I have noted them as far north as Fécamp. However, in these coastal sections they are only occassionally developed within chalk dominated by bands of flint nodules typical of the Anglo-Paris Basin. All the Micrasters which I have from these sections are typical of the Anglo-Paris Basin Province.

Much more detailed collecting is needed to define this boundary on palaeontological evidence.

CHAPTER XVII THE PYRENEAN REGION

INTRODUCTION

The Cretaceous rocks of northern Spain are best developed along the margins of the Elbro Valley. Complete successions in any one area are rare except in the centres of complex basins. Rios (1961) recognises five such basins along the margins of the Elbro Valley showing great mobility of the areas of maximum sedimentation. Lower Cretaceous strata are restricted to these major basins. Albian beds show a greater uniformity of lithology, as do the Upper Cretaceous rocks, but great variations in thickness persist. The major basins discussed by Rios are :-

I Montsech area (region around Tremp)

II Cantabrian Trough (Bilbao-Santander)

III Demanda area

IV Maestrazgo area

V Montserrat

The numbers of these regions correspond to those on figure 1 of Rios (1961). The less well developed Oviedo Basin is described by Barrois (1879).

On the French side of the Pyrenees thick successions are developed in the Aude - Ariège region(the Petites Pyrénées and Corbières), the Haute Pyrénées and Landes.

When most of the works on the echinoids were published the stratigraphy of these areas was very poorly known. The classical echinologists such as Cotteau and Lambert relied upon other people to collect the fossils. The stratigraphical horizons asigned to these fossils appear to have been guessed in many cases. The recent work of Raabe (1966) is an exception to this, in that the material was collected bed by bed.

THE ECHINOIDS

APTIAN

The earliest spatangoids in the Pyrenean region are from rocks of Aptian age. They are all typical of the North African Realm.

Toxaster collegnoi is found near Barcelona, in the Aude, Ardèche, Castellon, Tarragona, Lleyda, and Aragon. It is indistinguishable from specimens from Syria, Judea and the Lebanon (Lambert 1902, 1927).

Enallaster oblongus is recorded from Barcelona, Castellon, Catalogne, Aragon, Teruel and Penedes (Lambert 1902, 1927, 1928). Barrois (1879) records it from the Neocomian of Santander and the Urgonian of the Oviedo Basin.

Pliotoxaster paquieri is described from Santander (Lambert 1919).

Epiaster priori is found in Catalogne (Lambert 1902).

As in more northern regions destined to become the European Realm, holasteroids are also found. Holaster prestensis is found in Castellon (Lambert 1928) and H. aptiensis in the province of Barcelona (Lambert 1902).

ALBIAN

The only Albian spatangoid recorded is Hemiaster minimus from Montiberri (Lleyda) (Lambert 1927). If the identification of this specimen is correct, it shows that the European Realm included this part of the Pyrenean region in Albian times.

CENOMANIAN

Heteraster delgadoi is regarded by Lambert (1902) as an Aptian species from Castellon and Portugal, Palestine and Syria. In 1922 Lambert regarded the same species as being typical of the Cenomanian, and extended its geographical range to include Catalogne, Santander and the Lebanon. In 1928 he restricted the species to the base of the Cenomanian (Zone of Placenticeras uhligi). This species is typical of the North African Realm.

The Cenomanian fauna (Epiaster dallonii, Hemiaster dallonii, H. incrassatus and H. aragonensis) from Sopeira (Aragon) described by Lambert (1910) is of European aspect. Three species of Holaster are known from single specimens from the same locality. The same fauna is found at Castarne near Tremp (Lambert 1927).

A species described by Lambert (1919) as Epiaster crassus comes from the basal beds at Cabo Menor (Santander). The stratigraphical horizon of this species is not certain, Lambert suggests that it may be from the Coniacian. The species appears, from the figures of Lambert, to be a North African Realm type from either Albian or Cenomanian beds.

The Hemiaster mancus from the Cenomanian of La Alta (Santander) (Lambert 1920) is a European Realm type.

The Periaster insolitus from Alhama de Aragon is assumed by Lambert (1927) to be of Cenomanian age. This species is typical of the North African Hemiaster stock.

Raabe (1966) described the irregular echinoids from the Cenomanian and Turonian of part of the Cantabrian Trough. He collected echinoids from six of seven numbered horizons. The Lower Cenomanian is represented by horizon I, the Upper Cenomanian by II - IV, and the Turonian by VI and VII.

The Lower Cenomanian yields essentially European Realm elements (*Holaster nodulosus*, *Hemiaster aragonensis* and *Epiaster dallonii*), but the four specimens refered by Raabe to *Hemiaster verneuli* show North African affinities. Raabe's *H. verneuli* is not the true Turonian species characteristic of Touraine and Aquitaine.

Horizon II is undoubtedly European. It yields *Holaster nodulosus* and *Hemiaster aragonensis*.

Horizon III yields *Hemiaster griepenkerli* and *Hemiaster* cf. *grossouvrei* according to Raabe, whose identifications are not reliable. It is difficult to decide to which Realm the figured specimens belong.

No clear picture of the distribution of the Faunal Realms in this region can be given for Cenomanian times. It is obvious from the remarks above that the situation is complex.

TURONIAN

Raabe's horizon VI yields a Turonian fauna typical of the Touraine - Aquitaine region. Raabe identifies the spatangoids as *Hemiaster gauthieri* and *Epiaster meridanensis*. The spatangoid from horizon VII is equally a Touraine - Aquitaine "*Epiaster*". It is most certainly not *Micraster leskei*.

Lambert records certain spatangoids from the Cenomanian of Santander (Epiaster meridanensis, 1919, Hemiaster mancus and Micraster michelini, 1920) which are all forms characteristic of the Touraine-Aquitaine "Epiaster" stock, and are more likely to be Turonian.

Periaster verneuili is another form typical of the Touraine-Aquitaine Province, which is found in the Aude at Soulatage and in Lot-et-Garonne at Fumal (Cotteau 1863).

MICRASTERS FROM THE SENONIAN

MICRASTER BREVIS

The individuality of the Pyrenean Province does not manifest itself until the appearance of M. brevis in the Upper Coniacian. This abundant and widespread species is obviously evolved from M. turonensis. The close relationship of the two species lead to their confussion by some authors (eg. Cotteau 1869).

The exact stratigraphical range of M. brevis is uncertain. The "marnes à Micraster " is a term used for the strata containing this species. These marls are divided into two zones, one on either side of the Coniacian/Santonian boundary. The upper of these zones is characterised by the appearance of Cyclaster and Cardiaster integer.

I have collected M. brevis, Cyclaster and Echinocorys near Contrasta. Mr. Peake regards the Echinocorys as coming from an horizon equivalent to the lower third of the Coranguinum Zone of southern England (?= Upper Coniacian).

The same echinoids were found at the quarry west of St. Martin, the Echinocorys from here being typical of the

Lower Santonian (determined by N.B.Peake).

There is some variation in the facies in which this species is found. At St. Martin it comes from alternations of grey and brownish marls, at the locality between Eulate and Larraona it is found in yellow-grey marly limestones which alternate with dark grey or brown marls. Alternations of grey and brown marls also outcrop at Sougraigne, from which I have collected M. brevis. At Pobla de Segur I have collected this species from over 25 metres of hard dark grey marly limestone. The morphology of the species does not change in this section despite some changes in lithology such as the disappearance of glauconite up the succession and the presence of a distinct burrowed sponge bed in,the lower part of the glauconitic marls.

The specimens which I have from the Tremp région (Pobla de Segur) appear to be slightly more advanced than those from the Alava-Navaronne region (Contrasta, San Vicente, St. Martin and Eulate-Larraona).

MICRASTER HEBERTI

There is little evidence as to the true horizon of this species. It is more advanced than M. brevis but not as much as M. aturicus. It is thus most likely to be high Santonian or low Campanian in age. M. heberti is relatively abundant at the few localities where it occurs. I have collected it from a pit at Sauvatierra (Spain), de Lacvivier (1877) records it as being extremely abundant at Foix (Ariège). Lambert (1919) records it from localities in Santander, under various names, and from Alhama de Aragon.

MICRASTER ANTIQUUS

I have only found this species in the marly limestones at Kilometre post 38 south of Arce (Spain). From the Echinocorys evidence Mr. Peake (in Rios & Hancock 1961) dates these rocks as the top of the Lower Campanian and perhaps the base of the Upper Campanian. Here M. antiquus and M. aturicus are found together, with intermediates predominating. I have found no specimens which resemble M. corcolumbarium, M. gourdoni or M. faasi at this locality, although these forms are recorded from this locality in Rios & Hancock. As M. aturicus is a typically Upper Campanian form, it is reasonable to assume that M. antiquus represents its Lower Campanian ancestor.

MICRASTER ATURICUS

This species first appears in the uppermost Lower Campanian, as at Arce, but the typical large form seems to be restricted to the Upper Campanian. Nicklès (Thesis quoted in Lambert 1895) records the species from the Maastrictian of Almacérès.

MICRASTER CORCOLUMBARIUM

M. corcolumbarium is most probably restricted to the Upper Campanian. It is widespread within the Pyrenean Province, being recorded from the Tercis region, Aragon, Alava, Catalogne and Lleyda.

MICRASTER GOURDONI

This species seems to be restricted to the Upper Campanian in the Montsech area.

THE OLD QUARRY AT TERCIS (see fig. 27)

Echinocorys is the most abundant fossil here. Mr. Peake has determined the stratigraphical horizons of the Echinocorys which I have collected here. These determinations are given on the sketch plan of the quarry on page . One sees that small M. aturicus occurs in the Gonioteuthis Zone. The Main Echinocorys Band with its fauna of large Inoceramus, Pectenoid lamellibranchs and sponges may well correlate with the exposures at Arce. The typical large M. aturicus is found only in the grey-green-blue marly limestones in the Upper Campanian. The two large specimens of this species in the Museum d'Histoire naturelle (Paris) labelled Tercis are seen from their matrices to have come from this horizon. Unfortunately the only specimen of M. corcolumbarium which I have was collected loose in this quarry.

THE SANTANDER REGION

The echinoids of this region were described by Lambert (1919 - 1922). Many specimens of Micraster from this area differ from those of the Pyrenean Province proper. The stratigraphical horizons given to these specimens by Lambert are in need of verification.

Lambert's M. michelini (1920) represents the occurance of the Touraine-Aquitaine "Epiaster" stock and is more likely to be Turonian than Cenomanian.

The typical Pyrenean form M. brevis is recorded as abundant in many localities under the name M. corbaricus.

This is presumably the earliest occurance of Micraster in the Santander Basin.

Lambert records M. icaunensis and M. gosseleti from Upper turonian horizons. These stratigraphical determinations are highly dubious. The specimen from Llencres (Lambert Coll.) recorded as the latter species bears no comparison with the form from the north of France, nor to any other Micrasters which I have seen. Its elongate flattened shape, etremely long narrow petals with numerous pores clearly distinguish it from all other Micrasters. Unfortunately I did not note any of the three specimens of M. icaunensis from Santander in the Lambert Collection. As a consequence of this identification Lambert had to regard them as Upper Turonian.

M. heberti, another form diagnostic of the Pyrenean Province, also occurs in the Santander region. Lambert regards it as Santonian and states that certain specimens (his M. proclivis) occur in the "marnes à Micraster". This stratigraphical attribution is extremely dubious. It is most likely that M. heberti represents an horizon higher than M. brevis .

Certain of Lambert's new species from Santander are distinct, namely M. coribericum, M. douvillei, M. mengaudi.

MICRASTER CORIBERICUM

This is the first non gibbose Micraster to appear in the Pyrenees. Its origin and stratigraphical horizon are uncertain. It may be a small form derived from the Anglo-Paris Basin M. coranguinum indicating a southward migration of this latter Province west of Touraine and Aquitaine. All of Lambert's specimens appear to be from the same horizon, they all show a matrix of dark grey micaceous marl. One specimen has the shape of _M. corcolumbarium_, indicating that _M. coribericum_ is probably the ancestor of the Upper Campanian form.

MICRASTER DOUVILLEI

This species is found at Santa Marina, but its horizon is uncertain. It is obvious from the manuscript labels in the Lambert Collection that some specimens of this species were recorded as _M. coranguinum_ var. _lata_ in Lambert 1920. I have not seen all Lambert's specimens which he recorded as _M. coranguinum_ from Santander, but it is highly improbable that this species occurs in the Pyrenean Province.

MICRASTER MENGAUDI

This distinctive species is stated to be Santonian by Lambert (1920). The arrangement of the plates in interambulacrum 1, and those in the apical system show that this must be a Campanian form, and most probably Upper Campanian.

None of the species _M. coribericum_, _M. douvillei_ and _M. mengaudi_ are known to me outside the Santander region.

THE GEOGRAPHICAL EXTENT OF THE PYRENEAN PROVINCE

The Pyrenean Province probably extended as far north as the Bordeaux region. Upper Cretaceous outcrops north of Tercis are restricted to a few poor sections in river valleys. _Micraster_ is recorded from such an outcrop at Villagrains, and is identified as _M. aturicus_ by Fallot (1893 quoted in de Grossouvre 1898).

Eastwards the Province includes the Beausset Basin of the Var in Coniacian/Santonian times, typical *M. brevis* occuring here. It must also have extended into the Bakony Moutains of Hungary at a similar time.

The Upper Cretaceous spatangoids of southern Spain are poorly known. Cisneros (1917) records two species of *Micraster* from Alicante, identifying them as *M. coranguinum* ? and *M. turonensis* ?. These identifications are indeed questionable. Mr. H. Gamble has kindly given me a *Micraster* which he collected from the Upper Cretaceous Senonian Sandstones of the Sub-Betic tectonic zone at Baie del Mascarat near Altea. The specimen is sufficiently well preserved to show that it is an intermediate between *M. antiquus* and *M. aturicus*, and thus it probably comes from the highest part of the Lower Campanian. This is the most southerly region from which I know of evidence of the Pyrenean Province.

CHAPTER XVIII THE RHONE VALLEY REGION

The oldest spatangoids of this region come from the Barremian of the Gard. Lambert (1904) records the following species :- Toxaster ricordeaui from Seynes, T. amplus from Sauve, Quissac and Herault à Montaulieu, T. retusus from Saturargues.

From the Aptian of Serviers Lambert (1904) records Miotoxaster collegnoi.

The above mentioned spatangoids are all typical of the North African Realm. All later spatangoids of this region are of European Realm type. The following comments on the Upper Cretaceous forms are based on information in de Grossouvre 1898.

The Cenomanian at Pont-Saint-Esprit yields Epiaster distinctus and Hemiaster bufo along with Holaster subglobosus.

Turonian forms from Saint-Paul-Trois-Châteaux, north of the Uchaux Basin (Hemiaster cf. gaudryi and Periaster cf. verneuili) show affinities with species typical of the Touraine - Aquitaine region. At the top of the succession at this locality Hemiaster leymeriei is found, a species also typical of Touraine and Aquitaine.

In the Basin of Dieulefit, south of the Forest of Saou, at Nyons, the ammonite rich Cenomanian marls are followed by a white limestone yielding Micraster decipiens and other echinoids in its upper part. If the Micraster is correctly identified this horizon must be Coniacian and not Upper Turonian as de Grossouvre would have it. It would also show a southern migration of the Anglo-Paris Basin Province Micrasters around the eastern side of the Massif Central.

The Grès Verdâtre of Dieulefit is stated to yield Hemiaster leymeriei and H. cf. fourneli. Both these forms are typical of Turonian horizons and are characteristic of Touraine and Aquitaine. It is difficult to understand how this horizon could be correlated with horizons higher than those yielding M. decipiens at Nyons (see de Grossouvre 1898, p. 491 and tab. XIXb).

CHAPTER XIX SOUTH-EAST FRANCE AND SWITZERLAND

These regions yield similar echinoid faunas throughout the Lower Cretaceous. For this reason these areas are dealt with together. Evidence of post Turonian echinoids is lacking in Switzerland. It would be unwise to assume that such forms, had they been preserved, would necessarily be the same as those from the Nice region.

The earliest echinoids present come from the VALANGINIAN. Echinospatangus granosus is recorded from the cantons of Vaud, Neuchâtel and Doubs (de Loriol 1873). Savin (1903) attributes the same species to the genus Toxaster and describes it from Monte Saleve (Haute Savoie). He also records T. kiliani and Holaster cordatus from Savoie. The latter species is described from Vaud and Doubs by de Loriol (1873). Savin (1902) records T. kiliani from the Alpes Maritime and the Bouche-du-Rhône.

In the HAUTERIVIAN Toxaster retusus is abundant in the Savoie (Savin 1903) and at Le Souhait (Demoly 1913). Echinospatangus ricordeanus is described from the Vaud, and Doubs, by de Loriol. E. cordiformis is found in the Hauterivian in most Cretaceous regions of Switzerland, and also in the Valanginian of the Vaud (de Loriol 1873). Holaster intermedius is found in several localities in Savoie (Savin 1903), and is widespread in Switzerland, where H. cordatus also occurs in Vaud and Neuchâtel (de Loriol 1873).

The BARREMIAN yields abundant Enallaster oblongus in the

Savoie, along with E. couloni and E. renevieri, especially in the Upper Barremian (Savin 1903, Demoly 1913). De Loriol did not recognise the Barremian in Switzerland.

The LOWER APTIAN yields Enallaster fittoni in Neuchâtel and Vaud. Heteraster oblongus and Echinospatangus collegnii are known from most parts of Switzerland, the former species being found in the Ain as well (de Loriol 1873).

From the UPPER APTIAN Echinospatangus collegnii is recorded from Vaud and Ain, and Holaster prestensis from these regions and Neuchâtel (de Loriol 1873).

The spatangoids of the Lower Cretaceous up to, and including the Aptian are all typical of the North African Realm. As in other ares destined to become part of the European Realm, holasteroids appear in the Valanginian.

In ALBIAN times there was a distinct change to a typically European spatangoid fauna. Holaster laevis, H. perezi, Hemiaster minimus, Epiaster distinctus, E. polygonus and E. ricordeaui are recorded as Albian species occuring throughout Switzerland, the Haute Savoie and Ain. This so-called Albian fauna is probably a remanié fauna in Cenomanian beds (personal communication J.D. Hollis). De Loriol's records of Epiaster polygonus and Hemiaster murchisonianus from the Upper Aptian are very dubious because these species are characteristic of the Albian.

Spatangoids are not recorded from CENOMANIAN beds, but typical European holasteroids (H. subglobosus and H. laevis) are widespread in Switzerland (de Loriol 1873).

MICRASTER LESKEI

This Turonian species is recorded by Peron (1902) from la Trinité Victor and Granges de Villars in the Nice region, and Cap Martin and the road from Menton to Requebrune further east. The forms from near Nice were identified as *M. normanniae* by Fallot (1882). I have not seen any of these specimens, but it would not be surprising to discover that many of them belong to the Touraine - Aquitaine "*Epiaster*" stock.

De Loriol (1873) figures a large *M. leskei*, under the name *M. breviporus*, from Ste. Croix in the Vaud.

MICRASTER BREVIS

This species is known from the Beausset area in the Var. It is recorded under the name *M. corbaricus* by Lambert (1895), and Middlemiss et. al. (1970). The latter authors state that the horizon is Coniacian. I have seen two typical specimens of this species from le Beausset in the Musée d'Histoire Naturelle, Paris.

MICRASTER MATHERONI

M. matheroni is recorded from le Beausset by Lambert (1895). The only specimen of this species which I have seen from le Beausset (Toucas Coll. MHNP) is too poorly preserved, and damaged by previous workers, to be identified. The species is also recorded from Rennes-les-Bains (Aude), but the only specimen labelled as such from this locality (Lambert Coll.) is indistinguishable from *M. brevis*.

MICRASTER CORDATUS

The name M. cordatus Sismonda 1843 is here provisionally used to cover the Coniacian Micrasters of the Nice region, which are derived from the Anglo-Paris Basin M. decipiens. Peron (1902) records the species, under the name M. decipiens, from Menton, Gando, Cantaron and la Trinité, and from the Châteauneuf - Contes area under the name M. arenatus Sismonda (non Agassiz). I have seen specimens of this "species" from the Ravin de Cantaron (Lambert Coll.), Contes and Menton (MHNP). That from Contes is labelled M. matheroni, and the horizon of the Menton specimen is stated to be Santonian. The Cotteau Collection contains two specimens with M. decipiens affinities labelled "Senonien Nice."

During the Coniacian the south-east of France shows an eastward extension of the Pyrenean Province into the Beausset Basin of the Var (M. brevis and M. matheroni being diagnostic of this Province). Regions north and east of the Var yield Micrasters showing strong affinities with the Anglo-Paris Basin Province M. decipiens, from which they are almost certainly derived.

SANTONIAN MICRASTERS

I have seen no typical Santonian Micrasters from the south-east of France. Peron (1902) records M. coranguinum from a locality near Font de Jarrier, and gibbose Micrasters from the Emscherian of an unnamed locality. I know of no evidence to support his statements. The fact that Peron regards plate XII figures 4 & 5 of Lambert 1896 (figures of a typical Campanian gibbose form) as representing an Emscherian species would suggest that he had misidentified the horizon of his own material.

MICRASTER SCHROEDERI

Crushed and fragmentary specimens of *M. schroederi* are found at la Pointière, Savoie (Savin 1903). A MS label of Lambert, accompanying the only specimen I have seen from this region, states that the horizon is his Zone P. The specimen could equally well have come from the Lower Campanian.

MICRASTER SISMONDAI & MICRASTER STOLLEYI

These species are found in the Upper Campanian near Nice. Lambert (1895) describes *M. sismondai* and *M. stolleyi* (as *M. gibbus*)from a locality called La Palarea. Peron (1902) writes as though this is the same locality as his Font -de - Jarrier near Blausasc. Peron refers to the two species as *M. gottschei* and *M. fastigatus* respectively. *M. sismondai* is obviously derived from the *M. glyphus* / *schroederi* stock.

The occurance of *M. sismondai*, *M. stolleyi* and *M. schroederi* in the south -east of France shows a southward migration of the Northern Faunal Province. The region was certainly within this Province in Upper Campanian times.

The lack of reliable evidence concerning Santonian and Lower Campanian Micrasters makes it impossible to assign this region to any particular province during these periods.

CHAPTER XX CORRELATION OF THE FAUNAL PROVINCES

INTRODUCTION

The Turonian and Senonian stages were established by d'Orbigny (1842) for the Upper Cretaceous around the towns of Tours and Sens respectively. These stages thus have their type sections in different faunal provinces.

Coquand (1857) subdivided the Senonian into Coniacian (Cognac), Santonian (in the Petite Champagne) and Campanian (the Aubeterre region). The type sections of these substages are therefore in a different faunal province from the type sections of d'Orbigny's major stage, but in the same province as the Cenomanian and Turonian type sections.

Many problems of correlation remain, despite de Grossouvre's work (1895-1901) based on ammonites.

The abundance of echinoids in the Upper Cretaceous of most regions makes them, potentially, a most valuable stratigraphical tool. However, bed by bed collections are required before any accurate correlation can be attempted.

TOURAINE - AQUITAINE PROVINCE

Jeffries (1962) work on the Plenus Subzone provides an excellent correlation of the basal Touronian throughout the Anglo-Paris Basin Province and into Touraine. Exact correlations of higher strata are lacking.

The "Epiaster" stock of this province is very widespread in Turonian times. The value of these echinoids for the purposes of exact correlation is limited by their very stable characters.

M. turonensis from bed C of the Craie de Villedieu (de Grossouvre 1897 = the lower part of bed 4 of the Zone of *Spondylus truncatus* of Triger in Cotteau & Triger 1869) hardly differs, other than in the development of the petals, from typical *M. decipiens* such as are found in beds 21 - 24 of Wood on the East Cliffs of Dover. This correlates the Upper Coniacian of the type region with that of the Anglo-Paris Basin Province.

Not having seen the Micrasters from bed A of the Craie de Villedieu (= Lower Coniacian) any comments upon them are dubious. However, the fact that they are called *M. decipiens* and *M. aff. decipiens* by de Grossouvre (1897) suggests that they are younger than the Lower Coniacian of southern England, and thus the Turonian - Coniacian boundary in southern England ought, perhaps, to be drawn above the Normanniae horizon.

PYRENEAN PROVINCE

M. brevis of the Pyrenean Province presents the same general features as *M. turonensis*, except for its more globose shape and the number of pores in the paired petals. Its range may be equivalent to that of typical *M. turonensis*, and therefore Upper Coniacian. This statement is not supported by the evidence of the *Echinocorys* and an ammonite which I have collected with typical *M. brevis*. These fossils show the relevant horizon to be Santonian.

NORTHERN FAUNAL PROVINCE (see fig. 28)

The use of the terms Turonian, Coniacian and Santonian in northern Germany does not correspond to their usage in England and France. The bottom and top of this series of stages does correspond to international usage. The Lower Turonian is represented by the Labiatus Zone (Schlüter had a Plenus Zone beneath this), and the Upper Santonian consists of the Zones of Uintacrinus and Marsupites. Correlation between these levels is most difficult.

The rich echinoid fauna of the Lamarcki Zone hardgrounds at Wüllen, yielding Holaster planus, appears to be the equivalent of our Planus Zone on Micraster evidence.

Early M. bucailli from the Vancouverensis Zone probably correspond to M. normanniae of the Anglo-Paris Basin.

M. cortestudinarium of the Deformis Zone of the Münster Basin show the same stage of development as is seen in M. decipiens of southern England, excepting the more gibbose shape and the number of pores in the paired petals. However, my Echinocorys from the Deformis Zone of Erwitte were determined by Mr. Peake as being typical Turonian forms.

M. coranguinum appears at the base of the Coniacian in northern Germany, and at the base of the Santonian in the Anglo-Paris Basin. These facts are difficult to reconcile. Equally, the occurance of very advanced M. coranguinum, comparable with those from the Uintacrinus Zone of southern England, in the Lower Middle Santonian at Lägerdorf is difficult to explain.

THE VALUE OF THE GENUS MICRASTER IN CORRELATING THE UPPER CRETACEOUS

Correlations of different faunal provinces based on the genus *Micraster* are most dubious. From the generalevolutionary stage reached by *M. decipiens*, *M. turonensis*, *M. brevis* and *M. cortestudinarium* one would expect them to be contemporary. This is not the case, as is shown above.

The correlation of the southern English chalk with that of north Germany shows that Micrasters evolved at a faster rate in the latter region. An alternative interpretation, that the Micrasters evolved at the same rate, seems impossible to accept due to the evidence of *Echinocorys*, *Uintacrinus* and *Marsupites*.

Micrasters also evolved a differing rates within the same faunal province. *M. bucailli* appears much earlier in the region south of Braunschweig than it does at Staffhorst.

These examples suffice to cast doubt on any correlations based soley on the genus *Micraster*.

Although the genus *Micraster* shows distinct provincial speciation, the genus *Echinocorys* does not. Echinocorys from all regions of the European Realm from which I have collected are readily assigned to their equivalent horizons in England by Mr. Peake.

CHAPTER XXI THE MIGRATION OF FAUNAL REALMS AND PROVINCES IN THE CRETACEOUS OF EUROPE (see Maps 1 - 3)

In Neocomian and Aptian times no European Realm spatangoids exist, and thus all regions are placed in the North African Realm.

In western Europe Neocomian spatangoids are only known from Yorkshire, the south-east of the Paris Basin and south east France.

Marine conditions and spatangoids became more widespread in Aptian times. The spatangoids of this stage are all of North African type. They occur in the same regions as the Neocomian spatangoids but also spread into southern England, the Bakony Mountains and the Pyrenees.

The Albian shows the appearance of European Realm spatangoids in all the regions mentioned above. However, North African Realm <u>Enallaster</u> continue into the Albian of southern England, but they are restricted to the greensand facies.

Cenomanian echinoids of the Anglo-Paris Basin are all distinctly European. In the Bakony Mountains and the Pyrenees one sees a mixing of forms from both Realms, and in the case of the Bakony Mountains a reversion to the North African Realm in the Upper Cenomanian. In the Bouche du Rhône European Realm spatangoids occur with <u>Heterodiadema</u> <u>libycum</u>, the latter being characteristic of the North African Realm.

The Bakony Mountains, the Pyrenees and the Buche du Rhône are thus interpreted as being near the boundary between the two Realms in Cenomanian times.

During the Turonian all of Europe north and west of the Alps appears to have been in the European Realm. During this stage one sees a wide distribution of the Touraine-Aquitaine "Epiaster" stock, and the appearance of the genus Micraster.

TURONIAN - SANTONIAN MICRASTERS OF THE NORTHERN FAUNAL PROVINCE

Problems of correlation make a synchronous appreciation most difficult. These problems are most accutely felt when dealing with the Northern Faunal Province. For this reason the Turonian to Santonian forms of this province are discussed in isolation. This treatment appears justified in view of the fact that this province has little effect on the rest of Europe during these stages. Correlation within the province is difficult, and the Micrasters are not homogeneous at any time.

M. borchardi from Wüllen and Ulceby is distinct from M. leskei and M. corbovis of the Anglo-Paris Basin. The same cannot be said of the Turonian forms from Poland, the Crimea and the Caucasus.

M. bucailli is found in Yorkshire, north Germany, the Caucasus and Crimea. Similar horizons in the Münster Basin and at Salder bei Saltzgitter yield M. cortestudinarium, a distinctive form occurs in Poland, and the form from the Koppet Dagh appears close to M. decipiens.

The Northern Faunal Province M. coranguinum cannot be distinguished with any certainty from the narrow form from the Anglo-Paris Basin other than on its stratigraphical occurance.

MICRASTER PROVINCES OF THE REST OF WESTERN EUROPE

Typical M. leskei is diagnostic of the Anglo-Paris Basin Province. Its occurance in Czechoslovakia shows an eastward extension of this Province in Chalk Rock times.

In Zones E and F of the South-East Paris Basin, a sub-province is developed typified by the presence of M. renati. Elsewhere in the Anglo-Paris Basin these horizons yield advanced M. leskei in the upper part of the Planus Zone, and M. normanniae in beds generally regarded as lower Coniacian.

Zone G of the South-East Paris Basin shows an invasion of M. decipiens from more northern regions of the Province.

The migration of M. decipiens into the Touraine - Aquitaine region (Bed A of the Craie de Villedieu) is probably of the same age as that into the South-East Paris Basin. In Touraine M. decipiens rapidly evolved into M. turonensis, the latter being typical of the Upper Coniacian and diagnostic of the Touraine - Aquitaine Province.

A continued southward spread of Micraster around the west of the Massif Central gave rise to M. brevis in the uppermost Coniacian of the Pyrenees. This established the Pyrenean Province. This Province extended eastward to include the Beausset Basin in the Var, and probably included the Bakony Mountains of Hungary.

This same southward migration gave rise to the *M. peini* stock of Algeria and Tunisia. The exact age at which *M. peini* first appears is uncertain. It is generally regarded as a Santonian form.

The Micrasters which result from this southward spread in Coniacian and Santonian times are most easily assigned to their respective provinces by the number of pores in the paired petals (see fig.). These are seen to increase in number passing southwards.

To the east of the Massif Central the *M. decipiens* stock migrated into the south-east of France giving rise to a variety of forms here lumped together and tentatively called *M. cordatus*. Specimens from this region show the same number of pores as specimens from the Anglo-Paris Basin.

Once established the Touraine - Aquitaine and Pyrenean Provinces propagate endemic species of *Micraster* in the Santonian.

The Lower Campanain shows a migration of the Northern Faunal Province into the south-east of the Paris Basin. This migration is presumably via the Mons Basin or over the Ardennes. The *M. schroederi* from the Savoie may also be of Lower Campanian age, and thus show an even greater spread at this time. Southern England, the Touraine - Aquitaine and Pyrenean Provinces maintained derivatives of their endemic stocks.

The Upper Campanian is a period of great expansion for the Northern Faunal Province. It invaded Aquitaine, presumably via Touraine, but the relevant strata are not preserved here. It is firmly established in the south-east of France, and a single specimen of a Northern Faunal Province *Micraster* is known from Tunisia. Geographical speciation of the main lineage Micrasters gave rise to *M. brongniarti* in the Paris region and *M. sismondai* around Nice. The latter species is found as far east as Djidde, Anatolia.

Southern England and the Pyrenean Province retained their respective stocks in the Upper Campanian.

INTERPRETATION OF THE FAUNAL PROVINCES

As was stated in Chapter II of Part I of this thesis, the faunal provinces are interpreted as reflecting distinct water masses. The migration of the faunal provinces thus shows movement of these water masses. Ursin (1960) points out that the constituents distinguishing present day water masses remain unknown.

There is one line of evidence to suggest that temperature is a contributing factor with regard to Upper Cretaceous water masses, although Ursin shows that temperature is of no great importance in North Sea water masses. *Echinocorys*, although showing the same shape variations from northern Europe to the Pyrenees, show an elongation of the pores in the apical region passing southwards. Mr. Peake interprets this fact as showing an increase in respiratory surfaces necessitated by the greater difficulty in extracting oxygen from warmer waters in the south. The same phenomenon is seen in *Holaster subglobosus* (Sorenyi 1955). The increase in the number of respiratory tube feet in Micrasters passing southward is easily explained in the same manner.

The southward movement of the faunal provinces, particularly in the Coniacian and Campanian, may thus reflect periods of cooling in which cooler water masses migrated southwards.

PROBLEMS IN RECONSTRUCTING THE DISTRIBUTION OF FAUNAL PROVINCES AND THEIR MIGRATION

East of the much worked sections extending from northern Spain to Germany, and south of the relatively undisturbed Cretaceous of the Northern Faunal Province, little is known of the echinoid faunas. The Bakony Mountains of Hungary are an exception to this. It is therefore difficult to trace the faunal provinces previously described in an easterly direction.

Another major problem with attempts to reconstruct the migration of faunal provinces is that some regions yield spatangoids from a limited number of horizons. Thus, although Serbia is within the North African Realm in Neocomian times, I know of no evidence to establish its position within the Upper Cretaceous distribution of provinces. Conversely, Anatolia is known to be in the European Realm during the Upper Cretaceous, but no Lower Cretaceous spatangoids are recorded from here.

To obtain a succession of faunas one is forced to move geographically along the strike of the beds, unless working on cliff sections. The possibility of changing faunal provinces in the process is ever present. In de Grossouvre's work on the Craie de Chartres (1892), whilst he may have been working up the succession from St. Prest to Soussay (although this is dubious), he passed from the Touraine - Aquitaine to the Anglo - Paris Basin Province in the process.

PART III

SYSTEMATIC SECTION

"To the student of Cretaceous palaeontology there could be suggested, probably, no more puzzling question than that of the determination of the species of the genus Micraster."

Meyer 1878

CHAPTER I THE GENUS *MICRASTER*

Genus *Micraster* Agassiz 1836

Spatangus (pars), Leske 1778, p. 221.

Micraster (pars) Agassiz 1836, p. 184.

Spatangus, Bayle 1878, pl. 156.

Pycnaster Pomel 1883, p. 42.

Plesiaster Pomel 1883, p. 42.

Micraster (*Gibbaster*) Gauthier 1887, p. 237.

Micraster (*Isomicraster*) Lambert 1901, p. 959.

Micraster (*Paramicraster*) Maczynska 1968, p. 154.

Epiaster (pars) auctorum

TYPE SPECIES *Micraster coranguinum* (Leske) 1778, designated by Pomel 1883, p. 42.

GENERIC DISCRIPTION

A brief diagnosis of this genus is made difficult by the numerous morphological trends (see chapter II of this part) to which it was prone.

Small to large sized spatangoids, typically with a thick test. Usually cordiform in shape, the anterior notch is variable in depth. Overall form very variable, it may be narrow and high, broad anf flat, globular or conical. The apical system consists of four genital plates, each bearing a genital pore, and five ocular plates. It is ethmophract ie. ocular plates I and V always touch each other and are never separated by the madreporite. The ambulacral petals are variable in depth and the degree of ornamentation. The paired petals usually show elongate pores in the outer rows and round pores in the inner rows, the pores of each pair being linked by a groove (conjugate condition). The pores of these petals nearest the apical system (usually 4 - 7 pairs) are all round and separated by a distinct granule or double granule. The pores of the unpaired petal usually show the latter condition throughout. In gibbose species of the genus the pores of the unpaired petal become like those of the paired petals. This is also seen in broad forms belonging to the main Micraster lineage. The plastron is of amphisternous type ie. the labral plate is followed by two large sternal plates. The labral plate may touch neither, one, or both of the sternal plates. Peristome transversely oval at a variable distance from the anterior border. The test is ornamented by tubercles and miliary granules. On the upper surfaces the tubercles are smaller and more widely spaced than on the lower surfaces. The plastron is ornamented with large tightly packed tubercles. The periplastronal areas vary from being covered with miliary granules to being covered with tubercles. Fascioles are often present, usually in the form of a subanal fasciole only. An additional incomplete peripetalous fasciole is developed in some North African and North American representatives of the genus.

STRATIGRAPHICAL RANGE Turonian to Lower Maastrichtian.

GEOGRAPHICAL DISTRIBUTION North and Central America (Gulf States of the U.S.A., Mexico and Cuba), ? Greenland, the British Isles, Belgium, France, Spain, Switzerland, Austria, Germany, Sweden, Denmark (Bornholm), Poland, Hungary, Ukraine, Caucasus, Crimea, Russian Platform, Koppet Dagh, Afghanistan, Madagascar, Tunisia, Algeria and Morocco.

SPECIES RESTRICTED TO THE NORTHERN FAUNAL PROVINCE

MICRASTER CF. BORCHARDI Hagenow 1853

? Micraster Borchardi Hagenow 1853

Micraster leskii, Quendstedt 1874, pl. 88, figs. 3 - 5,

? pl. 88, figs. 2 & 6.

NOTE The nomenclature of this species has not yet been unravelled. The name M. borchardi is used for convenience.

DESCRIPTION Variable in size (40 - 75 mms long). Large specimens have an inflated aspect. The smaller specimens resemble M. leskei greatly, but differ in having a thin test. Larger specimens resemble the Planus Zone M. corbovis of the Anglo-Paris Basin, but have a thick test. The apical system is situated more to the anterior than in Anglo-Paris Basin forms, but the finer details of ornamentation are as in M. leskei. The periproct is situated high on the posterior face (65 - 80 % of total height).

DISTRIBUTION Restricted to the Northern Faunal Province. In north Germany ranging from the Lamarcki to the Vancouverensis Zone. Known from Lincolnshire and north Germany.

MATERIAL EXAMINED 3 specimens from Ulceby, Lincs (C.J.Wood Coll) 23 specimens from the Lamarcki Zone at Wüllen (Author's Coll.).

MICRASTER BUCAILLI Parent 1892

Pl. 23, fig. D.

Micraster Bucailli Parent 1892, p. 15, pl. I, fig. 1a-c.

Micraster Bucaillei, Lambert 1895, p. 234.

? *Micraster cor testudinarium*, Wolleman 1902, p. 31.

Micraster praecursor, Wright & Wright 1942, p. 119.

Micraster cortestudinarium, Moskvin & Poslavskaia 1959, p. 280, text-fig. 93, pl. XIX, fig. 2, pl. XX, fig. 1.

HOLOTYPE Specimen figured by Parent from the "Craie à *M. cortestudinarium* et *Inoceramus involutus*" of Ennequin near Lille. Not seen.

DESCRIPTION Species of medium size (45 - 60 mms long), narrow form, characterised by its side profile which shows a relatively horizontal posterior upper surface, a steeply sloping anterior, and an inward sloping posterior face. The peristome is not far from the anterior border and is covered by a projecting labrum. The periproct is situated fairly high (about 64% of the total height). The Interporiferous zones of the paired petals are inflated to subdivided.

DISTRIBUTION Characteristic of the Northern Faunal Province. In north Germany it ranges from the upper part of the Vancouverensis Zone to the top of the Turonian. In Yorkshire and the Lille region it is regarded as Coniacian. Known from Yorkshire, north Germany (except the Münster Basin), Caucasus, Crimea, ? Ukraine, and as a rare southern migrant in the

Anglo-Paris Basin Province near Lille.

MATERIAL EXAMINED 13 specimens from the Cortestudinarium Zone of Yorkshire (8 from Little Weighton, 5 from north of Kiplingcotes, C.W. & E.V. Wright Coll.), 15 from Little Weigton, 1 from Kleine Flöthe and fragments from Dorstadt (Author's Coll.), specimens from the Braunschweig region (Ernst Coll.) and from the Staffhorst Mine-shaft (Spiegler Coll.).

MICRASTER CORTESTUDINARIUM (Goldfuss) 1826

Pl. 33, figs. A - C.

Spatangus gibbus, Goldfuss 1826, p. 146, pl. 48, fig. 4a-c.
Spatangus cor testudinarium Goldfuss 1826, p. 146, pl. 48, fig. 5a-c, e.
Spatangus Cor anguinum (pars), Goldfuss 1826, p. 147.
Epiaster brevis, Schlüter 1869, p. 240, pl. 2, figs. 2, 2a-c.
Micraster cortestudinarium (pars), Wright 1878, p. 335, pl. 76, fig. 1a-f.
Epiaster schlueteri Coquand 1880, p. 275.
Micraster cortestudinarium, Lambert 1895, p. 174.
Spatangus gibbus, Lambert 1895, p. 176.
Micraster brevis, Lambert 1895, p. 182.
Epiaster brevis, Arnold 1964a, p. 492.

HOLOTYPE Specimen figured by Goldfuss 1826, pl. 48, fig. 5a-c. According to Schlüter this specimen comes from Quedlinburg. Not seen.

DESCRIPTION Species of medium to large size (usually 50 - 65 mms long). Characterised by its very rounded gibbose shape. The peristome is far from the anterior border (about one sixth of the total length), and is just covered by the labrum. Periproct situated at about 55% of the total height. Interporiferous zones of the paired petals inflated to subdivided. Unpaired petal showing the same arrangement of pores as in the paired petals. Periplastronal areas finely granular, and with many tubercles. Subanal fasciole usually absent.

DISTRIBUTION Upper Turonian of northern Germany. It is very common along the eastern and southern borders of the Münster Basin, and at Salder bei Saltzgitter. Also known from Weddingen near Hannover (Wright 1878). Wolleman's record (1902) of this species (sub _M. brevis_) from the Luneburg region needs confirmation.

MATERIAL EXAMINED 69 specimens from Erwitte, 16 from Paderborn, 2 from Schlangen, 6 from Kohlstadt, 9 plus many incomplete specimens from Salder bei Saltzgitter (Author's Collection).

MICRASTER ROGALAE Nowak 1909

Micraster rogalae Nowak 1909a, p. 876, pl. 46, figs. 1, 2.
Micraster belgicus (pars) Lambert 1911, p. 5, pl. I, figs. 1-3.
Gibbaster belgicus, Smiser 1935, p. 83.
"Micraster" rogalae, Moskvin & Poslavskaia 1959, p. 288, textfig 104, pl. 24, fig. 4, pl. 25, figs. 1, 2.
Micraster rogalae, Ernst 1963a, p. 105, pl. 14, figs. 1a-d, 2.
Micraster rogalae, Pasternak et. al. 1968, p. 222, pl. 50, figs. 5, 6.

HOLOTYPE Specimen Ee 631 (Muzeum Ziemi), figured by Nowak from his Bed II at Halicz (now in Russia). MS label of Kongiel states that the horizon is Turonian, but it is more likely to be Santonian.

DESCRIPTION Species of medium to large size (up to 88 mms long). Flat form, usually broader than long, with a shallow anterior notch. Often slightly deformed due to the characteristically thinnish test. Peristome relatively far from the border (about one fifth of the total length), not quite covered by the labrum. Pores in the oral regions of the ambulacra are well develcped. Interporiferous zones of the paired petals are subdivided. Pores of the unpaired petal become elongate in the outer rows of the distal portion, the granules between the pores of one pair tending to disappear. Well developed subanal fasciole present.

DISTRIBUTION Belgium, SW Holstein, Lvov region, Ukraine and Mangüshlaka (Central Europe). In north Germany the species is restricted to the Middle and Upper Santonian.

MATERIAL EXAMINED The holotype (Muzeum Ziemi), the holotype (no. 9209) and paratype (no. 9210) of M. belgicus (Mus. ROy. Hist. Nat. Bruxelles), numerous specimens from the Middle and Upper Santonian of Lägerdorf (Ernst Coll.), 23 specimens, mainly fragmentary, from the Rogalae Zone of Breitenburg Quarry, Lägerdorf (Author's Coll.).

<u>MICRASTER</u> <u>SCHROEDERI</u> Stolley 1891

Pl. 5, figs. F-J, Pl. 32, fig. D, Pl. 35, fig. A.

? *Spatangus cuneatus* Hagenow 1840, p. 654, pl. IX, fig. 5a-b.

Micraster darupensis Schlüter MS

? *Micraster Brongniarti*, Cotteau 1874, p. 655

? *Micraster* sp. Cotteau 1874, p. 657.

Micraster coranguinum, Quendstedt 1874, p. 642, pl. 87, fig. 28 & 29.

Micraster Haasi Stolley 1891, p. 257, pl. 8, fig. 3a-f.

Micraster Schröderi Stolley 1891, p. 259, pl. 8, fig. 5 & 5a, pl. 9, fig. 1a-d.

Micraster Brongniarti var *pseudoglyphus* (pars), Lambert 1895, p. 199.

Micraster Schroderi, Lambert 1901, p. 968.

Micraster cor anguinum (pars), Wolleman 1902, p. 31.

Micraster coranguinum, Savin 1903, p. 25.

Micraster cf. *Schröderi*, Savin 1903, p. 26.

Micraster schroderi, Lambert 1911, pp. 7&12, pl. I, fig. 6.

Micraster brongniarti, Lambert 1911, p. 38.

Micraster coranguinum var. *schroederi*, Smiser 1935, p. 82.

Micraster brongniarti, Smiser 1935, p. 82.

? *Micraster* cf. *decipiens*, Sorenyi 1955, p. 255, pl. XXI, fig. 11&13

Micraster rostratus, Moskvin & Poslavskaia 1959, p. 282, textfig. 95, pl. XXI, fig. 1.

Micraster schroederi, Moskvin & Poslavskaia 1959, p. 282, textfig. 96, pl. XXI, fig. 2.

Micraster cf. _schroederi_, Pasternak et al 1968, pl. 50, fig. 7, p. 223.

_M._ (_Micraster_) _schroederi schroederi_, Maczynska 1968, p. 112, textpl. III,5, textpl. IV,1-8, pl. IV,1a-f, pl. V,1a-d.

HOLOTYPE Specimen figured by Stolley from the Quadratensenon of Lägerdorf, destroyed during the bombing of Hamburg 1943.

DESCRIPTION Small to medium sized species (30-50 mms long usually). Narrower and higher than its contemporary _M. glyphus_. Peristome close to the anterior border, about one tenth of the total length, and covered by a strongly projecting labrum. Periproct relatively high on the posterior face (60 - 70% of the total height. Interporiferous zones of the paired petals inflated to subdivided.

DISTRIBUTION Restricted to the Campanian of the Northern Faunal Province. Known from Norfolk, Belgium, north Germany, Poland, Ukraine, Caucasus, Krimea, Kopet Dagh, SE Paris Basin, and south east France.

MATERIAL EXAMINED For Norfolk, Belgian, German and Polish material see under _M. glyphus_. 1 specimen from St. Aignan, Zone O, 1 from Reims, Zone N, and 1 from La Pointière (south-east France) Zone P (Lambert Coll.), 2 from Teutonia Quarry, Hanover, 1 from Alsen Quarry, Lägerdorf, 1 from Catton, Norfolk, 4 from Wiktorowice, Poland (Author's Coll.).

MICRASTER GLYPHUS Schlüter 1869

Pl. 20, figs. D - E, Pl. 35, figs. B - C.

Spatangus Cor-testudinarium (pars) Goldfuss 1826, p. 146.

Spatangus Cor-anguinum (pars), Goldfuss 1826, p. 147.

Micraster glyphus Schlüter 1869, p. 235, pl. I, fig. 2, 2a, 2b.

Micraster glyphus, Cotteau 1874, p. 656, pl. XX, figs. 6-10.

Micraster glyphus, Cotteau 1878, p. 505, pl. 84, figs. 1-4.

Micraster Brongniarti, Cotteau 1878, p. 507, pl. 85, figs. 5,6.

Micraster glyphus, Gauthier 1887, p. 233, pl. 6, figs. 6,7.

Micraster glyphus, Lundgren 1888, p. 9.

Micraster marginalis Arnaud 1888, p. 28.

Micraster glyphus, Stolley 1891, p. 255, pl. 8, fig. 2a-c.

Micraster Gottschei Stolleyi 1891, p. 258, pl. 8, fig. 4a-f.

Micraster Brongniarti var. pseudoglyphus de Grossouvre in Lambert 1895, p. 199.

Micraster Brongniarti var. marginalis, Lambert 1895, p. 200.

Micraster glyphus, Lambert 1895, p. 209.

Micraster Schloenbachi Desor MS in Lambert 1895, p. 210.

Micraster marginalis, Lambert 1895, p. 228.

Micraster glyphus, Lambert 1901, p. 965.

Micraster glyphus, Wolleman 1902, p. 32, pl. VII, fig. 4a-e.

Micraster Schroderi, Valette 1907, p. 140.

Micraster brongniarti, Valette 1907, p. 141.

Micraster glyphus (pars), Giers 1964, p. 227.

Micraster (Micraster) coranguinum, Macsynska 1968, p. 108, textpl. II, 1-3, textpl. III, 1-4, pl. III, 1-3.

<u>M</u>. (<u>M</u>.) <u>glyphus</u>, Maczynska 1968, p. 118, textpl. VI, 4-7, textpl. VII, 1-8, pl. VIII,1a-3c, pl. IX, 1a-5, pl. X, 1a-d.

<u>M</u>. (<u>M</u>.) <u>brongniarti</u>, Maczynska 1968, p. 124, textpl. VIII, textpl. IX, 1-6, pl. XI, 1a-5e, pl. XII, 2a-4.

<u>M</u>. (<u>M</u>.) <u>bibicensis</u> Maczynska 1968, p. 129, textpl. XXI, 1-4, pl. XIII, 1a-4.

<u>Micraster</u> (<u>Paramicraster</u>) <u>cracoviensis</u> Maczynska 1968, p. 155, textpl. XXI, 1-4, pl. XXIV, 1a-e, pl. XXV, 1a-d.

<u>M</u>. (<u>P</u>.) <u>latior</u> Maczynska 1968, p. 158, textpl. XXII, 1 & 2, pl. XXVI, 1a-e, pl. XXVII, 1a-f, pl. XXVIII, 1a-b.

<u>M</u>. (<u>P</u>.) sp. Maczynska 1968, p. 160, textpl. XXII, 3-6, pl. XXVIII, 2a-c.

HOLOTYPE Specimen figured by Sclüter from the marls with "<u>Belem</u>. <u>mucronata</u> ..." of Coesfeld. Schlüter Collection, Bonn. Easily recognised because the sutures between the plates have been inked in, presumably by Schlüter for the benefit of his artist.

DESCRIPTION Medium to large sized species (55 - 100 mms long). Characteristically broad and flat with an angular ambitus, particularly in large specimens. Anterior notch deep. Peristome very close to the anterior border,covered by the labrum which projects such that it often just reaches the anterior notch. Periproct situated at about 55 - 60% of the total height. Posteroir paired petals often curved. Interporiferous zones of the paired petals are sutured to subdivided. Distally the pores of the unpaired petal become conjugate, those of the outer rows being elongate. Periplastronal areas of coarse granules. Well developed broad subanal fasciole.

DISTRIBUTION Restricted to the Northern Faunal Province. In northern Germany it ranges from the Senonensis Zone of the Lower Campanian to the Upper Vulgaris Subzone of the lower Upper Campanian. It is more typical of the Upper Campanian. It is found in Northern Ireland, Norfolk, Belgium, northern Germany, Scania (Sweden), Poland, south-east of the Paris Basin and Aquitaine. The single poorly preserved specimen of *M. gossaviensis* Lambert from the Gosau Formation of Austria is most probably a *M. glyphus*.

MATERIAL EXAMINED 1 specimen from Northern Ireland (Wood Coll.) numerous specimens from Norfolk (BM(NH), IGS, Norwich Castle Museum), numerous specimens from Belgium, Craie de Nouvelles and d'Obourg (Mus. Roy. Hist. Nat. Bruxells), abundant German material (Schlüter Coll., Ernst Coll., Munster University Coll.), Maczynskas collection of numerous specimens from the Cracow - Miechow region (Muzeum Ziemi, Warszawa), 7 specimens from the Köpinge Sandstone of Scania (Lund University and Naturhistoriska Riksmuseet, Stockholm), 6 from Montbré near Reims (Peron Coll.), single specimens from Guillon (P31), Cailland, Talmont and Royan, Aquitaine (Cotteau Coll.), 12 specimens from Poskwitow, 1 from Jezowka, 16 from Wiktorowice, Poland, 1 from Höver near Hanover, 1 from Harmignies, Belgium (Author's Coll.).

MICRASTER FASTIGATUS Gauthier 1887

Pl. 34, figs. A - C, Pl. 10, figs. A - F, Pl. 11, figs. G - I.

Micraster cordatus Agassiz 1840, p. 2.

Micraster cordatus , Agassiz & Desor 1847, p. 23.

Micraster gibbus, Desor 1858, p. 365.

Micraster fastigatus Gauthier 1887, p. 237, pl. VI, figs 1 - 5.

Micraster gibbus, Stolley 1892, p. 260, pl. IX, fig. 2 (inner drawing)

Micraster fastigatus, Lambert 1895, p. 227.

Gibbaster gibbus, Lambert & Jeannet 1928, p. 165.

Isomicraster gibbus, Moskvin & Poslavskaia 1959, p. 286, textfig. 101, pl. XXIII, fig. 2.

Micraster (Gibbaster) gibbus, Maczynska 1968, p. 132, textfig. XI, fig. 1-3, textpl. XII, 1-6, pl. XIV, 1a - 2d, pl. XV, 1a - e.

Micraster (Gibbaster) belgicus, Maczynska 1968, p. 136, textpl. XII, 7-9, textpl. XIII, 1 & 2, pl. XV, 2a-b, pl. XVI, 1a - 2e.

Micraster (Gibbaster) fastigatus, Maczynska 1968, p. 138, textpl. XIII, 3 & 4, textpl. XIV, 1 - 8, textpl. XVII, 1 - 5, pl. XVII, 1a - 2c, pl. XVIII, 1a - 3b, pl. XIX, 1a - 2.

HOLOTYPE Specimen from the Peron Collection figured by Gauthier 1887. From the lower part of the Quadrata Chalk, presumably of Reims. Not seen.

DESCRIPTION Gibbose species of variable size (up to about 60 mms long). Very similar to M. stolleyi from which it is distinguished with difficulty. The sloping sides are more rounded than in M. stolleyi, and the periproct is situated higher (35 - 55 % of the total height). Interporiferous zones of the paired petals are sutured to subdivided. The unpaired petal is like the paired ones. Plates 1a1 and 1a2 are sometimes widely separated. A subanal fasciole is usually present, though often incomplete and diffuse.

DISTRIBUTION Restricted to the Northern Faunal Province. In Germany it ranges up from the Lingula-Quadrata Zone. Due to the difficulty of distinguishing this species from M. stolleyi the trivial name of this stock is changed arbitrarily at the Lower / Upper Campanian boundary. Known from Norfolk (I. cf. faasi of Peake & Hancock 1970), northern Germany (except the Münster Basin), Poland, North Caucasus, Crimea, Koppet Dagh and the south-east of the Paris Basin.

MATERIAL EXAMINED 1 specimen from Muizon, Marne (Lambert Coll.), 22 from the top of the Lower Campanian at Höver near Hannover, 2 from Zerwana, Poland (Author's Coll.).

MICRASTER STOLLEYI Lambert 1901

Pl. 16, figs. A - E, Pl. 37, figs. A - C.

Epiaster gibbus, Schlüter 1869, p. 237, pl. 2, figs. 1, 1a-c.
Micraster gibbus, Quenstedt 1874, p. 648, pl. 88, fig. 1.
Epiaster gibbus (pars), Wright 1878, p. 267, pl. 63, fig. 1a-k.
Micraster (Gibbaster) gibbus (pars), Gauthier 1887, p. 235.
Micraster gibbus, Stolley 1892, p. 260, pl. 9, fig. 2 (outline);
Micraster gibbus (pars), Lambert 1895, p. 168.
Micraster senonensis (pars) Lambert 1895, p. 239.
Isomicraster Stolleyi Lambert 1901, p. 959.
Epiaster gibbus, Wolleman 1902, p. 33.
Micraster ciplyensis, Lambert 1911, p. 43, pl. II, fig. 16.
Isomicraster Brueti Lambert 1931, p. 101, pl. IV, figs. 8, 9.
Isomicraster stolleyi (pars), Smiser 1935, p. 82.
Isomicraster faasi, Moskvin & Poslavskaia 1959, p. 285, textfig. 100, pl. 23, fig. 1.

HOLOTYPE Specimen figured by Schlüter and stated by him to be from the Mucronata Chalk of Holtwick near Coesfeld. Cooke (1953) and Kermack (1954) state that it is from Lüneburg. Not seen.

DESCRIPTION Gibbose species of variable size (up to 70 mms long usually), with a distinctly conical shape and steeply sloping sides. The peristome is close to the anterior border (about one eighth of the total length away), and covered by a projecting labrum. The periproct is situated very low

(25 - 45 % of the total height). Interporiferous zones of the paired petals are sutured to inflated. Unpaired petal like the paired ones. Plates 1a1 and 1a2 often widely separated. Subanal fasciole usually absent.

DISTRIBUTION Restricted to the Northern Faunal Province. Known from Ireland, Norfolk, Belgium, north Germany, Poland, north Caucasus, Crimea, Nice region and Tunisia. Range Upper Campanian (in north Germany up to the "Langei" Zone).

MATERIAL EXAMINED Specimens from Meerdorf near Peine, Vordorf near Braunschweig - lower lower Upper Campanian (Ernst Coll.), numerous specimens from the Cracow region (Maczynska Coll.), 1 from the Craie d'Obourg at Obourg (Mus. Roy. Hist. Nat. Belge), 40 from the Mucronata Zone of Norfolk (I.G.S., B.M.(N.H.), Norwich Castle Museum), 1 from Northern Ireland (Wood Coll.), 1 from La Palarea (neotype of _M. gibbus_ sensu Lambert) holotype of _I. brueti_ (Lambert Coll.), 1 from La Palarea (M.H.N.P.), 41 from lower lower Uper Campanianof Teutonia Quarry, Misburg, 2 from Alsen Quarry, Lägerdorf, 2 from Jezowka, 2 from Gnatowice, 1 from Komorow, 1 from Wiktorowice, 3 from Rzerzusnia and 2 from Bibice, Poland (Author's Coll.).

<u>MICRASTER GIBBUS</u> (Lamarck) 1816

Pl. 20, figs. A - C, Pl. 38, figs A & B.

unnamed Bruguières 1791, pl. 156, figs. 4 - 6.

<u>Spatangus gibbus</u> Lamarck 1816, p. 33.

<u>Micraster stolleyi</u>, Lambert 1911, p. 9, p. 16, pl. II, figs 1-3.

HOLOTYPE Specimen figured by Bruguières. Locality of origin and present location unknown. Not seen.

NOTE Lambert's interpretation (1895 & 96) of the Bruguières figures as representing a specimen from Nice is rejected along with his neotype (figured 1896).

DESCRIPTION Gibbose species similar to <u>M. stolleyi</u>. It differs from <u>M. stolleyi</u> in having the peristome far from the anterior border, a less projecting peristome and much better developed oral pores.

DISTRIBUTION Known from the Craie d'Obourg at Harmignies, Belgium.

MATERIAL EXAMINED 12 specimens from the Craie d'Obourg at Harmignies (Mus. Roy. Hist. Nat. Belge).

<u>MICRASTER GRIMMENSIS</u> Nietsch 1921

Pl. 9, figs. A - E, Pl. 33, fig. D.

<u>Micraster grimmensis</u> Nietsch 1921, p. 20, pl. 10, figs. 8,9.
<u>Micraster grimmensis</u>, Moskvin & Poslavskaia 1959, p. 284, textfig. 99, pl. 22, fig. 4.

HOLOTYPE Specimen figured by Nietsch from the Upper Campanian of Grimme near Löcknitz. Not seen.

DESCRIPTION Small species, 30 - 35 mms long. The individual plates of the test have a marked tendency to bulge outwards. Characterised by its heart-shape, and gibbose-like side profile. Peristome marginal, covered by the labrum which projects into the anterior notch. Periproct low. Paired petals show sutured to inflated interporiferous zones. Outer rows of pores in the unpaired petal becoming elongate, the granule between the pores of a single pair becoming much reduced. Labral plate sparated from the sternal plates by the posterior paired ambulacra. Viewed from above it looks like a very small <u>M. glyphus</u>, from which it was probably derived.

DISTRIBUTION Upper part of the Upper Campanian of the Kopet Dagh, northern Caucasus and Pommerania.

MATERIAL EXAMINED Specimen Ee 641 (Muzeum Ziemi, Warszawa) from Wolsu, USSR, collected and determined by Moskvin 1964.

MICRASTER CORAVIUM Poslavskaia 1959

Pl. 9, figs. F - J, Pl. 36, fig. C.

Micraster coravium Poslavskaia in Moskvin & Poslavskaia 1959, p. 283, textfig. 97, pl. 22, figs. 1,2.

? Micraster brongniarti, Moskvin & Poslavskaia 1959, p. 284, textfig. 98, pl. 22, fig. 3.

"Isomicraster" ciplyensis, Moskvin & Poslavskaia 1959, p. 289, pl. 25, fig. 5.

NON Ananchytes coravium Grateloup 1836

HOLOTYPE Not seen. Specimen figured by Moskvin & Poslavskaia pl. 22, fig. 1, from the upper part of the Lower Campanian, no exact locality given.

DESCRIPTION Species of small size, about 38 mms long. Characterised by its somewhat gibbose side profile. The peristome is marginal and covered by the labrum which projects into the anterior notch. Labral plate long and thin. Periproct situated at about 56% of the total height. Interporiferous zones of the paired petals subdivided. Periplastronal areas coarsely granular with a few scattered tubercles. Well developed subanal fasciole. Plates 1a1 and 1a2 widely separated by 1b1.

DISTRIBUTION Upper part of the Lower Campanian of the Kopet Dagh and the northern Caucasus.

MATERIAL EXAMINED Specimen Ee 640 (Muzeum Ziemi, Warszawa) from the Lower Campanian of Maly Belchen, USSR, collected and determined by Moskvin & Poslavskaia 1960.

MICRASTER BRONGNIARTI Hébert 1856

Pl. 15, figs. A - E, Pl. 32, fig. A.

Spatangus coranguinum, Brongniart & Cuvier 1822, p. 388, pl. IV, fig. 11.

Micraster cor-anguinum (pars), d'Orbigny 1853, p. 207.

Micraster Brongniarti Hébert 1856, pl. 29, fig. 14.

Micraster Brongniarti, Desor 1858, p. 365.

Micraster Brongniarti (pars), Lambert 1895, p. 199.

HOLOTYPE Specimen figured by Hébert from the chalk of Meudon. I strongly suspect that it is the specimen figured here.

DESCRIPTION Species of medium size, about 53 mms long. Narrow and high heart-shaped form with a very steep anterior slope and deep anterior notch. Peristome almost marginal, covered by the projecting labrum. Periproct high on the posterior face. Interporiferous zones of the paired petals strongly sutured to divided. The posterior paired petals are almost as long as the anterior pair, 11.8 and 13.9 mms respectively in a specimen 53.4 mms long. Periplastronal areas granular with scattered tubercles. Well developed subanal fasciole. Plates 1a1 and 1a2 appear to be widely separated by 1b1.

DISTRIBUTION Upper Campanian of the Paris region. Zone P according to Lambert 1895.

MATERIAL EXAMINED One specimen from Meudon and one from Issy-les-Moulineaux (MHNP), one from Meudon (BM(NH)). Both localities are now in the south-west suburbs of Paris.

MICRASTER SISMONDAI Lambert 1895

Pl. 18, figs. A - E, Pl. 42, figs. A - C.

Micraster glyphus (pars), Cotteau 1874, p. 656.
Micraster glyphus var. of..., Gauthier 1887, p. 234.
Micraster Brongniarti var. Sismondae Lambert 1895, p. 200.
Micraster glyphus var. Sismondai, Lambert in Lambert & Charles 1937, p. 394.

HOLOTYPE Specimen in the box labelled as such in the Lambert Collection, from the Upper Campanian of La Palarea, Nice.

DESCRIPTION Moderate sized species, 49 - 57 mms long. Characterised by its high carina, steep anterior slope, and almost vertical posterior face in side profile. The peristome is marginal, covered by a labrum projecting into the anterior groove such that it is visible from above. Periproct high on the posterior face, 63 - 67 % of the total height. Interporiferous zones of the paired petals sutured to subdivided. In the holotype only the pores of the unpaired petal appear oval in the inner rows and oblong in the outer rows, granules between them being absent save in the apical portion. This arrangement may well be due to weathering. Periplastronal areas coarsely granular. Well developed fasciole around the double subanal bulges. Plates 1a1 and 1a2 widely separated by 1b1.

DISTRIBUTION Upper Campanian of La Palarea near Nice and Djidde, Anatolia.

MATERIAL EXAMINED Two specimens from La Palarea, one being the holotype, 1 specimen from Djidde (Lambert Coll.).

SPECIES COMMON TO THE NORTHERN FAUNAL PROVINCE
AND THE ANGLO - PARIS BASIN PROVINCE.

MICRASTER LESKEI Desmoulins 1837
Pl. 26, figs. a - c.

Spatangus Cor Anguinum ( ) Norvagicum (pars) Klein 1754
Pl. 12, fig. G.

Spatangus Cor Anguinum, var. 3, Norvagicum (pars) Leske 1778,
p. 225, pl. 23, figs.e, f.

Micraster Leskei Desmoulins 1837, p. 392.

Micraster breviporus Agassiz 1840, p. 2.

Micraster breviporus, Agassiz & Desor 1847, p. 24.

Micraster cor-anguinum (pars), Forbes 1850a, pl. 10, fig. 9.

Micraster Leskei (pars), d'Orbigny 1853, p. 215, pl. 869, fig 1-8

Micraster Leskei, Desor 1858, p. 366.

Micraster breviporus, de Loriol 1873, p. 369, pl. 31, fig.5a-d.

Micraster breviporus, Wright 1878, p. 278, pl. 62a, fig. 3a-b.

Micraster breviporus var. de la Craie à Cornus Cayeux 1890,
p. 136, pl. 3, fig. 1.

Micraster Leskei, Lambert 1895, p. 178.

Micraster breviporus, Lambert 1895, p. 178.

Micraster breviporus (pars) Lambert 1895, p. 204.

Micraster leskei, Smiser 1935, p. 80, pl. 7, fig. 3.

Micraster leskei, Cayeux 1966, p. 38, pl. 2, fig. 12a-d.

HOLOTYPE Internal flint mould figured by Klein of unknown origin. Klein Collection is lost.

DESCRIPTION The typical form is small (up to 50 mms long). It is relatively narrow, with a shallow anterior notch. The peristome is far from the anterior border (a third to a quarter of the total length), with a poorly developed labrum. The periproct is relatively high on the posterior face; Interporiferous zones of the paired petals are usually sutured. The periplastronal areas are very finely granular.

DISTRIBUTION The typical small form is restricted to the Chalk Rock and equivalent horizons of the Planus Zone in the Anglo-Paris Basin Province. Higher horizons of the Planus Zone in the Anglo-Paris Basin (except the south-east region) yield a variety of shapes and sizes of Micrasters here called "large _leskei_". The latter include the Planus Zone _M. praecursor_ of Rowe (1899). Known throughout the Anglo-Paris Basin and from Czechoslovakia.

MATERIAL COLLECTED 13 specimens from Underwood Hall, Cambridgeshire, 1 from White Nothe, Dorset, 6 from the Chalk Rock at Kensworth, Herts, 4 from St. Margaret's Bay, 2 from Loos, Lille, 4 from Etretat, 4 from Les Andelys, 2 from Puys (east), 3 from Jeigny, Yonne.

MICRASTER CORBOVIS Forbes 1850

Pl. 23, fig. E.

Micraster cor-bovis Forbes in Dixon 1850, p. 342, pl. 24, figs. 3 & 4.

Micraster Cor-bovis, Desor 1858, p. 367.

Micraster cor-bovis, Wright 1878, p. 276, pl. 62A, figs. 1,2a-d.

Micraster corbovis (pars), Lambert 1895, p. 194.

Micraster corbovis (pars), Lambert 1901, p. 962.

Micraster Leskei, Kongiel 1936, p. 6, pl. II, fig. 5a-b.

Micraster subglobosus Poslavskaia in Moskvin & Poslavskaia 1959, p. 280, textfig. 92, pl. XIX, fig. 1.

"Micraster" corbovis, Moskvin & Poslavskaia 1959, p. 286; textfig. 102, pl. XXIV, fig. 1.

Micraster corbovis, Cayeux 1967, p. 39, pl. 4, fig. 13.

Micraster corbovis, Pasternak et. al. 1968, p. 217, textfig. 46, pl. 48, figs. 4 - 6.

HOLOTYPE Specimen figured by Forbes in Dixon from Sussex. Dixon Collection B.M.(N.H.) E 30156.

THE PLANUS ZONE FORM is that represented by the holotype. This is of large size (up to 80 mms long) and of inflated aspect. Characterised by the very thin test. The mouth is far from the anterior border, surrounded by a smooth rim. The paired petals are short and deeply excavated, their interporiferous zones are smooth. The periplastronal areas are also smooth.

THE LATA ZONE FORM is usually much smaller (up to 35 mms long) than the Planus Zone form. It tapers markedly toward the posterior and is characterised by a sloping posterior upper surface when seen in side profile. The detailed ornamentation is the same as that of the Planus Zone form. The Lata Zone form ranges up into the basal Planus Zone.

DISTRIBUTION The Anglo-Paris Basin and Northern Faunal Provinces. The descriptions above are based on Anglo-Paris Basin specimens. Not known to me from the south-east of the Anglo-Paris Basin.

MATERIAL EXAMINED

LATA ZONE FORM 5 specimens from East Cliffs, Dover (C.J.Wood Coll.); 1 from Senneville (Author's Coll.).

PLANUS ZONE FORM The holotype and other stratigraphically poorly localised material in the B.M.(N.H.).

<u>MICRASTER</u> <u>CORANGUINUM</u> (Leske) 1778

Pl. 1, figs. A-C, pl. 11, figs. D-F, Pl. 30, figs. A-C,

Pl. 37, fig. D.

<u>Encephaloides</u> Plott 1676, p. 92, pl. 2, fig. 11, pl. 7, fig. 9.

<u>Echinus</u> <u>praeter</u> <u>radios</u> Lister 1678, p. 224, pl. 7, fig. 28.

<u>Echinites</u> <u>cordatus</u> <u>vulgaris</u> Luidii 1699, p. 47, pl. 12, fig.964.

<u>Spatangus</u> <u>Cor</u> <u>Anguinum</u> ( ) <u>Anglicum</u> Klein 1734. p. 100,
pl. XII, fig. E of the 1754 edition.

" " " ( ) <u>Norvagicum</u> (pars) Klein 1734. p. 102,
pl. XII, fig. C,D of 1754 ed..

<u>Spatangus</u> <u>Cor</u> <u>Anguinum</u> Var. a <u>Anglicum</u> Leske 1778, p. 221,
pl. XXIII, fig. C,D.

" " " Var. 3 <u>Norvagicum</u> Leske 1778, p. 225,
pl. XXIII, fig. A, B.

Not named Bruguières 1791, pl. 155, figs. 4, 5, 76.

<u>Spatangus</u> <u>cormarinum</u> Parkinson 1811, vol. III, p. 28, pl. III,
fig. 11.

<u>Spatangus</u> <u>cor</u> <u>anguinum</u> (pars), Lamarck 1816, p. 32.

<u>Spatangus</u> <u>punctatus</u> Lamarck 1816, p. 32.

<u>Micraster</u> <u>Cor</u> <u>anguinum</u>, Agassiz 1836, p. 184.

<u>Micraster</u> <u>cor-anguinum</u> (pars), Agassiz & Desor 1847, p. 23.

<u>Micraster</u> <u>cor-anguinum</u> (pars), Forbes 1850, pl. 10, figs. 1-7.

<u>Micraster</u> <u>cor-anguinum</u> (pars), d'Orbigny 1853, p. 207.

<u>Micraster</u> <u>Cor-anguinum</u> (pars), Desor 1858, p. 364.

<u>Micraster</u> <u>cor-anguinum</u> (pars), Cotteau & Triger 1869, p. 326,
pl. LV, figs. 5-10.

<u>Micraster</u> <u>cor</u> <u>anguinum</u>, Loven 1875, pl. 33.

Micraster coranguinum, Cotteau 1878, p. 501, pl. 83, figs. 4,5.

Micraster cor-anguinum (pars), Wright 1878, p. 271, pl. LXII.

Micraster cor anguinum, Gauthier 1887, p. 232.

Micraster coranguinum (pars), Lambert 1895, p. 163.

Micraster cor-anguinum, Rowe 1899, p. 538.

Micraster coranguinum, Lambert 1901, p. 961.

Micraster cor anguinum (pars), Wolleman 1902, p. 31.

Micraster coranguinum, Valette 1907, p. 138.

Micraster coranguinum, Lambert 1911, p. 7.

Micraster coranguinum, Moskvin & Poslavskaia 1959, p. 281, textfig; 94, pl. XX, fig. 2.

Micraster coranguinum, Pasternak et al 1968, p. 221, textfig.49, pl. L, figs. 1-4.

HOLOTYPE Specimen figured by Klein as form alpha Anglicum, the Kleinian types are all lost (Peake & Melville 1970). By tradition the type locality is taken as the Gravesend pits (Lambert 1895), and thus the upper part of the Coranguinum Zone.

DESCRIPTION Species of medium to large size (50 - 70 mms long usually, but may be up to 90 mms). Variable in form from narrow and high to broad and flat. Anterior notch fairly deep, peristome close to the border, about one eighth of the total length, and covered with a projecting labrum. Periproct situated at about two thirds of the total height. Interporiferous zones of the paired petals usually divided, sometimes subdivided. Periplastronal areas coarsely granular usually.

DISTRIBUTION Santonian of the Anglo-Paris Basin. Lower Coniacian to Middle Santonian of northern Germany, and similar ranges in other Northern Faunal Province regions. The species is restricted to the Northern Faunal Province and the Anglo-Paris Basin Province.

COMMENTS It may well be shown in future that certain of the numerous variations of this species of of stratigraphical significance. The form which I have collected from the highest beds of the Coranguinum Zone and Uintacrinus Zone in the Anglo-Paris Basin appears distinctive. This is the form figured by Forbes 1850, with a distinctly arcuate carina and almost superficial petals. The periplastronal areas tend to become ornamented with small discrete granules, especially in the Uintacrinus Zone, as opposed to the coarse granules of lower horizons.

Broad flattish forms occur throughout the Coranguinum Zone and in the Barrois Sponge Bed. A specimen which I collected from this latter horizon is indistinguishable from _M. rogalae_ which I have from Lägerdorf. _M. rogalae_ and _M. coranguinum_ do not interbreed at Lägerdorf. In southern England there appears to be every intermediate between the narrow and high and the broad flat form represented in museum collections. This apparent continuum of forms may disappear when bed by bed collections are made.

SPECIES AND VARIETIES RESTRICTED TO THE
ANGLO - PARIS BASIN PROVINCE.

MICRASTER NORMANNIAE Bucaille 1883

Pl. 19, figs. A - E, Pl. 31, figs. A - B.

Micraster Normanniae Bucaille 1883, p. 29, pl. 6, figs. 1 - 7.

Micraster Normanniae, Lambert 1895, p. 221.

Micraster normanniae, Cayeux 1967, p. 35, pl. III, fig. 8a-c.

HOLOTYPE Specimen figured by Bucaille from the Lower Senonian, in the beds in contact with the Upper Turonian, of the Seine - Maritime. Exact locality not stated. Not seen.

DESCRIPTION Small to medium sized species (30 - 55 mms long). Maximum breadth close to the anterior, giving a wedge shaped appearance when viewed from above. Characteristically flat and low. Shallow anterior notch. Peristome far from the anterior border (about one fifth of the total length, with a poorly projecting labrum. Periproct high on the posterior face. Paired petals appear relatively short for the size of the individuals. Interporiferous zones of the paired petals usually inflated but may be sutured. Periplastronal areas finely granular.

DISTRIBUTION Restricted to the basal Coniacian (= Normanniae Zone of Cayeux 1967) of southern England and north-west France.

MATERIAL EXAMINED 3 specimens from East Cliffs, Dover (Wood Coll.), 1 from Hampshire (IGS), 1 from Setques (Pas-de-Calais) and 1 from Neuchâtel (Seine-Maritime) (de Grossouvre Coll.), 1 from Etaples collected and determined by Bucaille (Lambert Coll.), 9 from Etretat (Author's Coll.).

MICRASTER DECIPIENS (Bayle) 1878

Pl. 3, figs. A - F, Pl. 12, figs. A - C.

Micraster cor-testudinarium, Agassiz 1840, p. 2.

Micraster cor-anguinum (pars), Agassiz & Desor 1847, p. 23.

Micraster cor-anguinum var. lata Agassiz & Desor 1847, p. 23.

Micraster cor-anguinum (pars), Forbes 1850, pl. 10, fig. 10.

Micraster cor-anguinum (pars), d'Orbigny 1853, p. 207.

Micraster Cor-anguinum (pars), Desor 1858, p. 364.

Micraster cortestudinarium (pars), Cotteau 1878, p. 498.

Micraster cor-testudinarium (pars), Wright 1878, p. 335, pl. 76, fig. 2a-e.

Spatangus decipiens Bayle 1878, pl. 156, figs. 1,2.

Micraster decipiens, Lambert 1895, p. 217 (pars).

Micraster decipiens (pars), Valette 1907, p. 179.

Micraster decipiens, Cayeux 1967, p. 30, pl. II, fig; 7, 7B pl. III, fig. 7C.

HOLOTYPE Specimen figured by Bayle from the white chalk of Fécamp. Not seen.

NOMENCLATURE This species is usually called M. cortestudinarium by English workers.

DESCRIPTION Species of moderate to large size (50 - 70 mms long), with a very rounded outline when viewed from above or below. Somewhat inflated, when viewed in profile the upper surface is rather symmetrically arched. Peristome not very close to the anterior border, usually a little less than one fifth of the total length, and not completely covered by the labrum. Periproct relatively low. Interporiferous zones of the paired petals usually subdivided.

The above is a short description of the typical form figured by Bayle, which is characteristic of the upper part of the Decipiens Zone. Earlier forms tend to be narrower and slightly wedge shaped, and are found as low as the upper part of the Normanniae Zone of Cayeux.

DISTRIBUTION Restricted to the Coniacian of the Anglo-Paris Basin Province.

MATERIAL EXAMINED 1 specimen from Abbeville (Lambert Coll.), 23 specimens from East Cliffs, Dover (Wood Coll.), 3 specimens from Loos near Lille, 1 from Les Andelys, Eure, 1 from Rosoy, Yonne, 10 from Senneville, 3 from Yport, 4 from Fécamp, Seine-Maritime, 3 from Dieppe, 4 from Chalk Pit Inn, Sussex, 4 from Charnage Limestone Works, 7 (plus numerous specimens collected loose) from Dover - St. Margarets sections, Kent, (Author's Coll.).

<u>MICRASTER ANGLICUS</u> (Coquand) 1880

Pl. 2, figs. A-G, Pl. 11, figs. A-C.

<u>Micraster arenatus</u> Agassiz 1840, p. 2.

<u>Micraster cor-anguinum</u> var. <u>major</u> Agassiz and Desor, 1847, p.23.

<u>Micraster gibbus</u>, Forbes in Dixon 1850, p. 342, pl. 24,fig.5,6.

<u>Micraster cor-anguinum</u> (pars), Forbes 1850, pl. 10, fig. 12.

<u>Micraster Cor-anguinum</u> var. géante Desor 1858, p. 364.

<u>Epiaster gibbus</u> (pars), Wright 1878, p. 267.

<u>Epiaster gibbus</u> (pars), Cotteau 1878, p. 492, pl. 82, fig. 4.

<u>Epiaster anglicus</u> Coquand 1880, p. 282.

<u>Micraster gibbus</u> (pars), Gauthier 1887, p. 235.

<u>Micraster senonensis</u> (pars) Lambert 1895, p. 239.

<u>Micraster anceps</u> Lambert 1895, p. 245.

<u>Micraster Fortini</u> Lambert 1896, p. 328, pl. XII, figs. 6,7.

<u>Micraster</u> (<u>Isomicraster</u>) <u>senonensis</u>, Valette 1907, p. 133.

<u>Micraster Cayeuxi</u>, Valette 1907, p. 181.

<u>Micraster anceps</u>, Valette 1907, p. 182.

<u>Isomicraster senonensis</u>, Lambert & Jeannet 1928, p. 139 & 189.

<u>Micraster</u> (<u>Isomicraster</u>) <u>senonensis</u>, Kermack 1954, Pl.24,fig.13
Pl.25, fig.15,Pl.26, fig.17.

HOLOTYPE Specimen described by Coquand from the Upper Chalk of Sussex. Not seen.

NOMENCLATURE Agassiz based M. arenatus on a specimen represented by cast x88, to which was added cast R 70 by 1847. An ancient manuscript label in the Agassiz Collection states that R 70 and x 80 came from England. By x 80 reference is made to x 88 (x 80 being a Danian echinoid which could not have come from England). The same mistake is printed in Agassiz & Desor (1847) and Desor (1858). This label was overlooked by Lambert & Jeannet (1928) who state, without evidence, that R 70 came from Nice. Unfortunately the list of names published by Agassiz in 1840 are not accepted by the Internation Commission. The name M. arenatus must be restricted to the Nice form described and figured by Sismonda in 1843.

Lambert (1895) erected the name M. senonensis, under which name the M. arenatus of Agassiz is generally known to French and English workers. He states that the typical form ("type moyen") is represented by Wright's (1878) plate LXIII of Epiaster gibbus. This is the typical Upper Campanian form coming from Norwich. The Santonian forms, to which the name M. senonensis is usually restricted, are all described as varieties by Lambert. Valette (1907) refers to Wright's plate as representing the type.

Maczynska is entirely justified in describing Upper Campanian gibbose forms from Poland under the name M. sononensis which is a senior synonym of M. stolleyi.

To avoid further confussion the name of Coquand (1880) is resurrected.

DESCRIPTION Species of moderate to large size (45 - 64 mms long usually) with a test somewhat thinner than most Micrasters. Characterised by its conical shape. Peristome variable in position, sometimes almost marginal, more usually about one eighth of the total length from the anterior border. Periproct situated at about 50% of the total height. Paired petals have slightly more pores than the sympatric and contemporary M. coranguinum, one counts 34 pairs in one row of petal II in a specimen 53.8 mms long. Interporiferous zones usually subdivided. Pores of the unpaired petal like those of the paired petals. Subanal fasciole typically absent, but often present especially in juveniles.

DISTRIBUTION Restricted to the Anglo-Paris Basin. In the south-east Paris Basin it occurs in Zones G to I of Lambert (?middle Coniacian to Coranguinum Zone). In the north-west Paris Basin it is rare in the upper part of the Decipiens Chalk, being typical, as in southern England, of the Coranguinum Chalk.

MATERIAL EXAMINED 97 specimens, many of which are intermediate to M. coranguinum, from Northfleet Kent (Rowe Coll. BM(NH)), 3 specimens from the Coranguinum Zone of the Thanet coast (Wood Coll. IGS), 1 specimen from Zone H of Maillot (Lambert Coll.), 1 specimen from Fécamp (MHNP), 1 specimen from Coulsden, Kent, 1 specimen from Pourville, Seine - Maritime both from the Coranguinum Zone (Author's Coll.).

MICRASTER CORANGUINUM VAR. ROSTRATUS (Mantell) 1822

Pl. 1, figs. D-G, Pl. 29, fig. C.

Spatangus rostratus Mantell 1822, p. 192, pl. 17, figs; 10 & 17.

Micraster rostratus (pars), Lambert 1895, p. 173.

Micraster rostratus, Valette 1907, p. 180.

NON Micraster rostratus Bucaille 1883.

HOLOTYPE Specimen E 8662 (BM(NH)), figured by Mantell, from the chalk pits near Brighton.

DESCRIPTION Medium to large size, usually about 50 mms long but may be over 70. Characterised by its high form with a steeply sloping posterior upper surface which overhangs the low periproct forming a rostrum. Two subanal bulges are well developed within the fasciole. Pores of the paired petals more numerous than in M. coranguinum s.s., one counts 37 in one row of petal II on Lambert's specimen from St. Martin which is 51.8 mms long. Pores in the unpaired petal tend to become elongate in the outer rows, but the granule between the pores of one pair remains well developed.

DISTRIBUTION Restricted to the Anglo-Paris Basin, and apparently to the Marsupites Zone.

MATERIAL EXAMINED One specimen from St. Martin, Yonne (Lambert Coll.), plus about a dozen specimens from southern England labelled Marsupites Zone (BM(NH)).

MICRASTER CORANGUINUM VAR. SIMPSONI var. nov.

Pl. 19, figs. F-J, Pl. 30, fig. D.

HOLOTYPE Specimen S54 from the Tectiformis Belt, Saltdean, Sussex. R. Simpson Collection, London.

DESCRIPTION Variety of small to medium size, usually about 50 mms long. The test is somewhat thinnish, and often slightly crushed. Characterised by its shallow anterior notch and its side profile, which shows a gently sloping posterior upper surface and a relatively low periproct. The peristome is close to the anterior border and covered by a blunt labrum. The labral plate is long and thin. The interporiferous zones of the paired petals are strongly inflated to subdivided.

DISTRIBUTION Marsupites and Pilula Zones of southern England.

MATERIAL EXAMINED The holotype from the Tectiformis Belt of Saltdean, and a specimen from the top of the Marsupites Zone at Friars Bay (Simpson Collection), 1 specimen from the Elevata Band at Margate, 1 from the foreshore west of Newhaven (Pilula Zone), and 8 from the foreshore at Saltdean (Pilula Zone) (Author's Collection), 1 from Highfield, Iebbitt, Hants (Westlake Coll.).

MICRASTER WESTLAKEI sp. nov.

Pl. 22, figs. A - C, Pl. 29, figs. A & B.

HOLOTYPE Specimen no. 3320 Westlake Collection (Southampton University). Syntypes specimens 3321 and 3322 from the same Collection. All from the Mucronata Zone of Tichbourne Farm, Hampshire.

DESCRIPTION Large species (60 - 70 mms long) generally resembling *M. coranguinum*. Characterised by the regular arcuate curve of the posterior upper surface from the apical system to the periproct. The peristome is almost marginal and is covered by a strongly projecting labrum. The labral plate of specimen 3321 is separated from the sternal plates by the posterior paired ambulacra. The periproct is situated relatively low. Paired petals are shallow with divided inter-poriferous zones. The median groove in these zones is often obliterated due to the side walls coming together. The periplastronal areas are very coarsely granular.

DISTRIBUTION Known only from the Mucronata Zone of Tichbourne Farm, Hampshire.

MATERIAL EXAMINED Specimens 3320 - 3322 of the Westlake Collection.

<u>MICRASTER</u> <u>RENATI</u> (Gauthier) 1886

Pl. 4, figs. A-G, Pl. 15, figs. F-I, Pl. 28, figs. C-D.

<u>Micraster</u> <u>cortestudinarium</u> (pars), Quendstedt 1874, p. 648, pl. 87, fig. 33.

? <u>Epiaster</u> <u>brevis</u>, Barrois 1878, p. 409.

<u>Epiaster</u> <u>Renati</u> Gauthier 1886, p. 360, pl. VI, fig. 3-5.

<u>Micraster</u> <u>beonensis</u> Gauthier 1886, p. 360.

<u>Epiaster</u> <u>Renati</u>, Gauthier 1887, p. 239, pl. V, fig. 3-5.

<u>Micraster</u> <u>beonensis</u>, Gauthier 1887, p. 229, pl. IV, fig. 7-9, pl. V, fig. 1-2.

<u>Micraster</u> <u>beonensis</u>, Lambert 1895, p. 225.

<u>Micraster</u> <u>Renati</u>, Lambert 1895, p. 226.

<u>Micraster</u> <u>Cayeuxi</u> (pars), Lambert 1895, p. 232.

<u>Micraster</u> <u>icaunensis</u> Lambert 1895, p. 235.

<u>Micraster</u> (<u>Gibbaster</u>) <u>icaunensis</u>, Valette 1907, p. 136.

<u>Micraster</u> (<u>Isomicraster</u>) <u>Renati</u>, Valette 1907, p. 162.

<u>Micraster</u> <u>beonensis</u>, Valette 1907, p. 164.

<u>Micraster</u> (<u>Gibbaster</u>) <u>Gauthieri</u>, Valette 1907, p. 167

<u>Micraster</u> <u>Normanniae</u>, Valette 1907, p. 168.

<u>Micraster</u> (<u>Gibbaster</u>) <u>Gosseleti</u>, Valette 1907, p. 169

<u>Micraster</u> <u>decipiens</u> (pars), Valette 1907, p. 178.

<u>Micraster</u> <u>cortestudinarium</u> (pars), Cotteau 1878, p. 498.

HOLOTYPE Specimen from the Peron Collection figured by Gauthier (1886 & 1887) from the base of the Senonian at Grange-au-Rez, near Troyes, Aube (MHNP). The word Turonian also appears on the label of the holotype.

DESCRIPTION Species of moderate size (45-60 mms long). Characterised by its somewhat thin test and globose shape. The ornamentation of the test is not readily apparent to the naked eye. Peristome about one fifth of the total length from the anterior border, only partially covered by the labrum. Periproct situated at about 59-70% of the total height. Interporiferous zones of the paired petals varying from sutured (Zone E) to inflated (Zone F). One counts 32 pairs of pores in one row of petal II in a specimen 50.7 mms long. Pores of the unpaired petal usually oval, those of the outer rows often elongate, but always separated by a granule. Periplastronal areas granular with scattered tubercles. Subanal fasciole may be well developed (Zone E) or less so (Zone F).

DISTRIBUTION Zones E and F of Lambert of the South-East Paris Basin. According to Lambert 1920 it is found in the Yonne, Aube, Marne, Ardennes and Aisne.

MATERIAL EXAMINED The holotype plus the two specimens of the type series of _M. beonensis_ from Grange-au-Rez and Béon (Peron Coll. MHNP), the holotype of _M. icaunensis_ from Zone F of Cochepie, specimens from Zone F at St. Julien and Messon labelled _M. Gosseleti_ and _M. renati_ respectively, specimens from Zone E at Béon, St. Julien and Armeau labelled _M. beonensis_, _M. normanniae_ and _M. tropidotus_ respectively (Lambert Coll.), 24 specimens, mostly collected loose, from Zone F in the quarry at St. Julien (Author's Coll.).

MICRASTER;GOSSELETI Cayeux 1890

Pl. 14, figs. A-C, Pl. 31, figs. C-D.

Micraster Gosseleti Cayeux 1890, p. 180, pl. IV, fig. 1a-f.

Micraster Gauthieri Parent 1892, p. 10, pl. II, fig. 1a-c.

Micraster Cayeusi Parent 1892, p. 13, pl. II, fig. 2a-c.

Micraster Gosseleti, Lambert 1895, p. 229 (pars).

Micraster Cayeuxi, Lambert 1895, p. 232 (pars).

HOLOTYPE Specimen figured by Cayeux from the "assise à Micraster-cor-testudinarium" of either Ronchin or Ennequin near Lille. Not seen.

DESCRIPTION Species of moderate size (54-66 mms long), very inflated almost globular form. Peristome about one fifth of total length from the anterior border. Periproct situated at about 53% of the total height. Most easily distinguished by its long paired petals with numerous pores. One counts 38 pairs of pores in one row of petal II in a specimen 50 mms long. Interporiferous zones of the paired petals inflated to sub-divided. Distal half of the unpaired petal showing conjugate pores. Subanal fasciole incompletely developed.

DISTRIBUTION Uppermost Decipiens Zone of the Lille region and Coquelles near Calais, in the beds yielding I. involutus.

MATERIAL EXAMINED One specimen from Lumbres and one from Ennequin, both from the Coniacian (Lambert Collection).

SPECIES RESTRICTED TO THE TOURAINE - AQUITAINE PROVINCE.

<u>MICRASTER</u> <u>TURONENSIS</u> (Bayle) 1878

Pl. 17, figs. A - F, Pl. 27, figs. A - C.

<u>Micraster</u> <u>cor-anguinum</u>,(pars), d'Orbigny 1853, p. 207.

<u>Micraster</u> <u>brevis</u>, Hébert 1856, pl. XXIX, fig. 19.

<u>Micraster</u> <u>cortestudinarium</u> var. <u>brevis</u> (pars), Cotteau & Triger 1869, p. 320, not pl. LIV.

<u>Micraster</u> <u>cortestudinarium</u> (pars), Quenstedt 1874, p. 646, pl. 87, fig. 30.

<u>Micraster</u> <u>brevis</u> (pars), Peron 1877, p. 523.

<u>Spatangus</u> <u>turonensis</u> Bayle 1878, pl. 156, figs. 3,4.

<u>Micraster</u> <u>cortestudinarium</u>, Cotteau 1883, p. 164.

? <u>Micraster</u> <u>rostratus</u> Bucaille 1883 (non Mantell 1822), p. 34, pl. 8.

<u>Micraster</u> <u>turonensis</u>, Lambert 1895, p. 212.

? <u>Micraster</u> <u>Arnaudi</u> Lambert 1895, p. 244.

<u>Micraster</u> <u>Grossouvrei</u> Lambert 1895, p. 245.

HOLOTYPE Specimen figured by Bayle from the white chalk of Villedieu. Not seen.

DESCRIPTION Species of medium to large size (usually 45 - 55 mms long), with a broad, subgibose shape. The peristome is about one fifth of the total length from the anterior border, broad and only half covered by the labrum. The oral pores are well developed. Periproct situated at about 58% of the total height. Interporiferous zones of the paired peatls strongly inflated to subdivided. The species is distinguished by the number of pores in the paired petals, which number 34 in one row of petal II on a specimen 53.9 mms long. The pores of the outer row of the unpaired petal are distinctly oval distally, the granule between the pores of a single pair disappearing here. This arrangement is subject to great variation. The periplastronal areas are coarsely granular. In the apical system, occular IV is invariably in contact with the madreporite and usually one or other of the posterior occulars is as well (more often V).

The above description is based on the typical Upper Coniacian form from the Craie de Villedieu. Only specimens from this horizon and from this region have been examined in detail - 1 specimen from Villedieu (de Grossouvre Coll.), 1 from Villedieu (Lambert Coll.), 1 from Couture (Peron Coll.). Specimens from younger horizons in other regions show the peristome closer to the anterior border, but still only half covered by the labrum. Further study of these Santonian forms is needed. I have noted such specimens in the Musée d'Histoire Naturelle (Paris) coming from Le Tertre-Blanc, Cognac, Soulages (Dordogne), St. Fraimbault (Sarthe), and Cangey - Limeray (Indre et Loir).

DISTRIBUTION Upper Coniacian (the typical form) to Upper Santonian of the Touraine - Aquitaine Province. Lambert (1895) records the species from (other than localities quoted above) ;- Rousselières (L1), Bedochau (L), Perigeux (L2 & M1), Cognac (M1), Jonzac (L2), and Montissieu (L & M1). De Gossouvre (1892) records it from St. Prest near Chartres.

<u>MICRASTER</u> <u>TURONENSIS</u> VAR. <u>INTERMEDIUS</u> Bucaille 1883
Pl. 22, figs D - F, Pl. 28, figs. A, B.

<u>Micraster</u> <u>intermedius</u> Bucaille 1883, p. 31, pl. 7.
<u>Micraster</u> <u>intermedius</u>, Lambert 1895, p. 222.

HOLOTYPE Specimen figured by Bucaille from the middle Senonian, presumably of Elbeuf. Not seen.

DESCRIPTION Smaller than <u>M</u>. <u>turonensis</u> s.s. being usually 40 - 50 mms long. It is narrower than the parent species, being longer than wide. The peristome is smaller and narrower. Oral pores not as well developed as those of <u>M</u>. <u>turonensis</u> s.s.. Bucaille describes the unpaired petal as having conjugate pores distally. The specimens in the Lambert Collection show all the pores in this petal to be non conjugate. Plates 1a1 and 1a2 are only just touching each other, a condition indicative of high Santonian and younger forms.

DISTRIBUTION Santonian of Elbeuf. Bucaille's records of it from St. Valery and Yport are dubious. De Grossouvre (1892) records it from Le Mousseau near Chartres.

MATERIAL EXAMINED Two specimens from Elbeuf, collected and determined by Bucaille (Lambert Coll.).

MICRASTER TURONENSIS VAR. CONIACENSIS Lambert 1920

Pl. 23, figs. A - C, Pl. 27, fig. D.

Micraster coniacensis Lambert 1920, p. 5

HOLOTYPE Not specified by Lambert. Presumably a specimen from the Santonian of Cognac.

DESCRIPTION Distinguished from M. turonensis s.s. by its smaller size (the only specimen known to me being 34.5 mms long), and above all by its shape. The high form of the post apical region, and the very rounded posterior as seen in side profile, are not known in the parent species. The periproct is much higher than in M. turonensis s.s., being situated at 69.9% of the total height.

DISTRIBUTION Santonian of Cognac and Ile d'Oléron.

MATERIAL EXAMINED One specimen from Rocher de l'Epinette, Ile d'Oléron (Lambert Coll.).

MICRASTER REGULARIS Arnaud 1883

Pl. 5, figs. A - E.

Micraster regularis Arnaud in Cotteau 1883, p. 209, pl. XI, figs. 1 - 5.

Micraster regularis, Lambert 1895, p. 224.

HOLOTYPE Specimen figured in Cotteau 1883. Not seen. Presumably from Zone P1 of Chartuzac.

DESCRIPTION Species of small to medium size (up to 45 mms long). It is moderately inflated above, and has a broad and rounded posterior. Peristome is very close to the anterior border. In specimens over 40 mms long Lambert (1895) noted that the labrum projects so much that it is visible from above. Paired petals show distinctly divided interporiferous zones. The pores of the unpaired petal are slightly elongate and conjugate distally. Periplastronal areas are coarsely granular. The median suture of the plastron is asymmetrical, such that the right sternal plate does not touch the labral plate. Plates 1a1 and 1a2 do not touch each other.

DISTRIBUTION Restricted to the Lower Campanian of the Touraine - Aquitaine Province. Known from P1 of Chartuzac, Nieuil-le-Virouil, Jonzac, Tugeras, Mirambeau and Livernault. Also from Arces (Charentes), Caillau, Chaumont (Loir-et-Cher). Talvoisin near Chartres (Eure et Loir).

MATERIAL EXAMINED One specimen from Tugeras-Jonzac, Charente Maritime (MHNP), one specimen from Talvoisin (Author's Coll.).

SPECIES RESTRICTED TO THE PYRENEAN PROVINCE.

MICRASTER BREVIS Desor 1847

Pl. 12, figs. D - F, Pl. 39, figs. A - B.

Micraster brevis (pars) Desor, in Agassiz & Desor, 1847, p. 24.

Micraster cor-anguinum (pars), d'Orbigny 1853, p. 207, pl. 868, figs. 1 & 2.

Micraster brevis, Leymerie & Cotteau 1856, p. 346.

" " , Desor 1858, p. 364.

Micraster cortestudinarium, Cotteau 1863, p. 55

Micraster cor-testudinarium var brevis (pars), Cotteau & Triger 1869, p. 320, ?pl. LIV.

Micraster brevis, Quendstedt 1874, p. 655, pl. 88, fig. 18.

" " (pars), Peron 1877, p. 523.

Spatangus brevis, Bayle 1878, pl. 156, figs. 5-6.

Micraster brevis, Wright 1881-82, p. 339, pl. 75, fig. 3a-g.

" " , Cotteau 1887, p. 660.

" " , Cotteau 1889, p. 3.

Micraster corbaricus Lambert 1895, p. 237.

" " , Lambert 1902, p. 22.

" " , Lambert 1910, p. 814.

" " , Lambert 1920, p. 3.

" " , Lambert 1927, p. 46.

" " , Lambert & Jeannet 1928, p. 189.

? Micraster (Gibbaster) fastigatus, Sorenyi 1955, p. 256, pl. 21, figs. 15-19.

NON Micraster brevis, Hébert 1856

Micraster brevis, Lambert 1895

HOLOTYPE Original specimen, not seen, represented by cast R 69 in the Agassiz Collection, from the Craie à Hippurites of the Corbières.

Lambert's conclusion (1895) that this name must be restricted to a Westphalian form seems indefensible. Desor himself (1858), with the exception of Périgord, lists only Pyrenean localities. Quendstedt (1874), Bayle (1878) and Wright (1881) all figure specimens from the Corbières as *M. brevis*. Cotteau (1889) states that "le type se trouve dans la craie à hippurites des Corbières."

DESCRIPTION Species of moderate size (45-60 mms long) of globose shape and slightly convex lower surface. Peristome small, usually about one fifth of the total length from the anterior border, but sometimes as close as one eighth. Only partly covered by the labrum. Periproct situated at about 60% of the total height. Paired petals broad, usually superficial or only slightly sunken, with numerous pairs of pores (44 in one row of petal II in a specimen 51.5 mms long). Pores of the unpaired petal becoming elongate distally in the outer rows. Periplastronal areas granular in the posterior, tubercular, like the plastron, in the anterior portion.

DISTRIBUTION Uppermost Coniacian and Lower Santonian of the Pyrenean Province.

MATERIAL EXAMINED 33 specimens from Pobla de Segur region (BM(NH)), 3 from Rennes-les-Bains (Aude) (Lambert Collection), 9 from Contrata, 77 from San Vicente region, 6 from St. Martin, 4 from Larraona, 41 from Pobla de Segur (20 of which were collected loose), and 10 poorly preserved specimens from Sougraigne, Aude (Author's Collection).

MICRASTER HEBERTI de Lacvivier 1877

Pl. 13, figs. A - E. Pl. 39, fig. C.

Micraster Heberti de Lacvivier 1877, p. 538, pl. VIII, fig.1-4.

" " , Cotteau 1887, p. 660.

" " , Lambert 1895, p. 212.

Micraster Larteti Munier-Chalmas in Lambert 1895, p. 242.

" " , Lambert 1920, p. 4.

Micraster proclivis Lambert 1920, p. 6.

Gibbaster Heberti, Lambert 1920, p. 15.

Micraster Larteti, Lambert 1922, p.17, pl. II, figs. 3-4.

Micraster proclivis, Lambert 1922, p. 19, pl. II, figs. 5-6.

Micraster Larteti, Lambert 1927, p. 46.

HOLOTYPE Not seen. Specimen from de Lacvivier's Collection from the Turonian of Bastié, Foix (Ariège).

DESCRIPTION Species of medium to large size (50-60 mms long) of globose shape. Peristome close to the anterior border covered by a strongly projecting labrum (about one eighth of the total length from the border). Top of the periproct is situated at 55-65% of the total height. Inter poriferous zones of the paired petals inflated to subdivided, that of the unpaired petal sutured to inflated. In the distal part of the unpaired petal the pores are like those of the paired petals. Periplastronal areas coarsely granular, and often with numerous tubercles. Subanal fasciole narrow, often restricted to the plastron.

DISTRIBUTION Restricted to the Pyrenean Province. The stratigraphical range is uncertain. It is probably high Santonian or low Campanian, but certainly not Turonian as de Lacvivier states (1877).

MATERIAL EXAMINED One specimen from Loredo (Santander), the holotype of _M. proclivis_ from Llencres (Santander), the holotype of _M. larteti_ from Alhama de Aragon (Lambert Coll.). Three specimens from Salvatierra (Author's Coll.).

MICRASTER ANTIQUUS Cotteau 1887

Micraster antiquus Cotteau 1887, p. 642, pl. XVI, fig. 1-4.
" " , Lambert 1895, p. 227.

HOLOTYPE Not seen. Specimen from the Roussel Collection figured by Cotteau 1887. Stated to be from the Cenomanian of Sezenac (Ariège).

DESCRIPTION Species of medium to large size, heart shaped, broad in front. Slight carina. Generally resembling a broad M. coranguinum from the Anglo-Paris Basin, but differing in that the peristome is much closer to the anterior border, and more obviously by the much greater number of pairs of pores in the paired petals. In a specimen 62 mms long one counts about 43 pairs of pores in one row of petal II. The pores of the unpaired petal are round, those of one pair are separated by a granule. There is a well developed subanal fasciole.

DISTRIBUTION Restricted to the Pyrenean Province. I have collected it only in the uppermost Lower Campanian.

MATERIAL EXAMINED Two typical specimens plus numerous intermediates to M. aturicus from Acre, Spain (Author's Coll.).

<u>MICRASTER ATURICUS</u> Hébert 1880

Pl. 7, figs. A - D.

<u>Micraster cor-anguinum</u> (pars), d'Orbigny 1853, p. 207.

<u>Micraster aturicus</u> Hébert 1880

" " , Arnaud 1887, p. 19.

" " , Cotteau 1889, p. 7.

" " , Seunes 1891, p. 30, pl. IV, fig.1,pl.V,fig.1.

" " , Lambert 1895, p. 230.

" " , Lambert 1927, p. 48.

HOLOTYPE Specimen figured by Seunes from the <u>Heteroceras polyplocum</u> Zone of Tercis. Not seen.

DESCRIPTION Small to large in size. The typical Upper Campanian form from the Tercis region reaches 110 mms in length. Most easily distinguished by its side profile. This shows a sub-conical shape, a distinctly concave anterior slope and a slightly concave posterior face. The peristome is marginal, the labrum projecting into the anterior notch. The periproct is low. Paired petals are long with numerous compact pairs of pores, in a specimen from Angoumé (length 59 mms) one counts 48 in one row of petal II. Distally the outer rows of pores in the unpaired petal become elongate, but the pores of one pair do not become conjugate. Periplastronal areas of large compact granules of the same size as the plastronal tubercles. Well developed subanal fasciole present. Plates 1a1 and 1a2 separated by 1b1.

DISTRIBUTION Restricted to the Pyrenean Province. Small forms occur in the uppermost Lower Campanian. The typical large form occurs in the Upper Campanian. Nicklès (quoted in Lambert 1895) records the species from the Maastrichtian.

MATERIAL EXAMINED Single specimens from Ermitage de Seira and Montesquiu (Lambert Coll.), one specimen from Angoumé (MHNP), numerous small forms, many of which are intermediates to M. antiquus, from Arce (top of the Lower Campanian), one specimen from the Lower Campanian and three from the Upper Campanian of Tercis (Author's Coll.).

MICRASTER CORCOLUMBARIUM Desor 1858

Pl. 6, figs. A - E.

Ananchytes coravium Grateloup 1836, p. 167, pl. II, fig. 12.

Micraster cor-anguinum (pars), d'Orbigny 1853, p. 207.

Micraster Cor-columbarium Desor 1858, p. 365.

Micraster sub-carinatus Cotteau 1863, p. 57.

Micraster corcolumbarium, Seunes 1888, p. 792, pl. XXX, fig.4a-c.

Micraster cor columbarium, Cotteau 1889, p. 4.

Micraster corcolumbarium, Lambert 1895, p. 202.

" " , Lambert 1927, p. 47, pl. III,fig. 17-18.

SYNTYPES Not seen. Series of specimens from the Campanian of Tercis in the Musée de Zurich, mentioned by Desor.

NEOTYPE Specimen from Montesquiu (Lambert Coll.) figured by Lambert 1927, and here.

DESCRIPTION Small species, usually about 35 mms long, often showing a strong bilateral asymmetry. Peristome close to the anterior border (about one eighth of the total length) covered by a blunt labrum. The labral plate is long and thin. The paired petals are sunken, with few pore-pairs for a Pyrenean form. The neotype, length 31.7 mms, shows only 22 pairs in one row of petal II. Pores of the unpaired petal round and separated by a granule. A specimen from Tercis (Cotteau Coll. numbered 17) shows plates 1a1 and 1a2 separated by 1b1.

DISTRIBUTION Restricted to the Pyrenean Province. It is probably restricted to the Upper Campanian.

MATERIAL EXAMINED Six specimens from Tercis (Cotteau Coll.), two from the same locality and the neotype from Montesquiu (Lambert Coll.), one specimen from Tercis (Author's Coll.).

MICRASTER GOURDONI Cotteau 1889
Pl. 14, figs. D - F.

Micraster Gourdoni Cotteau 1889, p. 5, pl. I, fig. 1&2.

" " , Lambert 1895, p. 229.

Isomicraster Dallonii Lambert 1910, p. 814, pl. XV, fig. 13 & 14.

Gibbaster Gourdoni, Lambert 1927, p. 48.

Isomicraster Dallonii, Lambert 1927, p. 48.

HOLOTYPE Specimen from the Gourdon Collection figured by Cotteau 1889. From the Upper Senonian of Villacarli (Aragón). Not seen.

DESCRIPTION Species reaching great size, the holotype being 84 mms long. Conical shape with steeply sloping anterior and side faces, the posterior surface more gently sloping. Lower surface flat, but concave in the anterior part. Peristome close to the anterior border, with strongly projecting labrum. Periproct situated very low, as figured in Lambert 1910. Unpaired petal like the paired ones. The petals are long with numerous compact pores. Cotteau (1889) quotes the following number of pore pairs, presumably for the holotype :-
I 45-47, II 59-60, III 38-40. Lambert's specimen (length 64 mms) from Egea shows : I 35, II 43. Periplastronal areas of large compact granules of the same size as the tubercles on the plastron. No fasciole seen on Lambert's specimen from Egea. Cotteau states that his specimens show a well developed subanal fasciole.

Similar to M. aturicus, from which it is probably derived, but differing in that it is broader, more regularly conical, and lacks carina and rostrum.

DISTRIBUTION The species is apparently restricted to the Upper Campanian of the Montsech region (Aragon, Spain).

MATERIAL EXAMINED Plaster cast of the holotype (MHNP) and the holotype of *M. dallonii* (Lambert Coll.).

MICRASTER CORIBERICUM Lambert 1920

Pl; 40, fig. C.

Micraster coribericum Lambert 1920, p. 8, pl. III, figs. 3-5.

HOLOTYPE Specimen figured by Lambert from the Santonian of Llencres, Santander (Lambert Coll.).

DESCRIPTION Small species, the holotype (length 40 mms) is the largest specimen I have seen. Typically it has a globose shape, the height being about 75% of the length. The peristome is usually situated one quarter of the total length from the anterior border (one third in the holotype). Periproct situated fairly high, 57-70% of the total height. Paired petals almost superficial with relatively numerous pairs of pores, the holotype showing 27 in one row of petal II.

DISTRIBUTION It is only known from the ?Santonian of Llencres, Santander.

MATERIAL EXAMINED Six specimens, including the holotype, from Llencres (Lambert Coll.), two of which were labelled M. coranguinum.

MICRASTER DOUVILLEI Lambert 1920

Pl. 18, figs. F - J, Pl. 40, figs. A - B.

Micraster Douvillei Lambert 1920, p. 8.

Micraster coranguinum (pars), Lambert 1920, p. 7.

Micraster Douvillei, Lambert 1922, p. 20, pl. II, figs. 1-2.

HOLOTYPE Specimen from the Santonian of Santa Marina, Santander, figured by Lambert 1922. Lambert Collection.

DESCRIPTION Species of moderate size, 50-60 mms long. Broad form, not very high. Much less globose and gibbose than most Pyrenean Micrasters. Superficially like a broad M. coranguinum. Peristome very close to the anterior border, probably covered by a projecting labrum (broken in the specimens examined). Periproct situated moderately high - 58 - 64% of the total height. Paired petals with inflated to subdivided interporiferous zones and numerous pairs of pores - one counts 44 in one row of petal II in a specimen 57.9 mms long. Pores of the unpaired petal tend to become elongate in the outer rows, but each pair is still separated by a granule. Periplastronal areas coarsely granular with scattered tubercles.

DISTRIBUTION Known only from Santander. Its age may be younger than Santonian.

MATERIAL EXAMINED Three specimens from Santa Marina, including the holotype, one of which was labelled M. coranguinum (Lambert Coll.).

MICRASTER MENGAUDI (Lambert) 1920

Pl. 6, figs. F - J, Pl. 41, figs. A - C.

Gibbaster Mengaudi Lambert 1920, p. 14, pl. II, figs. 13-15.

HOLOTYPE Specimen figured by Lambert, from the Santonian of Cabo Menor. It has "Cme 4" written on in blue pencil.(Lambert Coll.).

DESCRIPTION

Species of moderate size and globose shape, 43-53 mms long. Peristome varying in its distance from the anterior border, from one fifth to:one ninth of the total length. The labrum is broken in all the specimens examined, but probably did not project greatly. Periproct situated from 48-64% of the total height. Paired petals subdivided to divided with numerous pores - one counts 48 pairs in one row of petal II in a specimen 53 mms long. Unpaired petal showing a variable arrangement of pores - in specimen "Cme 1" all the pores are round and separated by a granule, whereas in the other specimens they are congugate save for a few pairs in the apical portion. Periplastronal areas coarsely granular with some tubercles. Distinct subanal fasciole present. In specimens "Cme 4" and "Cme 2" plates 1a1 and 1a2 are separated by 1b1, this is not the case in "Cme 1". The occurance of this feature plus the very advanced arrangement of plates in the apical sytem shows that the species must be Campanian, and probably Upper Campanian.

MATERIAL EXAMINED Three specimens, including the holotype, from Cabo Menor, Santander - the only known occurance (Lambert Coll.).

SPECIES RESTRICTED TO THE ALGERO - TUNISIAN REGION
OF THE NORTH AFRICAN REALM.

MICRASTER PEINI Coquand 1862

Pl. 8, figs. A - G, Pl. 25 figs. a - c.

Micraster Peini Coquand 1862, p. 245, pl. 27, figs. 1 - 3.

Micraster Peini, Cotteau Peron & Gauthier 1881, p. 55.

? Micraster brevis, Cotteau Peron & Gauthier 1881, p. 55.

Micraster Peini, Pomel 1883, p. 42

? Micraster corbaricus, Lambert 1931, p.73.

Plesiaster Peini, Lambert 1931, p. 102.

HOLOTYPE Specimen figured by Coquand (1862) from the Santonian of Algeria. Not seen.

DESCRIPTION Species of small to large size (27 - 57 mms long), somewhat globose in shape, but with a distinct vertical posterior truncation. Anterior notch very shallow. Peristome one fifth to one nine of the total length from the anterior border. Periproct fairly high on the posterior face (63 - 72 % of the total height). Paired petals broad and long with numerous pores, all of which are elongate. One counts 47 pairs of pores in one row of petal II on a specimen 57 mms long. Interporiferous zones subdivided to divided. Unpaired petal usually showing conjugate pores distally at least. Periplastronal areas coarsely granular, usually with scattered tubercles present. Subanal fasciole well developed. Peripetalous fasciole developed at the extremities of the paired petals, more rarely it is continuous between the paired petals and across interambulacrum 5, but in these regions it is always diffuse. It never extends in front of the anterior paired petals.

DISTRIBUTION Known only from the Santonian of Algeria and Tunisia, where it occurs with North African Hemiasters.

MATERIAL EXAMINED 1 specimen from Khanguet Merouna (Cotteau Coll.), 1 from Djebel Touireuf and 2 from Khanguet Merouna (Lambert Coll.). All these specimens are from Tunisia.

MICRASTER ;SOLIGNACI sp. nov. (ex Lambert MS)

Pl. 7, figs. E - H, Pl. 25, fig. d.

? *Micraster coranghinum*, Cotteau Peron & Gauthier 1881, p. 57.
Plesiaster Solignaci Lambert MS

HOLOTYPE Specimen figured here, and labelled *Plesiaster Solignaci* in the Lambert Collection. From the Campanian of Koudiat Melhab, Tunisia.

DESCRIPTION Species of medium size (52.6 mms long) and of rounded shape with a very shallow anterior notch. Lower surface of the test is badly damaged, the ornamentation of that which remains has been removed by weathering. Periproct situated rather low (50 % of the total height). Paired petals broad and long, with numerous pairs of pores. One counts 49 pairs in one row of petal II on the holotype. Inner rows of pores are oval, outer rows elongate. Interporiferous zones inflated to subdivided. Unpaired petal with conjugate pores, inner rows slightly oval, outer rows distinctly so. Subanal fasciole well developed. Peripetalous fasciole well developed at the extremities of the paired petals extending, in varying degrees into the interambulacra. Best developed at the end of petal I, from which it almost reaches the middle of the ajacent interambulacra.

MATERIAL EXAMINED The holotype, this being the only specimen known of the species.

CHAPTER II MORPHOLOGICAL TRENDS IN THE GENUS MICRASTER.

Meyer (1878) stated that :-

i) The peristome became progressively closer to the anterior border.

ii) The apical system moved progressively backward.

iii) The number of plates impinging on, or notched by, the anal opening varies from seven in the early species to five and sometimes four in the later forms, or species. I have not confirmed this latter trend.

Rowe (1899) demonstrated several trends and indicated their stratigraphical importance. The more important ones are :-

a) The broadest part of the test moved progressively backward.

b) The highest part of the test moved progressively backward.

c) The anterior notch became gradually deeper.

d) The labrum projected more and more.

e) The periplastronal areas became progressively more granulated.

f) The petals became shallower and longer.

g) The interporiferous zones of the paired petals passed through stages which Rowe called smooth, sutured, inflated, subdivided and divided.

h) The subanal fasciole became broader in the main Micraster lineage.

i) The double subanal prominences (one in each lobe of the subanal fasciole) became more marked.

j) The paired grooves of the anterior paired phyllodes of Turonian forms became lost in later forms.

Nichols (1959) showed that the number of respiratory tube feet in the paired petals increased in Turonian to Santonian forms.

All the trends mentioned above are based on material coming from the Turonian to Santonian of southern England. These trends are applicable to Micrasters from comparable horizons throughout Europe.

In Campanian times one sees a reversion to sutured and inflated interporiferous zones of the paired petals. These zones, which are a useful guide to horizon up to the Santonian, are of little use to the Campanian stratigrapher.

OTHER TRENDS

In addition to the above mentioned trends, the following have been observed :-

I) There was an increase in the number of ocular plates touching the madreporite.(See figure 30.).

II) The number of interambulacral plates in contact with the peristome became reduced. (See figure 31). In the most general terms it could be said that Turonian and Lower Coniacian forms have all the interambulacra joining the peristome. In Upper Coniacian and Santonian forms the posterior pair had withdrawn, and in the Campanian one often sees the withdrawal of all the paired interambulacra.

III) The asymmetry of the sternal plates changes with time, passing through a stage in which the median suture is exactly longitudinal. (See figure 32).

IV) The labral plate became longer and narrower with time. In some Upper Campanian individuals this plate became separated from the sternal plates (See figure 32). This condition is known to occur in M. schroederi, M. stolleyi, M. grimmensis and M. westlakei.

V) There was a progressive reduction in,the distance along which plates 1a1 and 1a2 touched each other. In the vast majority of cases these plates are in contact. In many Campanian specimens these plates are separated by 1b1. This condition is restricted to the Campanian in my experience. (See figure 33).

The use of the more primitive arrangement of these plates, in broad flat Campanian Micrasters, as a taxonomic criterion diagnostic of the subgenus Micraster (Paramicraster) Maczynska 1968 is rejected along with the subgenus.

The Campanian condition occurs in specimens of different phylogenetic lineages and in different faunal provinces, for example in M. mengaudi (Pyrenean Province), M. westlakei (Anglo-Paris Basin Province), M. schroederi and the M. fastigatus - stolleyi stock (Northern Faunal Province).

VI) The situation of the periproct tended to become lower in any lineage, although reversals of this trend occur for example in the Mucronata Zone gibbose forms from Norfolk (See figure 17).

The situation of the periproct is an important feature in other irregular echinoids from the chalk. In the genus Echinocorys the periproct becomes increasingly inframarginal up the succession (Peake & Melville 1970). The Offaster - Galeola lineage of the German Campanian shows a reduction in the height of the periproct (See figure 4 of Ernst 1963b).

THE VALUE OF THE MORPHOLOGICAL TRENDS IN MICRASTER.

The trends discussed by Rowe (1899), including those of Meyer numbered i and ii above, have stood the test of time and remain of great use to the stratigrapher dealing with Turonian to Santonian forms.

Of the trends numbered I to VI above only the Campanian conditions described in IV and V are of great use to the stratigrapher. The other trends are too prone to exceptions to be reliable guides to horizon.

Perhaps one of the greatest values of the trends in the genus Micraster lies in the fact that they occur. Closely related spatangoids,such as the Epiasters and the genus Diplodetus described below, have often been mistaken for Micrasters. These forms are easily distinguished by their very conservative characters and the absence of such distinct trends as are listed above.

CHAPTER III THE ORIGIN AND EXTINCTION OF THE GENUS *MICRASTER*.

ORIGIN OF THE GENUS *MICRASTER*

Micrasters first appear in the Turonian of the Northern Faunal Province and the Anglo-Paris Basin Province.

i) ANGLO-PARIS BASIN PROVINCE

In the Anglo-Paris Basin the *M. corbovis* stock is clearly distinct from, and does not interbreed with, nor give rise to *M. leskei*. There is great justification for rejecting this stock (both Lata and Planus Zone forms) from the genus *Micraster*.

"*Epiaster*" *michelini* is found up to the Planus Zone in this Province, where it interbreeds with the earliest *M. leskei* in the Chalk Rock. This may suggest that true Micrasters evolved from the Touraine-Aquitaine "*Epiaster*" stock at this time.

ii) NORTHERN FAUNAL PROVINCE

The earliest Micrasters in northern Germany occur in the lower Middle Turonian (Lamarcki Zone). According to German stratigraphers *Micraster* appears much earlier here than in the Anglo-Paris Basin. Regarding the Lamarcki Zone as Upper Turonian, one sees the appearance of Micrasters at the same time in both Provinces.

One could conclude that true *Micraster* evolved.....

a) from "*E.*" *michelini* in the Anglo-Paris Basin and migrated almost immediately into the Northern Faunal Province.

b) independently in the two Provinces.

c) from a pre-existing spatangoid stock in the Northern Faunal Province and migrated into the Anglo-Paris Basin where it interbred with "E." michelini for a short time.

I am not familiar with other Turoniah spatangoids from the Northern Faunal Province, and thus do not know whether the latter hypothesis is possible.

EXTINCTION OF THE GENUS MICRASTER.

The last Micrasters known come from the Lower Maastrichtian. In Europe the only accurately recorded Micrasters at this horizon come from the Northern Faunal Province.

Hawkins (1936) interprets the morphological trends shown by Micraster as being due to orthogenesis. Extinction of the genus he explains as resulting from these trends continuing beyond their optimal development to a stage where they become possitively harmful.

An alternative theory for the extinction of the genus Micraster is that it was unable to adapt to changing conditions. However, the chalk facies shown by the Upper Maastrichtian in Denmark and southern Sweden is well within the range of facies previously occupied by Micrasters.

One feels that Hawkin's expanation of extinction being due to uncontrollable orthogenesis is closer to the truth.

The extinction of the genus Micraster was complete. The genus was not the ancestor of any other forms of spatangoids.

CHAPTER IV

Genus EPIASTER d'Orbigny 1853

Type species Epiaster crassissimus (Defrance) 1827, designated by Savin (1905).

The genus Epiaster is in great need of revision. At the moment it includes a variety of forms on the basis of a lack of fascioles.

Only the species previously attributed to the genus Micraster are discussed here. Confirmation of the validity of the trivial names used awaits a revision of other species of Epiaster.

Group of "E." michelini, "E." laxoporus and "E." carentonensis.

DESCRIPTION OF THE GROUP.

Small to medium sized (25 - 45 mms long), thin tested spatangoids with a characteristic subanal heel. The term rostrum is defined by Melville & Durham (1966 p. U256) as "Raised or attenuated area of interambulacrum 5". This term thus has a double meaning as it applies to areas both above and below the periproct. The term heel is introduced here for such areas below the periproct. The anterior notch is broad and shallow. The peristome is situated far from the anterior border with, at most, a very feebly projecting labrum. The peristome is surrounded by a smooth rim and well developed oral pores in the adjacent ambulacral areas. All the inter - ambulacral areas join the peristome and are often thickened to add strength to the delicate peristomal rim. The paired petals are relatively short, closed, and deeply sunken. The conjugate pores of these petals are all elongate, in some cases more so in the inner than the outer rows. The interporiferous zones are smooth. The apical part of the unpaired ambulacrum is broad with divergent edges. The arrangement of pores in this petal is variable, but they are never conjugate. The inter - poriferous zone of this petal is about four times as wide as one pore zone. In the ethmophract apical system none of ocular plates I, IV or V touch the madreporite. The periproct is typically oval in shape, elongated in a vertical snese, and situated high on the outwardly sloping posterior face. The plastronal tubercles never become very tightly packed together. The broad periplastronal areas are finely granular. The subanal fasciole is narrow when developed, and often diffuse in nature. On the oral surface it is situated immediately behind a distinct swelling at the posterior of the plastron.

STRATIGRAPHICAL RANGE (? Upper) Cenomanian to Maastrichtian.

GEOGRAPHICAL DISTRIBUTION Characteristic of the Touraine - Aquitaine region. The group was widespread in Turonian times occuring in the Anglo - Paris Basin, south east France and the Pyrenees. In post Turonian times it is exceedingly rare outside the Touraine - Aquitaine Province.

"EPIASTER" MICHELINI (Agassiz) 1847

Pl. 12, figs. G-H, Pl. 21, figs. A-F, Pl. 24, figs. a & b.

Micraster Michelini Agassiz in Agassiz & Desor 1847, p. 23.

Micraster Michelini, d'Orbigny 1853, p. 205, pl. 866.

Micraster Michelini, Desor 1858, p. 363, pl. 41, fig. 5 - 8.

Micraster Michelini, Cotteau & Triger 1859, p. 244, pl. 39, figs. 13, 14.

Micraster Sanctae-Maurae Gauthier 1886, p. 356 (pars).

Micraster Michelini, Lambert 1895, p. 192.

Micraster corbovis (pars), Rowe 1899.

Micraster leskei (pars), Rowe 1899.

Micraster leskei var. joviniacensis Lambert in Lambert & Thierry 1924, pl. XII, fig. 10.

? Micraster micranthus Lambert in Lambert & Thierry 1924.

HOLOTYPE Original specimen represented by cast T 49 in the Agassiz Collection. Stated to be from the Turonian of Touraine (Lambert & Jeannet 1928). Original specimen not seen.

DESCRIPTION Small to medium sized species (30 - 45 mms long). Peristome broad and far from the anterior border (one third to one quarter of the total length). In the paired petals the pores of rows IIa and IVb are usually more elongate than those of IIb and IVa, and thus give rise to broader poriferous zones. One counts 31 pairs of pores in one row of petal II on a specimen 33.7 mms long. Pore pairs of the unpaired petal are not at right angles to the edge of the petal but are in the form of 'V's pointing towards the apical system. Pores of this petal vary from round to oblong in shape in both rows, they are always separated by a well developed single or double granule. In the paired ambulacra, immediately after the petaloid portions, occur ares in which tubercles are almost absent and the granules smaller and more tightly packed giving a smooth appearance in comparison with the rest of the upper surface of the test. The subanal fasciole is very variable in its development, often incomplete or diffuse.

DISTRIBUTION Upper Cenomanian and Turonian in Touraine and Aquitaine. Turonian of the Anglo-Paris Basin.

MATERIAL EXAMINED 1 specimen from Bousse, Sarthe, 2 from Briollay - 1 Cenomanian and 1 Turonian (Cotteau Coll.); 1 from the Cenomanian of Briollay (MHNP); type material of Micraster Sanctae-Maurae from Ste. Maure, Aube (MHNP); 5 from the Lata Zone, 1 from the Planus Zone, Dover (Wood Coll.); specimens in the Rowe Collection from the Labiatus Zone of South Devon, from the Lata Zone of Hooker, White Cliff, South Down Common and Compton Bay, from the Planus Zone of Pinhay Bay, Westerham and Dover; 1 from the Labiatus Zone of Beer (C.W. Wright Coll.), 1 from the Planus Zone at Kensworth, Herts (Author's Coll.).

"EPIASTER" LAXOPORUS (d'Orbigny) 1853

Pl. 16, figs. F - H, Pl. 24, figs. c, d.

Micraster laxoporus d'Orbigny 1853, p. 217, pl. 870.

Micraster laxoporus, Desor 1858, p. 366.

Micraster latiporus Cotteau in Cotteau & Triger 1869, p. 385, pl. 64, figs. 1 - 3.

Micraster laxoporus, Lambert 1895, p. 195.

HOLOTYPE Specimen figured by d'Orbigny from the Senonian of La Rousselière, commune de Moutiers, Charente. Not seen.

DESCRIPTION The essential characteristics of this species are the relatively few pairs of pores in the paired petals and the lack of a well developed heel. The specimen figured in plate 16 shows only 23 pairs of pores in one row of petal II (legth 27.1 mms).

DISTIBUTION The species is known from the Coniacian and Santonian of Touraine and Aquitaine.

MATERIAL EXAMINED Two specimens from Villedieu (presumably Bed C - Coniacian) Cotteau Collection.

Lambert divided the post Santonian forms of this species into two varieties, of which I have seen no specimens. He did not designate holotypes for these varieties.

"EPIASTER" LAXOPORUS VAR. CAMPANIENSIS Lambert 1895, p. 196.

This variety differs from "E." laxoporus in that it lacks a heel completely, has narrower and shorter petals with fewer pairs of pores. Although Lambert quotes the number of pores pairs for two specimens (I 15, II 19; I 16, II 21), these figures are of little use without the size of the specimens being given.

This variety is known from the Campanian of Aquitaine.

"EPIASTER" LAXOPORUS VAR. DURANICA Lambert 1895, p. 196.

This variety resembles the proceeding one, but differs in that it is smaller, more elongate, narrower and with a better developed heel. The paired petals are shallower and have more numerous pores. Lambert quotes the following figures for the number of pores :-

locality	horizon	length (mms)	I	II
Pertaillac	R1	35	17	20
Vallières	R	27	17	20
"	R	25	18	18
"	R1	24	16	17

As the var. duranica is stated to be smaller than var. campaniensis, it seems reasonable to assume that the pore counts for the latter variety were taken on larger specimens, and that Lambert's use of the number of pore pairs in distinguishing his varieties is justified.

"EPIASTER" CARENTONENSIS (Lambert) 1895

Pl. 24, fig. e.

Micraster laxoporus, Cotteau & Triger 1869, p. 324, pl. 55, figs. 1 - 4.

Micraster carentonensis Lambert 1895, p. 240.

Micraster latiporus, Lambert 1895, p. 208

HOLOTYPE By implication the large specimen from Pl of Mensignac described by Lambert 1895 p. 241. Not seen.

DESCRIPTION Differs from "E." laxoporus in having braoder paired petals with more numerous pores. Lambert quotes the following pore counts for this species :-

	length (mms)	I	II
All from Pl of Mensignac	47	24	30
	34	22	26
	34	23	28
	42	31	38

According to Lambert the Campanian forms of this species differ from the typical form in having a more elongate polygonal shape, a deeper anterior groove, and a more prominent heel. These variations may be a reflection of size. The Campanian examples are larger than the Santonian ones, and as in the genus Micraster the polygonal shape may be due to old age.

DISTRIBUTION Senonian of Touraine and Aquitaine. The specimens recorded from the Corbières (Lambert 1895, 1901) are almost certainly Cyclaster by virtue of their thick tests.

CHAPTER V (Figs. 35 & 36)

Genus DIPIODETUS Schlüter 1900

Micraster (pars) Lambert 1895, p. 156

Micraster (pars) Lambert 1901, p. 966

Plesiaster Schlüter 1900 (non Pomel 1883), p. 363

Diplodetus Schlüter 1900, p. 364

Micraster (pars) Lambert 1911, p. 50

Micraster (pars) Lambert & Tierry 1924, p. 479

M. (Plesiaster) (pars) Lambert & Thierry 1924, p. 483

M. (Diplodetus) Lambert & Thierry 1924, p. 484

Micraster (pars) Mortensen 1950, p. 364

Plesiaster (pars) Mortensen 1951, p. 368

Diplodetus Mortensen 1951, p. 370

Schlüter originally erected this genus for specimens of so-called Micraster which had both a subanal and a distinct peripetalous fasciole. Those specimens with an incomplete peripetalous fasciole he placed in the genus Plesiaster. Lambert & Thierry (1924) maintained the same species in the same genera (regarded by them as subgenera) as Schlüter despite the fact that they reversed the diagnoses of the genera given by Schlüter. As I attach little importance to the development of fascioles, the genus Diplodetus is here revised so that it includes all the species belonging to a distinct lineage of spatangoids from the Upper Cretaceous of the Northern Faunal Province of Europe.

GENERIC DESCRIPTION

Thin tested spatangoids of small to fairly large size (up to 70 mms long). The anterior notch is shallow or absent. The characteristic side profile shows a high arched posterior, a steeply sloping anterior, a more or less vertically truncated posterior , and a slightly convex oral face. Peristome far from the border (one quarter to one third of the total length), transversely oval with, at the most, a feebly projecting labrum. The peristome is sorrounded by a smooth rim, the pores in the peristomal region are well developed. The periproct is high on the posterior face (usually 65 - 70 % of the total height). The apical system is usually completely destroyed, Schlüter (1900) states that it has four genital pores. Paired petals deeply sunken, closed, the posterior ones about two thirds of the length of the anterior ones. The interporiferous zones of these petals are roughly as broad as one pore zone, apparently smooth or sutured, but covered with microscopic granules. Both the inner and outer rows of pores are elongate. The unpaired petal is broad and shallow with narrow pore zones situated at the edge of the groove. All the pores in this petal are round and separated by a granule, the interporiferous zone is very broad, being at least three times as wide as one pore zone. Periplastronal areas appear smooth, but are covered by microscopic granules. Distinct subanal fasciole. Peripetalous fasciole absent or partially developed.

GEOLOGICAL RANGE Upper Santonian to Danian.

GEOGRAPHICAL DISTRIBUTION Belgium, the Münster Basin (Germany), southern Sweden and Poland. The distribution of this genus within the Northern Faunal Province appears to be controlled by facies. The Köpinge Sandstone of Scania, the Danian deposits of Pulawska and the Craie Marneuse of Slenaken are all fine grained glauconitic marly sandstones. Bather (1896) describes the Upper Santonian of Recklinghausen as "a glauconiferous sandstone, the grains of which are cemented by carbonate of lime." Arnold (1964) describes the Dulmener and Osterwicker Schichten of Coesfeld, Lette, Darup and Holtwick (from which most of the German Campanian forms were collected) as being composed mainly of fine sandy marls or marls.

The species of this genus are very stable in their shape and ornamentation. The only variable characters appear to be the depth of the anterior notch and the development of the peripetalous fasciole. One doubts whether many of the species from different countries could be distinguished with any certainty if they were examined together. Unfortunately I have not been able to make such comparisons.

The following is an annotated list of the species included in the genus. The comments on the German species, which I have not examined, are taken from Schlüter's works.

TYPE SPECIES <u>Diplodetus schlueteri</u> Lambert 1924, designated by Lambert in Lambert & Thierry 1924.

<u>Brissopsis brevistella</u> Schlüter 1870b, p. 132.

<u>Diplodetus brevistella</u>, Schlüter 1900, p. 364, pl.XV, figs. 3-5.

<u>Diplodetus schlueteri</u> Lambert in Lambert & Thierry 1924,p.484.

From the Mucronata Zone of Coesfeld and Darup, Westphalia.

Schlüter's observation that one can see four genital pores on one of his dozen examples is the only evidence as to the structure of the apical system in this genus. The peripetalous fasciole is well developed, arching inwards between the petals, on occasional examples lacking on the sides of the unpaired petal. Anterior notch minimal.

<u>Diplodetus cretaceus</u> (Schlüter) 1870

<u>Brissopsis cretacea</u> Schlüter 1870a, p. 956.

<u>Brissopsis cretacea</u>, Schlüter 1870b, p. 132.

<u>Diplodetus cretaceus</u>, Schlüter 1900, p. 366, pl. XV, fig. 2.

<u>Diplodetus cretaceus</u>, Lambert & Thierry 1924, p. 484.

From the Upper Campanian (<u>Heteroceras polyplocum</u> Zone) of Halden, Lemförde and Königslutter.

Due to poor preservation Schlüter could only assume that the peripetalous fasciole is complete from fragments of it in different postions on different specimens. Anterior notch absent.

Diplodetus recklinghausenensis Schlüter 1900

Diplodetus (?) recklinghausenensis Schlüter 1900, p. 368, pl. XV, fig. 1.

Diplodetus recklinghausenensis, Lambert & Thierry 1924, p.484.

From the Upper Santonian (Uintacrinus & Marsupites Zones) of Recklinghausen and Braunschweig.

Distinct (? complete) peripetalous fasciole. No anterior notch.

Diplodetus minor (Schlüter) 1870

Brissopsis minor Schlüter 1870b, p. 132.

Plesiaster minor, Schlüter 1900, p. 369, pl. XVI, figs. 3-5.

Plesiaster minor, Lambert & Thierry 1924, p. 484.

From the Lower Campanian (Quadrata Zone) of Lette, Coesfeld and Holtwick, Westphalia.

Peripetalous fasciole poorly developed, apparently restricted to the extremities of the paired peatls. No anterior notch.

Diplodetus cavifer (Schlüter) 1900

Plesiaster (?) cavifer Schlüter 1900, p. 371, pl. XVII, figs. 3,4.

Plesiaster cavifer, Lambert & Thierry 1924, p. 484.

From the uppermost Lower Campanian (Becksia soekelandi Zone) of Lette and Coesfeld.

Peripetalous fasciole as in D. minor.Anterior notch feeble;

Diplodetus cordiformis (Schlüter) 1900

Plesiaster (?) cordiformis Schlüter 1900, p. 372, pl. XVI, figs. 1,2.

Plesiaster cordiformis, Lambert & Thierry 1924, p. 484.

From the lower part of the Upper Campanian near Coesfeld.

Only minor fragments of the peripetalous fasciole preserved on occasional specimens due to the ornamentation of the test having been destroyed during cleaning before Schlüter examined them. Anterior notch quite well developed.

Diplodetus parvistella (Schlüter) 1899

Plesiaster parvistella Schlüter 1899, p. 121, pl. IX, fig. 5.

Plesiaster parvistella, Lambert & Thierry 1924, p. 484.

From the Hornstein of the Aachener Waldes.

Diplodetus aquisgranensis (Schlüter) 1899

Hemiaster (?) aquisgranensis Schlüter 1899, p. 123, pl. X, figs. 1,2.

From the Hornstein of the Aachener Waldes.

Diplodetus bucardium (Goldfuss) 1826

Spatangus Buccardium Goldfuss 1826, p. 157, pl. 49, fig. 1.

Micraster Bucardium, Agassiz 1836, p. 184.

Hemiaster Bucardium, Agassiz & Desor 1847, p. 17.

Hemiaster bucardium, d'Orbigny 1853, p. 264, pl. 894, fig.1-3.

Periaster bucardium, Desor 1858, p. 384.

Plesiaster bucardium, Schlüter 1899, p. 119, pl. IX, fig.1-4.

Plesiaster bucardium, Lambert & Thierry 1924, p. 484.

Hemiaster bucardium, Zoeke 1951.

From the Hornstein of the Aachener Waldes.

Diplodetus duponti (Lambert) 1911

Pl. 13, fig. G.

Micraster Duponti Lambert 1911, p. 50, pl. II, fig. 21
pl. III, fig. 1,2;

Micraster Duponti, Lambert & Thierry 1924, p. 481.

Micraster duponti, Smiser 1935, p. 81.

? Micraster duponti, Kongiel 1935, pl. V (VIII), fig. 1a-b.

The holotype (I.G. 4285, Bruxelles Museum) is stated by Lambert (1911) to come from Slenaken. My notes state that this specimen came from the Maastrichtian of Kunraad.

I was unable to confirm Lambert's statement that there are four genital pores, because the apical system of the holotype is, as usual, destroyed by slight crushing. Nor could I detect a peripetalous fasciole.

Smiser (1935) records the species from Maastricht. Other specimens, in the Musée Royal d'Histoire Naturelle, belonging to this species are :- I.G. 4285 from the Assise de Nouvelles at Kundort (Limbourg); two specimens numbered I.G. 5185 from the Lower Maastrichtian of Kunraad; I.G. 9457 from Eben-Emael (Canal Albert) from the Maastrichtian (probably Cr4 - Meijer MS); and two specimens numbered I.G. 6521 from the Lower Maastrichtian of Kunraad. I have also seen specimens from Maastricht in the collection of M. Garsay of Maastricht. Kongiel has a specimen of Diplodetus (Muzeum Ziemi Ee 240) from the Danian of Pulawska which he refers to this species (Kongiel 1935).

Diplodetus idae (Cotteau) 1870

Pl. 13, fig. F.

Micraster Idae Cotteau 1870, p. 3, pl. 12, figs. 4-7.

Micraster Idae, Lambert 1895, p. 211.

Micraster Idae, Lambert 1901, p. 966.

Micraster Idae, Lambert & Thierry 1924, p. 482.

From the Köpinge Greensand (Mucronata Zone) of Köpinge, Scania. The holotype (not seen) is in the Nielsen Collection at Lund University, and not the Cotteau Collection as stated by Lambert, this specimen being a plaster cast of the holotype.

Specimens of this species in the Riksmuseet (Stockholm) are variously labelled as M. coranguinum (which may account for records of this species in Sweden), M. corbovis, M. Idae and Brissopsis (?) cretacea.

The Köpinge region of the Ystad Basin once yielded this species in abundance when the greensand was exposed. There are about 50 specimens from this area in the Riksmuseet coming from Köpinge, Arup, Ofvarp, Ystads-Trakten, and Svenstorp. The Nielsen Collection contains many more specimens.

The Upper Campanian of the Kristianstad Basin is represented in part by calcilutites. From such a facies at Bäckaskog I have seen only two specimens of Diplodetus in the Riksmuseet.

Diplodetus depressus (Kongiel) 1936

Micraster depressus Kongiel 1936, p. 116, pl. I (V), figs. 6 - 9.

The holotype (Muzeum Ziemi Ee 254) comes from the Lower Danian of the Pulawy region.

Moskvin & Poslavskaia (1959) attribute Lower and Middle Danian spatangoids from the Caucasus and Crimea to Kongiel's species, which they transfer to the genus Protobrissus of Lambert. They donated a typical example of the Russian form to the Muzeum Ziemi (Ee 652). Comparison of this specimen with the holotype of Kongiel shows that the two forms are in no way related.

CONCLUSIONS

I) FAUNAL REALMS AND PROVINCES

On the basis of spatangoid echinoids the Cretaceous seas of the American, European and north African continents are divided into two Faunal Realms - the North African and European Realms.

The North African Realm is characterised by Toxasters and a distinctive <u>Hemiaster</u> stock. It lacks holasteroids which, along with the genus <u>Micraster</u>, typify the European Realm.

Contemporary allopatric species of <u>Micraster</u>, resulting from rapid geographical speciation during the major migration in Coniacian times, enable distinct Faunal Provinces to be established within the European Realm. These Provinces are called the Northern Faunal Province, Anglo - Paris Basin Province, Touraine - Aquitaine Province, and Pyrenean Province. Distinctive Micrasters also occur in the Algero - Tunisian region of the North African Realm.

The south-east of the Paris Basin forms a Subprovince of the Anglo - Paris Basin Province in Upper Turonian times.

Following work on the distribution of modern echinoderms, the Faunal Provinces are interpreted as reflecting Cretaceous water masses, which themselves may reflect differences in temperature.

The European Faunal Realm and the Provinces within it are shown to migrate southward with time. Major southward migrations are seen in the Coniacian and the Campanian. These migrations may reflect climatic cooling during the Upper Cretaceous. The migrations of Faunal Realms and Provinces are summarised in Part II Chapter XXI.

The Faunal Provinces of the European Upper Cretaceous are based solely on the species of one genus - Micraster. With the exception of certain forms which are common to both the Northern Faunal Province and the Anglo - Paris Basin Province, the Provinces are based on the mutual exclusion of contemporary species. The Provinces do not appear to be facies controlled

The conclusions expressed in the latter paragraph are in contrast to those expressed by workers on Jurassic Faunal Realms. Hallam (1969) emphasises that the Boreal and Tethyan Realms of the Jurassic are characterised by the relative abundance of contemporary organisms, that the differences are gradational, and that they are facies controlled.

II) SYSTEMATICS

The present system of classifying spatangoid echinoids, based essentially on the development of various fascioles, is rejected. A revision of spatangoid classification must await an examination of actual specimens.

MICRASTER is shown to be a very varied, rapidly changing, widespread, dead-end genus of Turonian to Lower Maastrichtian age. It was most probably derived from the conservative Touraine - Aquitaine "Epiaster" stock.

The Turonian to Santonian trends of Micraster described by Rowe (1899) with reference to southern England are paralleled in Micrasters from other regions, but not necessarily at the same rate. Micrasters in the Northern Faunal Province evolved more rapidly than those elsewhere in Europe.

Sympatric species of Micraster are shown to be most easily distinguished by the relative height of their periprocts.

DIPLODETUS is redefined and, although it is shown to be strongly facies controlled in its occurance, it is restricted to the Northern Faunal Province. It ranges from the Santonian to the Danian.

III) STRATIGRAPHY

SOUTHERN ENGLAND

It is suggested that the name Cortestudinarium Zone be replaced by the name Decipiens Zone. The lower part of this Zone is characterised by Micraster normanniae and is most probably of Turonian age.

CORRELATION OF THE UPPER CRETACEOUS OF THE DIFFERENT FAUNAL PROVINCES is summarised in Part II Chapter XX.

COLLECTIONS EXAMINED

ENGLAND

BRITISH MUSEUM (NATURAL HISTORY)

Rowe, T. Wright, and other Collections

INSTITUTE OF GEOLOGICAL SCIENCES

C.J. Wood, H.B. Woodward, and other Collections

NORWICH CASTLE MUSEUM

Rose, Brydone, and other Collections

PRIVATE COLLECTIONS OF

C.W. & E.V. Wright, J.M. Hancock, J.D. Hollis

FRANCE

UNIVERSITE DE PARIS VI

Lambert Collection

MUSEE D'HISTOIRE NATURELLE, PARIS

De Grossouvre, Peron, and other Collections

UNIVERSITE D'ORSAY

Cotteau Collection

SWITZERLAND

UNIVERSITE DE NEUCHATEL

Agassiz & Desor Collection of plaster casts

BELGIUM

MUSEE ROYAL D'HISTOIRE NATURELLE, BRUXELLES

Various Collections

GERMANY

UNIVERSITAT MUNSTER

HUMBOLDT UNIVERSITY and other Collections

TECHNISCHE UNIVERSITAT BRAUNSCHWEIG

Ernst Collection and specimens in the care of Dr. Ernst from the Collections of Spiegler (Hamburg), Tröger (D.D.R.), Schlüter (Bonn), Schmidt (Hannover).

DENMARK

MINERALOGICAL MUSEUM, COPENHAGEN

Various Collections

SWEDEN

LUND UNIVERSITY

Nielsen Collection

NATURHISTORISKA RIKSMUSEET, STOCKHOLM

Hägg and other Collections

POLAND

MUZEUM ZIEMI, WARSAW

Maczynska Collection, remains of Nowak and Kongiel Collections, specimens from Moskvin & Poslavskaia and other Collections.

ABBREVIATIONS

The numbers and letters used for ambulacral and inter-ambulacral areas and rows are those given by Lovén (1874).

I.G.S. Institute of Geological Sciences, London.

B.M.(N.H.) British Museum (Natural History), London.

M.H.N.P. Musée d'Histoire Naturelle, Paris.

B.S.G.F. Bull. Soc. géol. France.

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ERRATA AND ADDENDA

p. 23 line 10 for calk read Chalk

p. 34 " 7 " Thierry " Thiery

p. 41 The ages of *Isomicraster danei*, *Micraster uddeni* and *M. americanus* are Santonian, Santonian and Maastrichtian respectively.

p. 51 line 1 for Idid read I did

" " 3 " Lamert " Lambert

p. 60 " 13 " rest " rests

p. 90 " 17 " groun " ground

p. 97 " 24 " is " are

p. 112 " 12 " *M. regularis* read *M. marginalis*

p. 128 " 12 " *T. kiliani* " *T. cf. lorioli*

p. 130 " 7 " (1882) " (1885)

p. 133 " 20 " (1962) " (1963)

" " 21 " Touronian " Turonian

p. 159 " 6 " XXI " X

" " 14 " Sclüter " Schlüter

p. 161 " 22 " XVII, 1-5, " XV, 1 -5

p. 183 " 10 " Internation " International

p. 200 " 1 " Contrata " Contrasta

p. 232 " 2 Not restricted to the Münster Basin

p. 254 add HALLAM A., 1969 : Faunal Realms and Facies in the Jurassic. *Palaeontology* 12, 1 - 18.

p. 368 (Pl. 33, figs. A - C) for *M. schlueteri* (Coquand) read *M. cortestudinarium* (Goldfuss).

FIG. 1

SUBDIVISIONS OF THE CRETACEOUS

DANIAN		
MAASTRICHTIAN		
CAMPANIAN	SENONIAN	UPPER CRETACEOUS
SANTONIAN		
CONIACIAN		
TURONIAN		
CENOMANIAN		
ALBIAN		LOWER CRETACEOUS
APTIAN		
BARREMIAN	NEOCOMIAN	
HAUTERIVIAN		
VALANGINIAN		
BERRIASIAN		

FIG. 2

RELATIVE STRATIGRAPHICAL POSITIONS OF NORTH AMERICAN FORMATIONS

From Clark & Twitchell 1915

Western Interior	Texas		Eastern Gulf Area	North Atlantic Border		Europe
				MANASQUAN		
LARAMIE						DANIAN
				RANCOCAS		
			RIPLEY	MONMOUTH		
	NAVARRO					
MONTANA	TAYLOR					SENONIAN
	AUSTIN		SELMA	MATAWAN		TURONIAN
COLORADO	EAGLE FORD					
			EUTAW			
DAKOTA				MAGOTHY		
	WOODBINE		TUSCALOOSA			
				RARITAN		CENOMANIAN
	WASHITA					
FUSON						ALBIAN
				PATAPSCO		APTIAN
	FREDERICKSBURG	COMANCHE SERIES				
				ARUNDEL	POTOMAC SERIES	BARREMIAN
LAKOTA	TRINITY					
			BASAL CLAYS ? = PATUXENT	PATUXENT		NEOCOMIAN
MORRISON						

FIG. 2A

TURONIAN AND SENONIAN ZONES OF NORTHERN GERMANY

UPPER CAMPANIAN	UPPER	Langei Zone Minor / Polyplocus Zone	Kca4
	LOWER	Upper Vulgaris Subzone Vulgaris / Basiplana Subzone Upper Conicus / Senior Subzone Lower Conicus / Senior Subzone	Kca3
LOWER CAMPANIAN	UPPER	Gracilis / Senior Zone Conicus / Papillosa Zone Papillosa Zone Senonensis Zone Pilula / Senonensis Subzone	Kca2
	LOWER	Pilula Zone Lingua / Quadrata Zone Granulataquadrata Zone	Kca1
SANTONIAN	UPPER	Marsupites Zone Uintacrinus Zone	Ksa4
	MIDDLE	Westfalicagranulata Zone	Ksa3
		Cordiformis / Westfalica Zone	Ksa2
	L.	Undulatoplicatus Zone	Ksa1
CONIACIAN	U.	Subquadratus Zone	Kco3
	M.	Involutus Zone	Kco2
	L.	Koeneni Zone	Kco1
TURONIAN	U.	Deformis Zone	Kt4
	MID.	Vancouverensis Zone	Kt3
		Lamarcki Zone	Kt2
	L.	Labiatus Zone	Kt1

FIG. 3
STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS
IN NORTHERN GERMANY

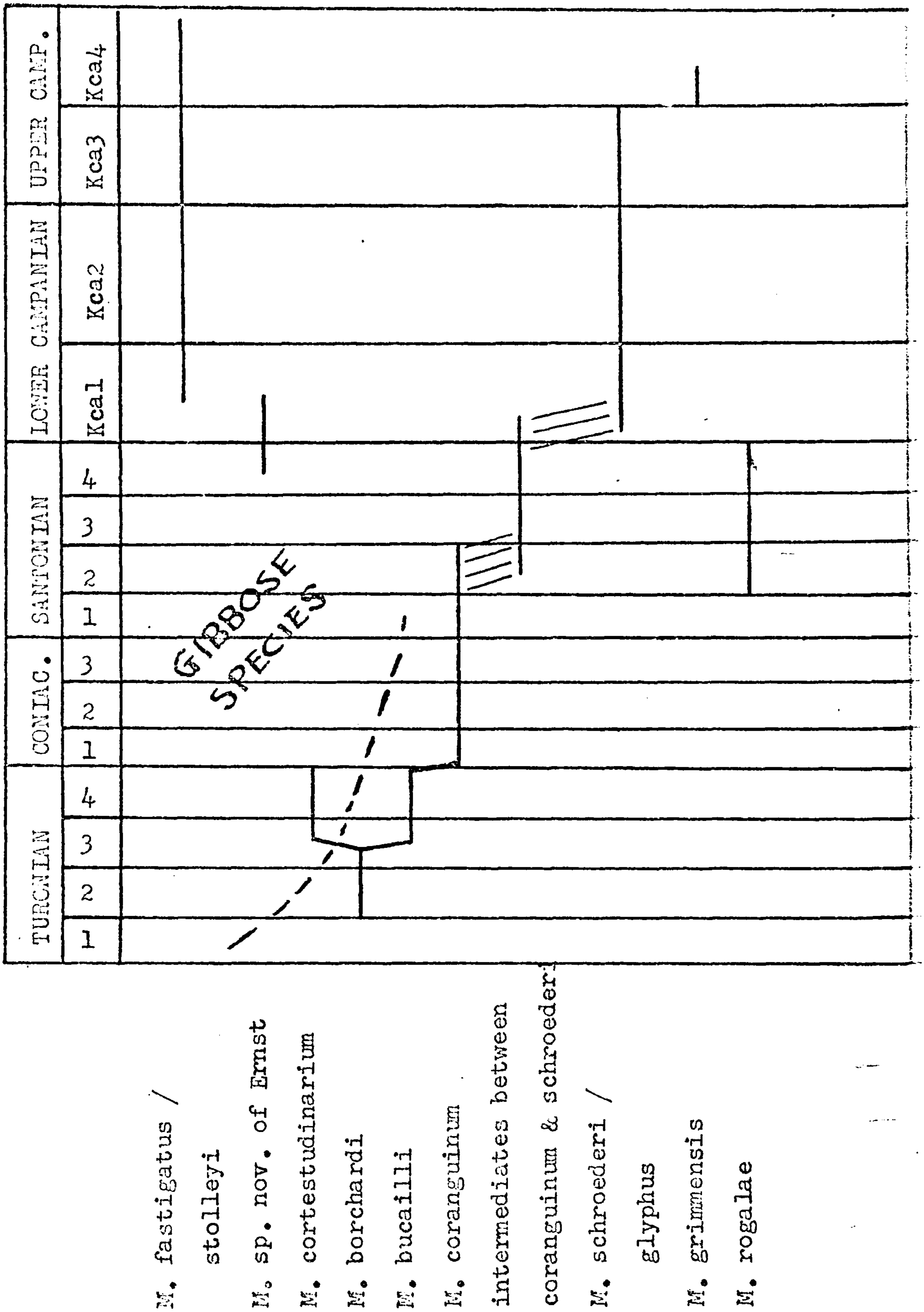


FIG. 4
MICRASTERS FROM THE STAFFHORST MINE-SHAFT

DEPTH IN METRES	INOCERAMUS STRAT.	FORAM. STRAT.	MICRASTER occurance
	Tertiary	Tertiary	
250	pinniformis Middle Santonian	upper Middle Santon.	
		lower Mid. Sant	
300	Lower Sant.		*M. coranguinum* of very advanced type 295-300
	Upper Coniacian	Lower Santon.	
350	Middle Coniacian	Upper Coniac.	
400	Lower Coniacian	Lower Coniac.	*M. coranguinum* 387-406
450	Upper Turonian	Upper Turonian	Intermediated between *M. bucailli* and *M. coranguinum* 447-460
			M. bucailli 473-477
500			Intermediates between *M. borchardi* and *M. bucailli* 480-514
			M. borchardi 528-537
550	evidence lacking		
	upper M. Tur		
600	lower Middle Turonian	Middle Turonian	

The specimens were examined thanks to the kindness of Dr. G. Ernst, who also provided the unpublished work on the stratigraphy of this section.

FIG. 5

An interpretation of the depth of burrowing of Micrasters in northern Germany outside the Münster Basin.

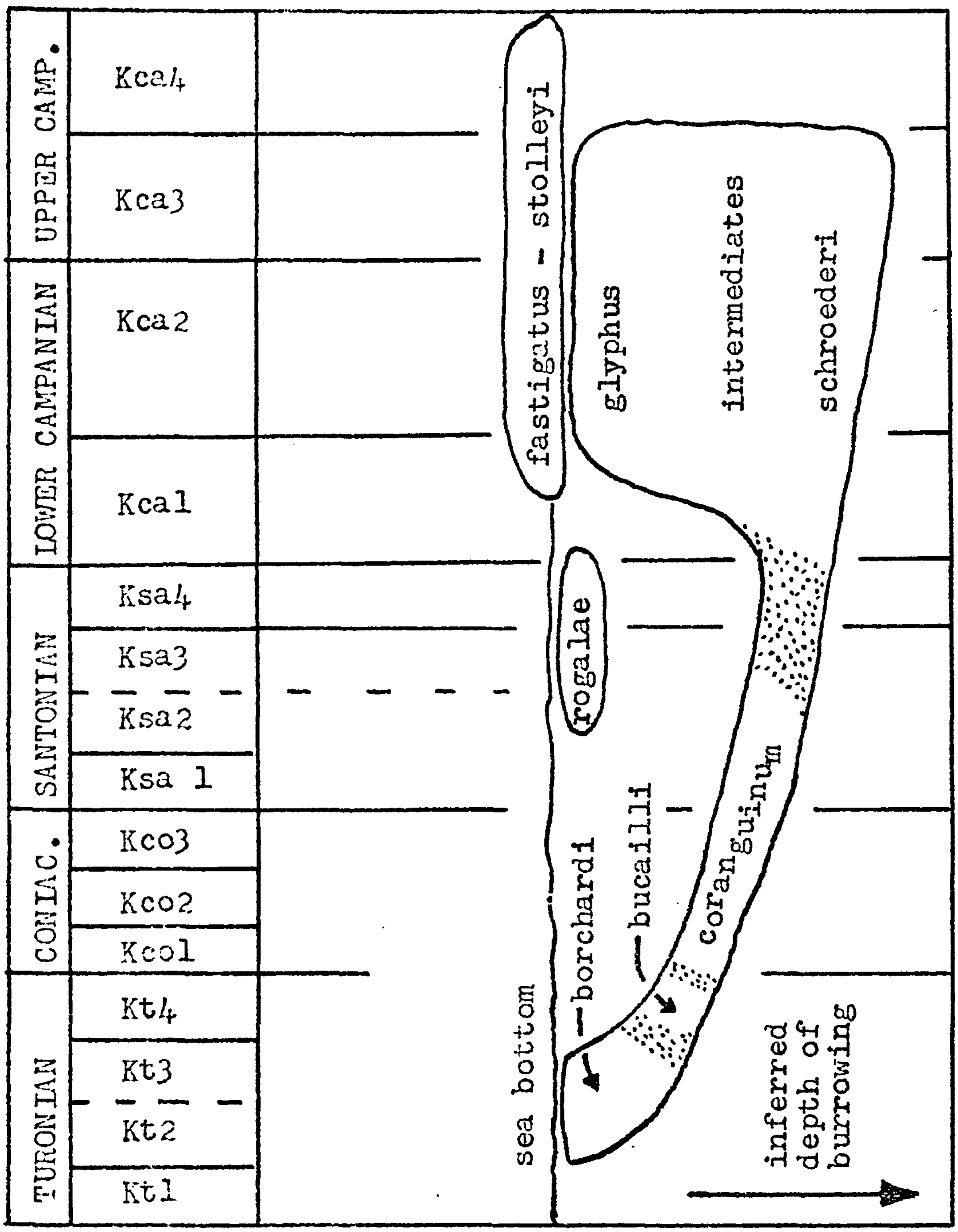


FIGURE 6

Graph showing the distinction between *M. bucailli* and *M. cortestudinarium* on the basis of the relative height of their periprocts.

Solid Triangles	*M. cortestudinarium* from the Deformis Zone of Paderborn. Author's Collection
Open Triangles	*M. cortestudinarium* from Salder bei Saltzgitter. Author's Collection
Open Squares	*M. bucailli* from the Cortestudinarium Zone of Yorkshire. C.W. & E.V. Wright Collection.

FIG 6

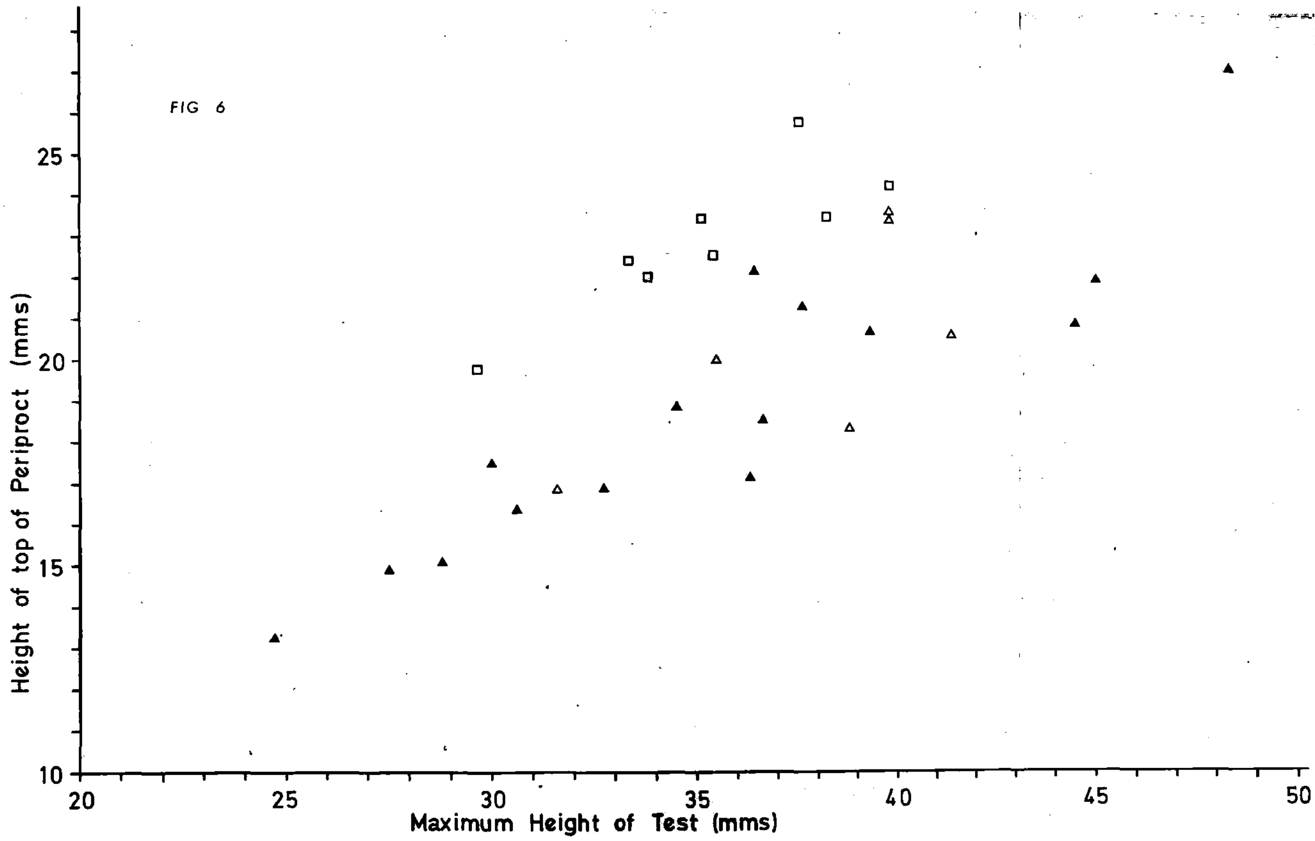

Height of top of Periproct (mms)
25
20
15
10
20
25
30
35
40
45
50
Maximum Height of Test (mms)

FIGURE 7

Graph showing the distinction between *M. fastigatus* and *M. schroederi* / *glyphus* in the Lower Campanian of northern Germany.

Circles *M. schroederi* / *glyphus*
1 specimen from Breitenburg, Schmidt Coll.
2 from Höver, C.W. & E.V. Wright Collection.
13 from Höver, Author's Collection.

Triangles *M. fastigatus* 1 specimen from Alsen Quarry (Lägerdorf), and 18 from Höver Quarry (Hannover) Author's Coll.

LOWER CAMPANIAN of NORTHERN GERMANY FIG 7

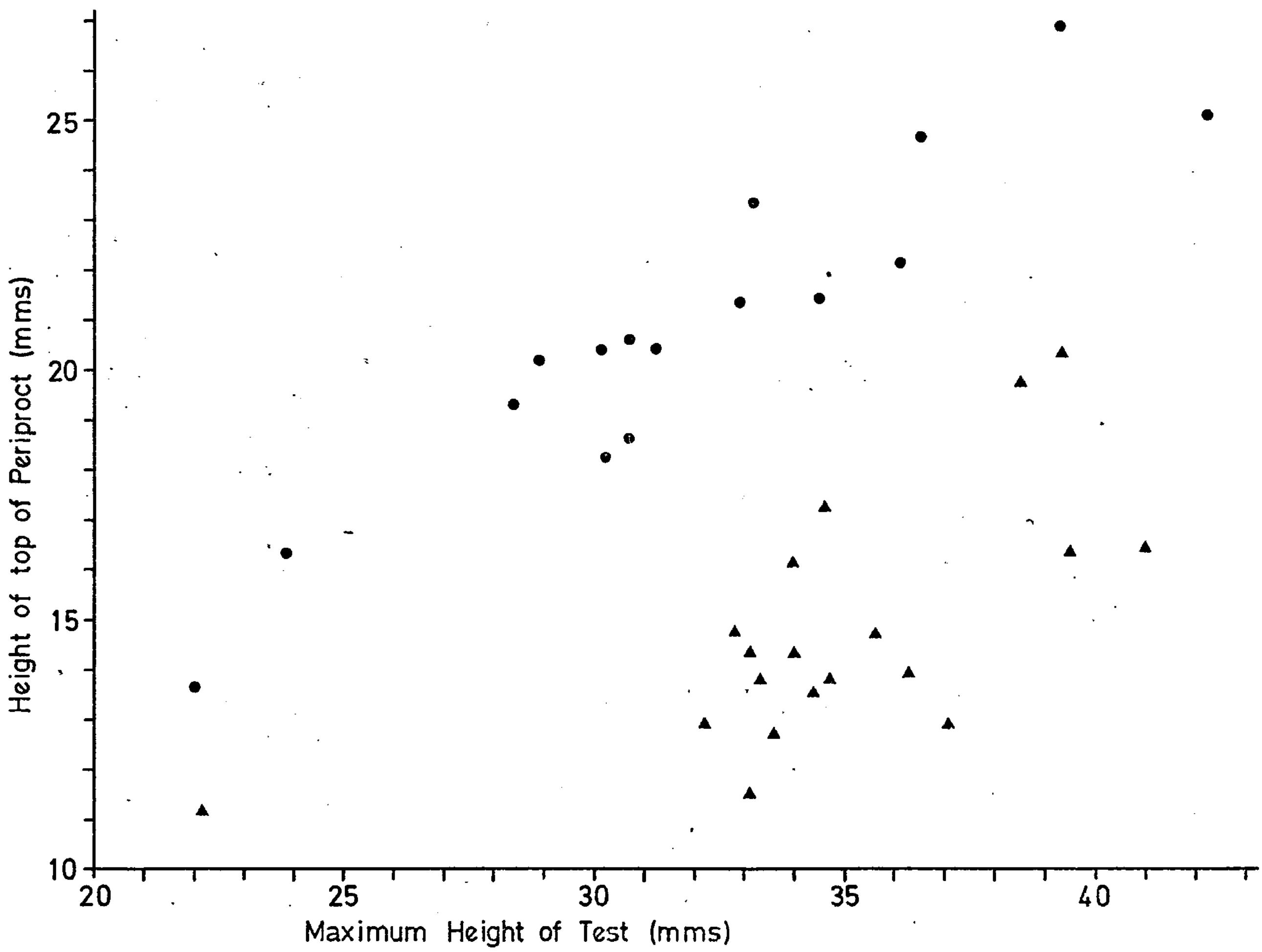


FIGURE 8

Graph showing the distinction between *M. stolleyi* and *M. schroederi* / *glyphus* in the Upper Campanian of north Germany.

Circles *M. schroederi* / *glyphus*

2 from Darup, Schlüter Collection.

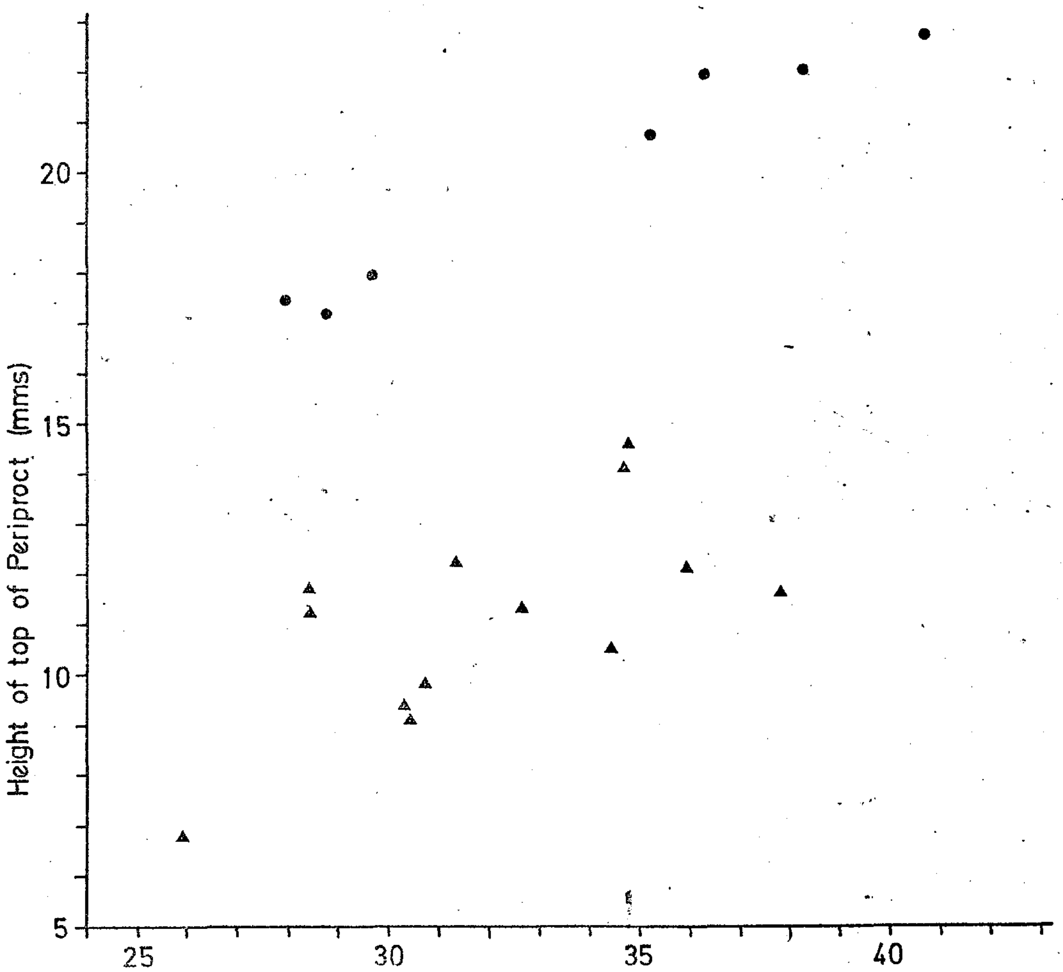
2 from Dolburg, Munster University.

1 from Porta Westfalica, Munster Univ.

2 from Teutonia Quarry (Hannover) Author's Collection.

Triangles *M. stolleyi* 13 specimens from Teutonia Quarry (Hannover) Author's Collection.

UPPER CAMPANIAN of NORTHERN GERMANY FIG 8



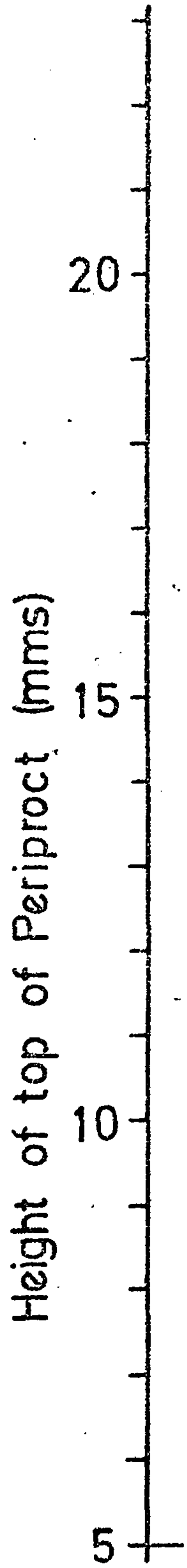
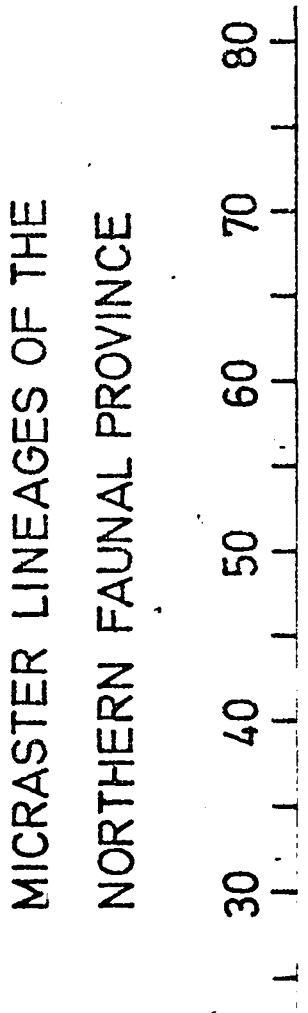

Height of top of Periproct (mms)
20
15
10
5

FIGURE 9

Periproct height ratio of some Northern Faunal Province Micrasters.

MIDDLE TURONIAN	*M. borchardi*. 6 specimens. Lamarcki Zone, Wüllen. Author's Collection.
UPPER TURONIAN	*M. cortestudinarium*. 21 specimens. Paderborn (Deformis Zone) and Salder bei Saltzgitter. Author's Collection.
CONIACIAN	*M. coranguinum*. 1 specimen. Lower Coniacian, Staffhorst Mineshaft. Spiegler Collection.
LOWER SANTONIAN	*M.* sp. Bavnodde Greensand, Bornholm. Ravn Coll., Min. Mus. Copenhagen.
SANTONIAN	*M.* sp. Hibernian Greensand, County Derry. Hancock Collection.
CAMPANIAN	Explanation as in Figures 7 and 8. The gibbose species (*M. fastigatus* & *M. stolleyi*) are those with the lower periproct height ratios.

FIG. 9


MICRASTER LINEAGES OF THE
NORTHERN FAUNAL PROVINCE
30
40
50
60
70
80

MICRASTER LINEAGES OF THE NORTHERN FAUNAL PROVINCE

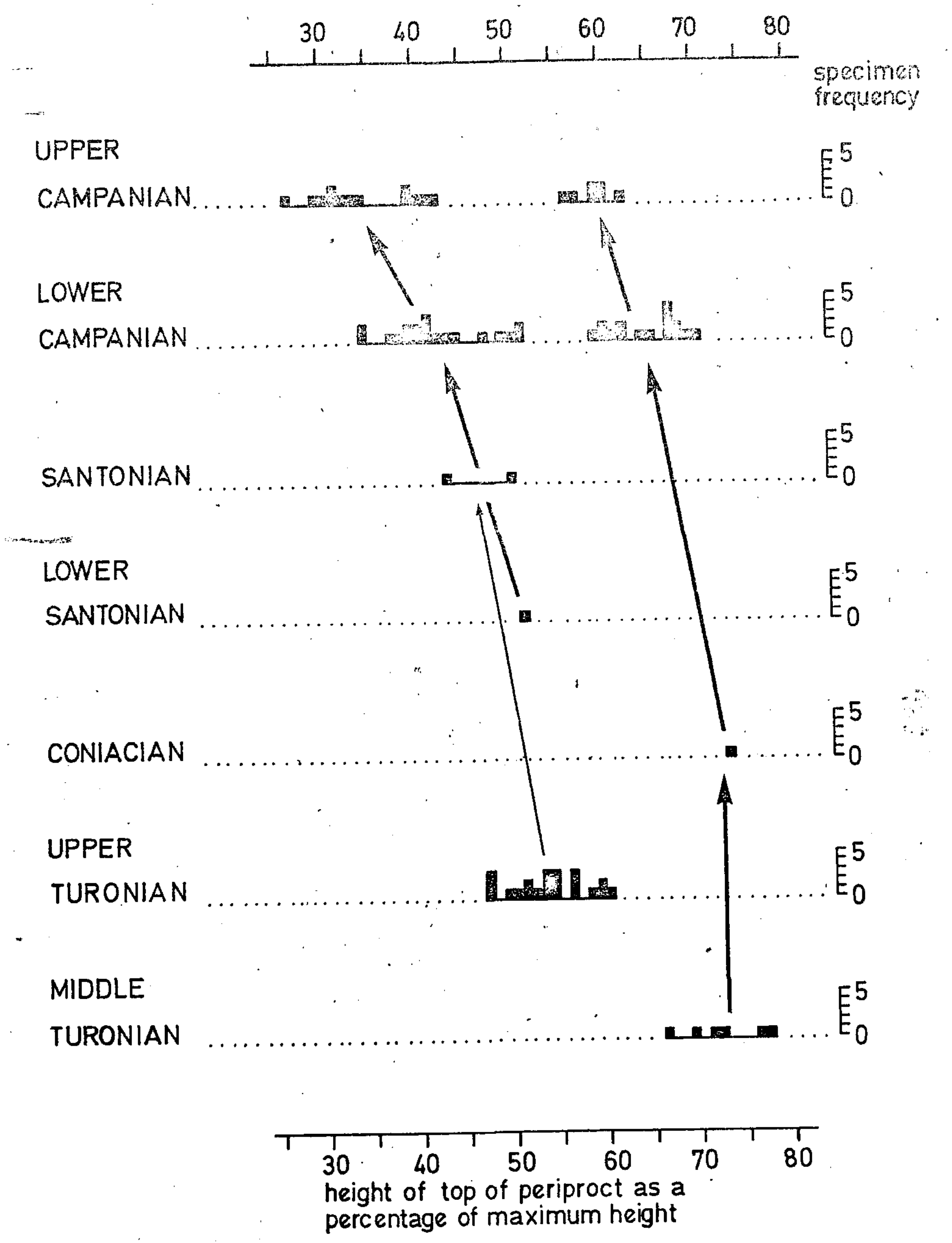


FIG. 10

STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE SENONIAN OF BELGIUM

M. stolleyi var. ciplyensis

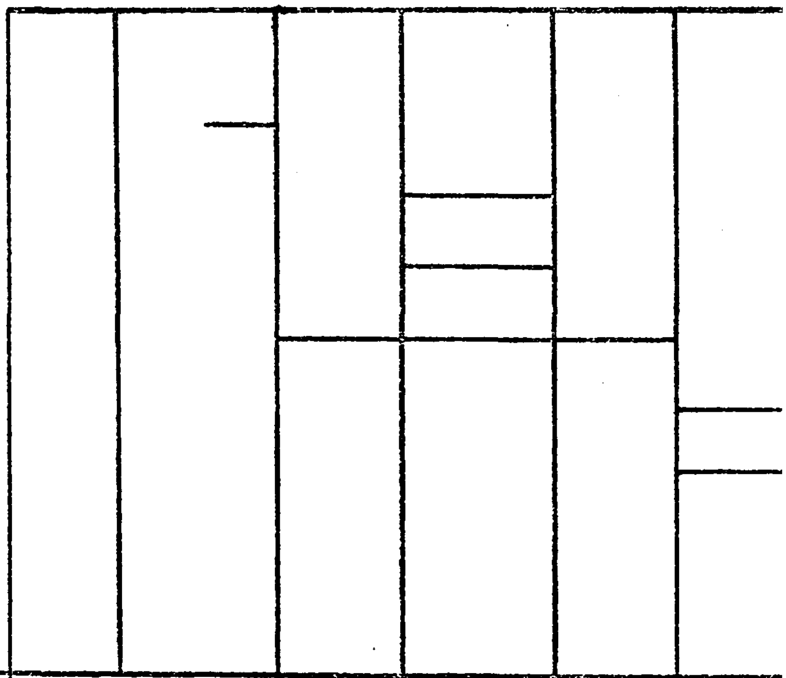
M. stolleyi s. s.

M. gibbus

M. schroederi / glyphus

M. rogalae

M. coranguinum



LAMBERT 1911	PEAKE & HANCOCK 1961	LITHOLOGICAL UNITS
	Belemnella licharewi	CRAIE DE CIPLY
		?
R	Belemnella lanceolata	CRAIE DE SPIENNES
	Belemnitella langei	?
P	Belemnitella mucronata minor	CRAIE DE NOUVELLES
N	Belemnitella mucronata s.s.	CRAIE D'OBOURG
M	Gonioteuthis quadrata	CRAIE DE TRIVIERES
SANTONIAN		CRAIE DE ST. VAAST

FIG. 11

STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE UKRAINE ACCORDING TO PASTERNAK ET. AL. 1968

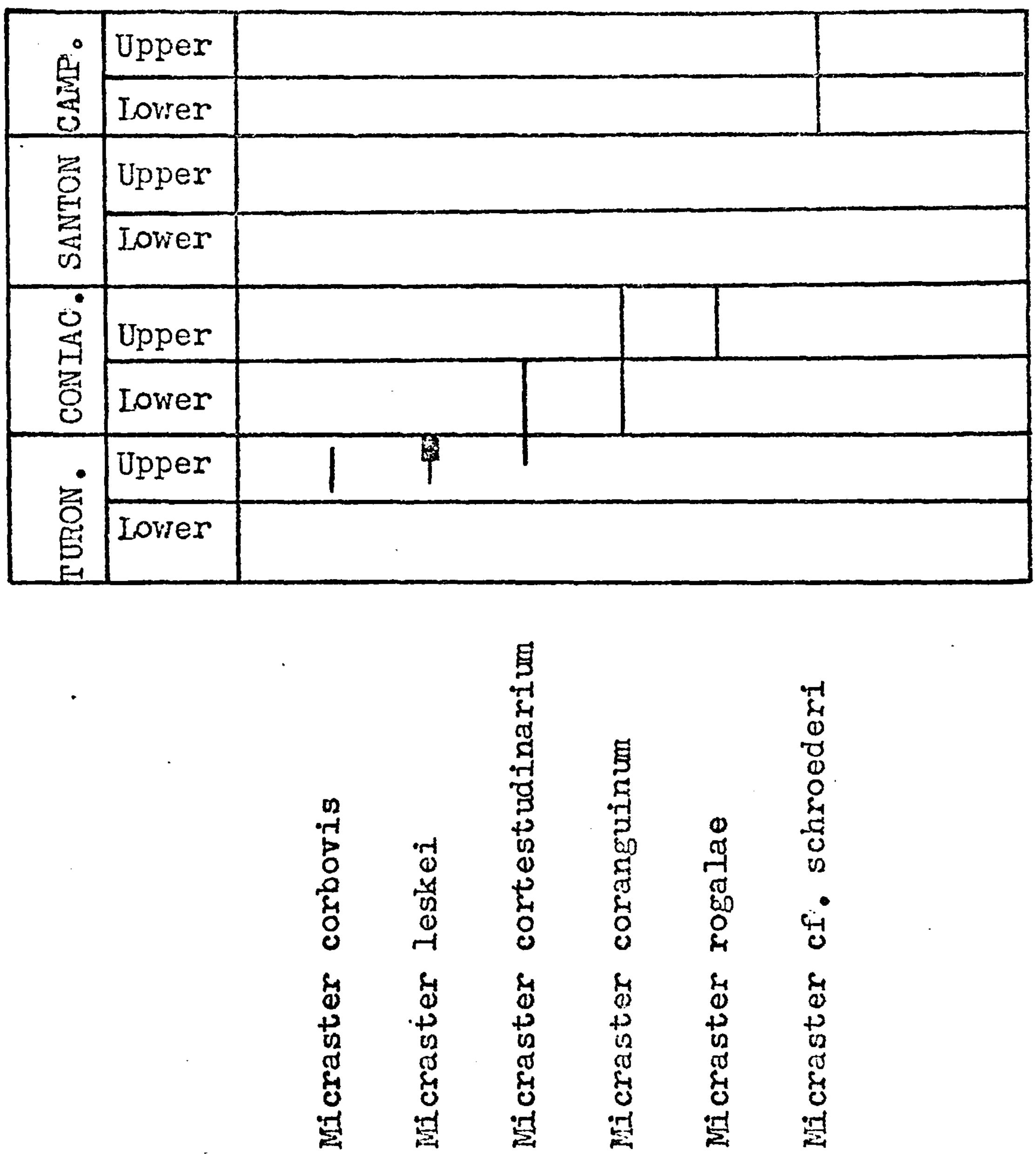


FIG. 12

STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE DONETZ BASIN ACCORDING TO SAVCHINSKAYA 1967

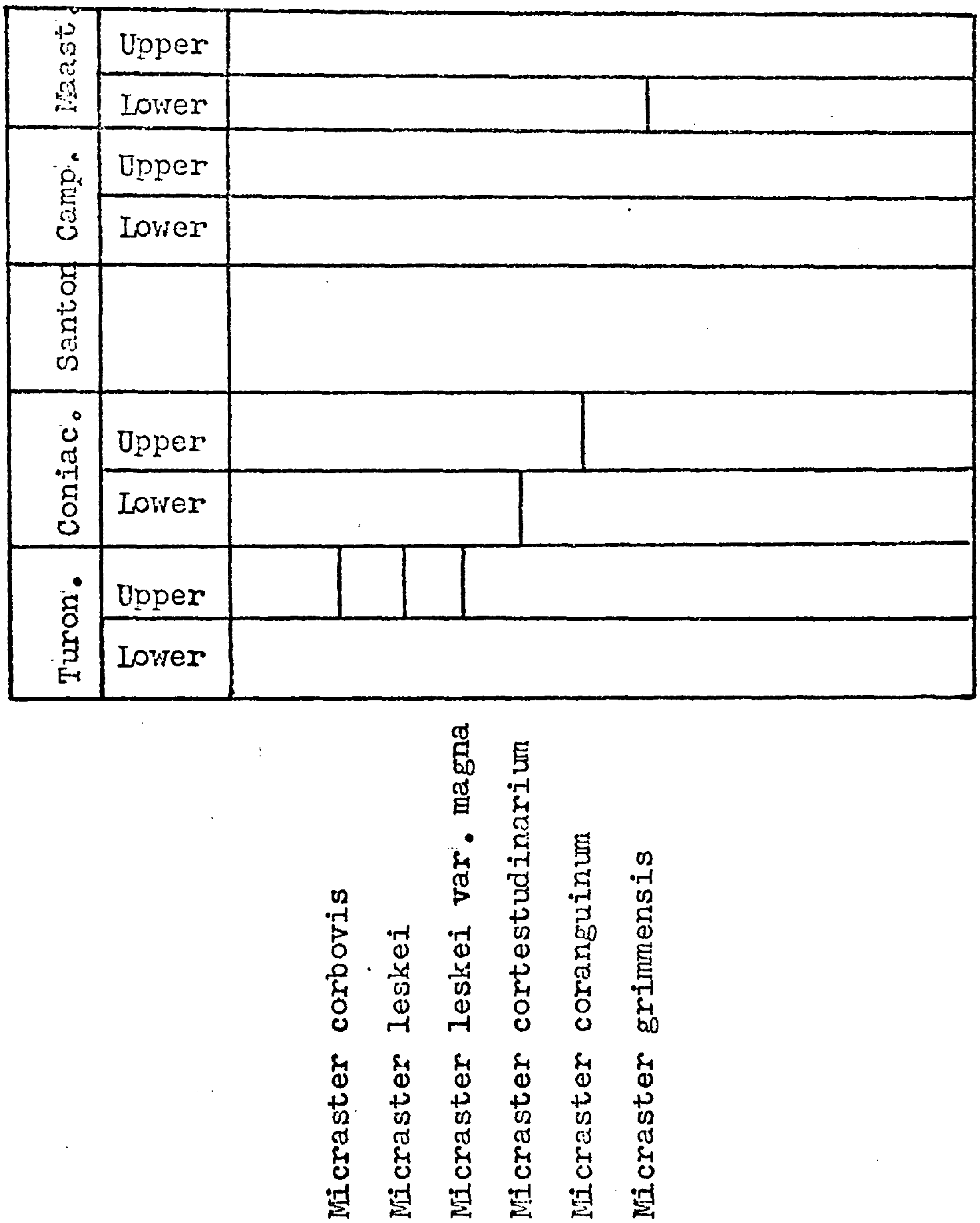
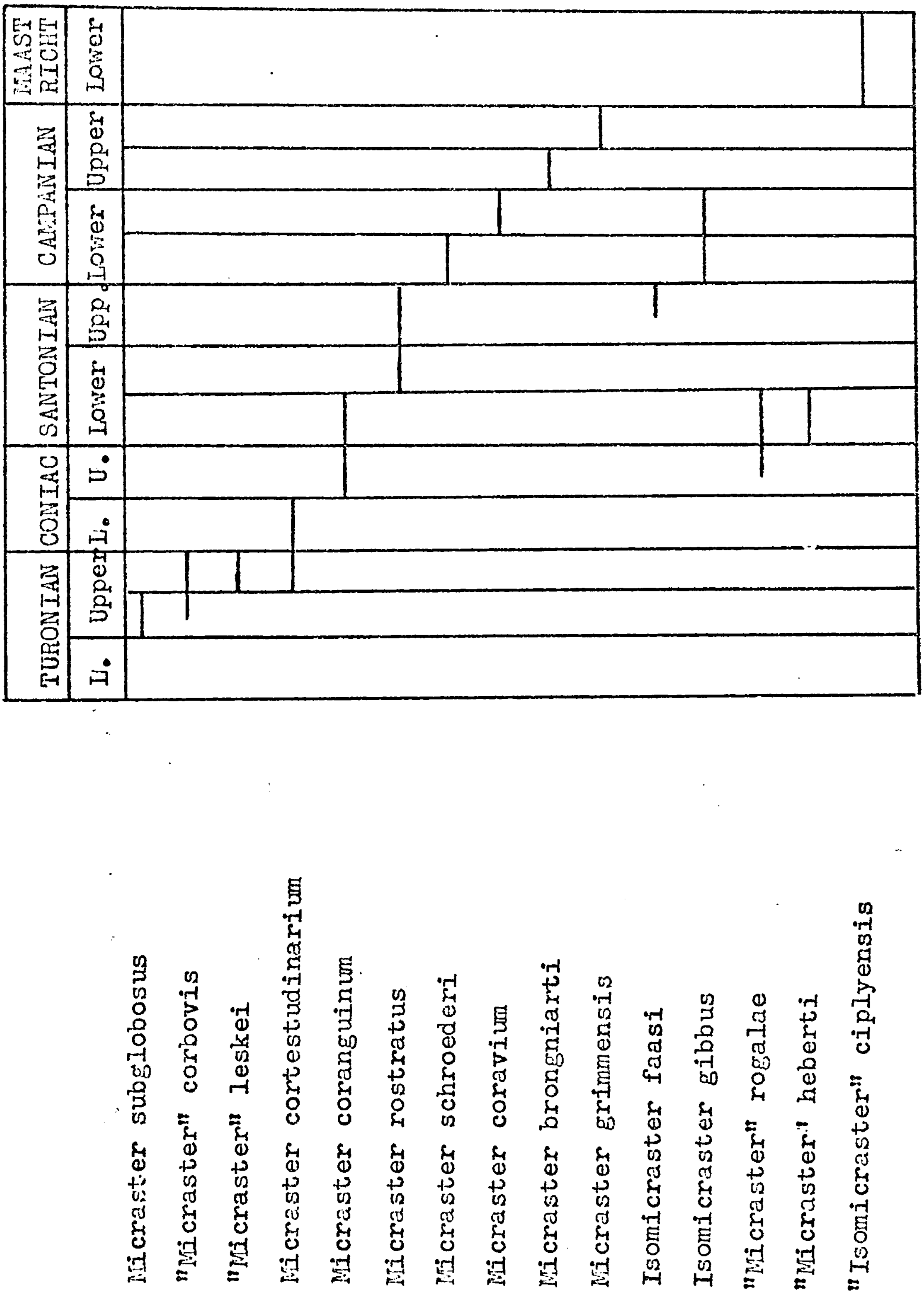
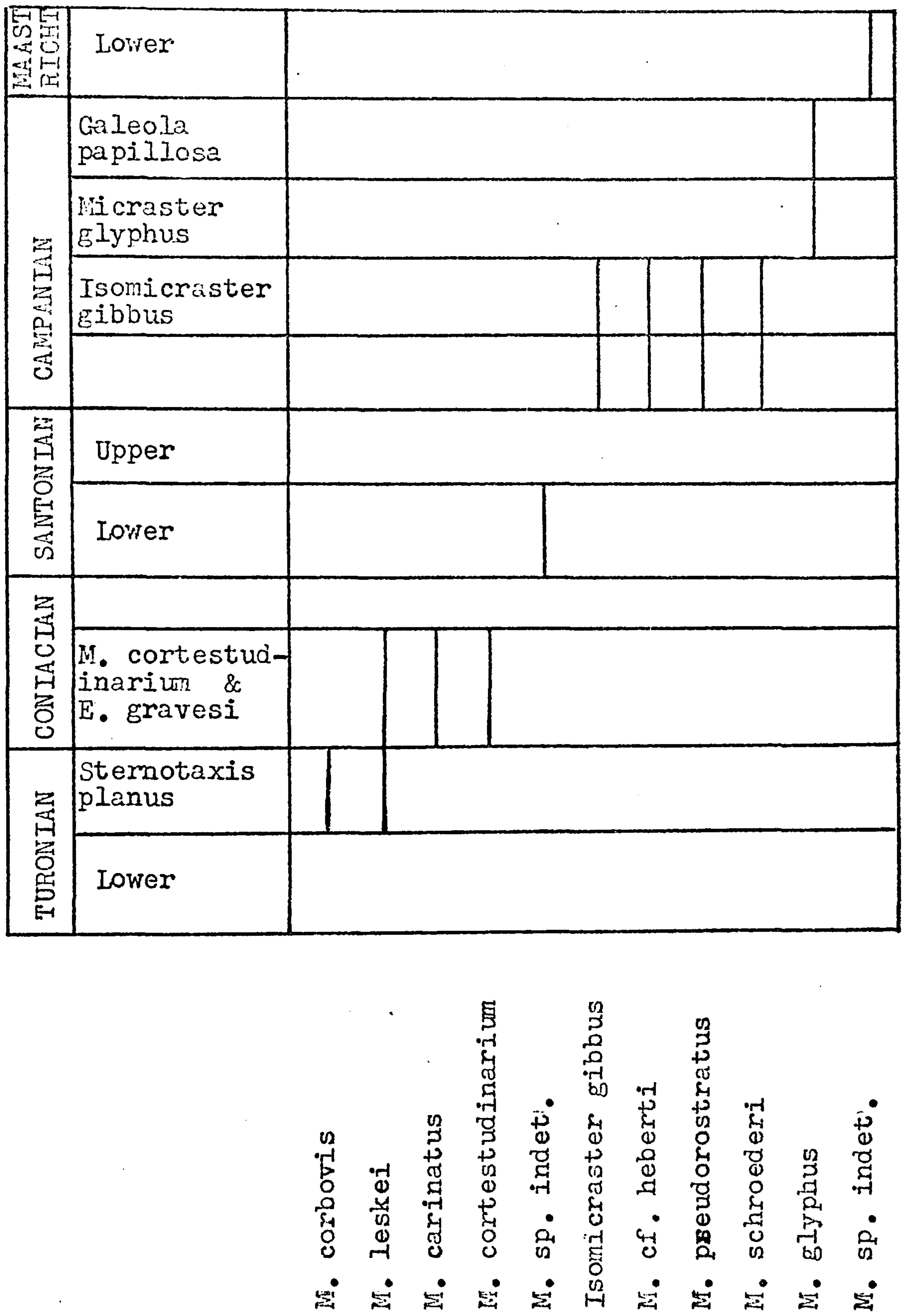


FIG. 13
STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE NORTHERN CAUCASUS AND THE CRIMEA ACCORDING TO MOSKVIN & POSLAVSKAJA 1959



STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE KOPET DAGH MOUNTAINS ACCORDING TO DZABAROV 1964

FIG. 14



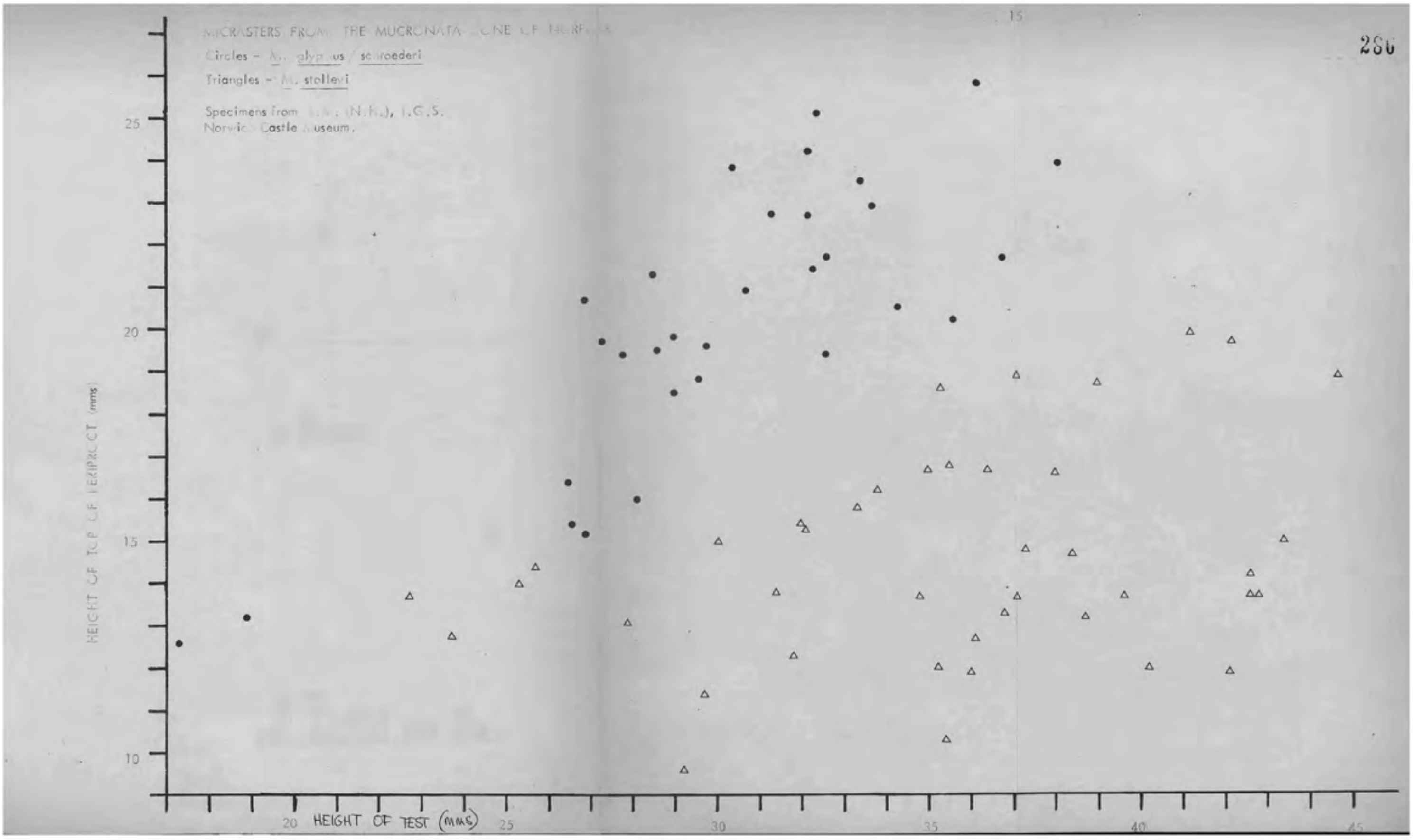

Triangles - M. stollevi
Specimens from (N.H.), I.G.S.
Castle Museum.
HEIGHT OF TEST (MMS)
20
25
30
35
40
45
10
15
20
25

FIG. 17 NORFOLK MUCRONATA ZONE MICRASTERS FROM RESTRICTED HORIZONS

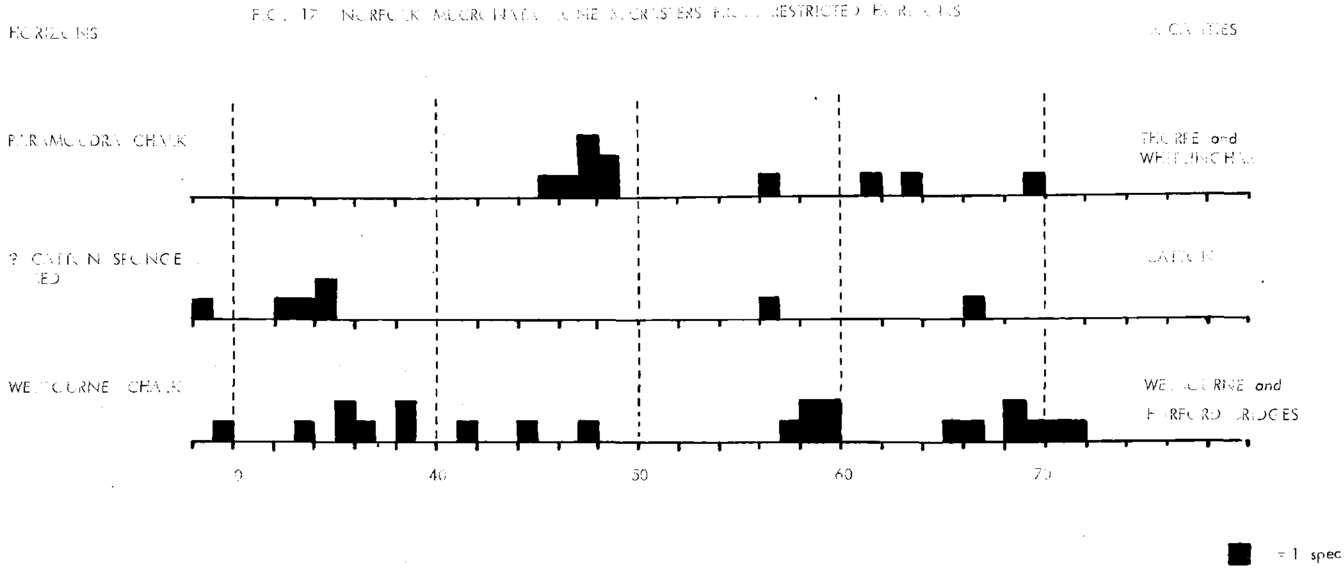


FIG. 16 NORFOLK MUCRONATA ZONE MICRASTERS MEASURED

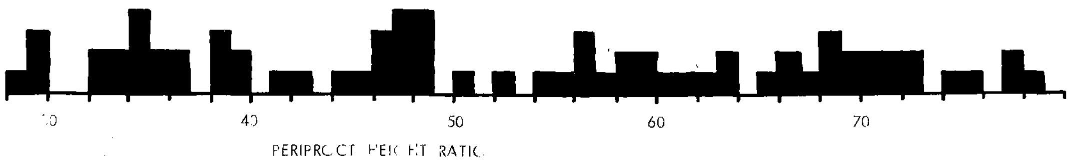
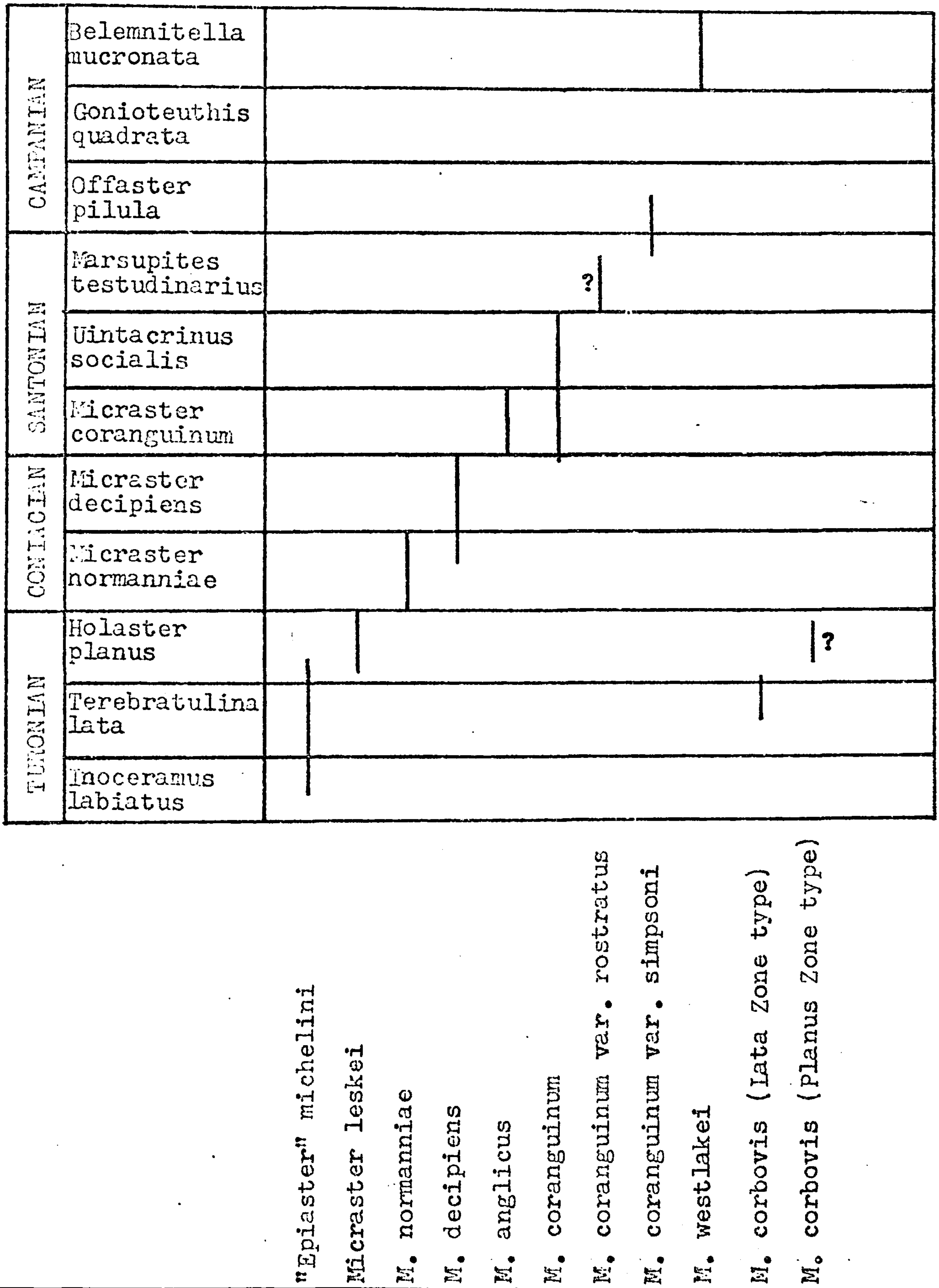


FIG. 18

STRATIGRAPHICAL DISTRIBUTION OF CERTAIN SPATANGOIDS IN THE TURONIAN AND SENONIAN OF SOUTHERN ENGLAND AND NORMANDY



EXPLICATION OF FIG. 19

The succession exposed beneath U2 was not accurately measured. On the right of the rock column marl bands and tabular flints are indicated by m and t respectively. Hard nodular chalks are stippled. Flint bands are represented by irregular black spots.

Two Lata / Planus Zone boundaries are given - those of Rowe and the Geological Survey.

At least part of the section obscured on Langdon Stairs is bridged by a section (not to scale) from the East Cliffs (from C.J.Wood).

The ranges of spatangoids given on the right are based on identification of specimens in the Wood Collection (including some specimens from M.K.Durkin). The solid circles mark occurances - sometimes of more than one specimen.

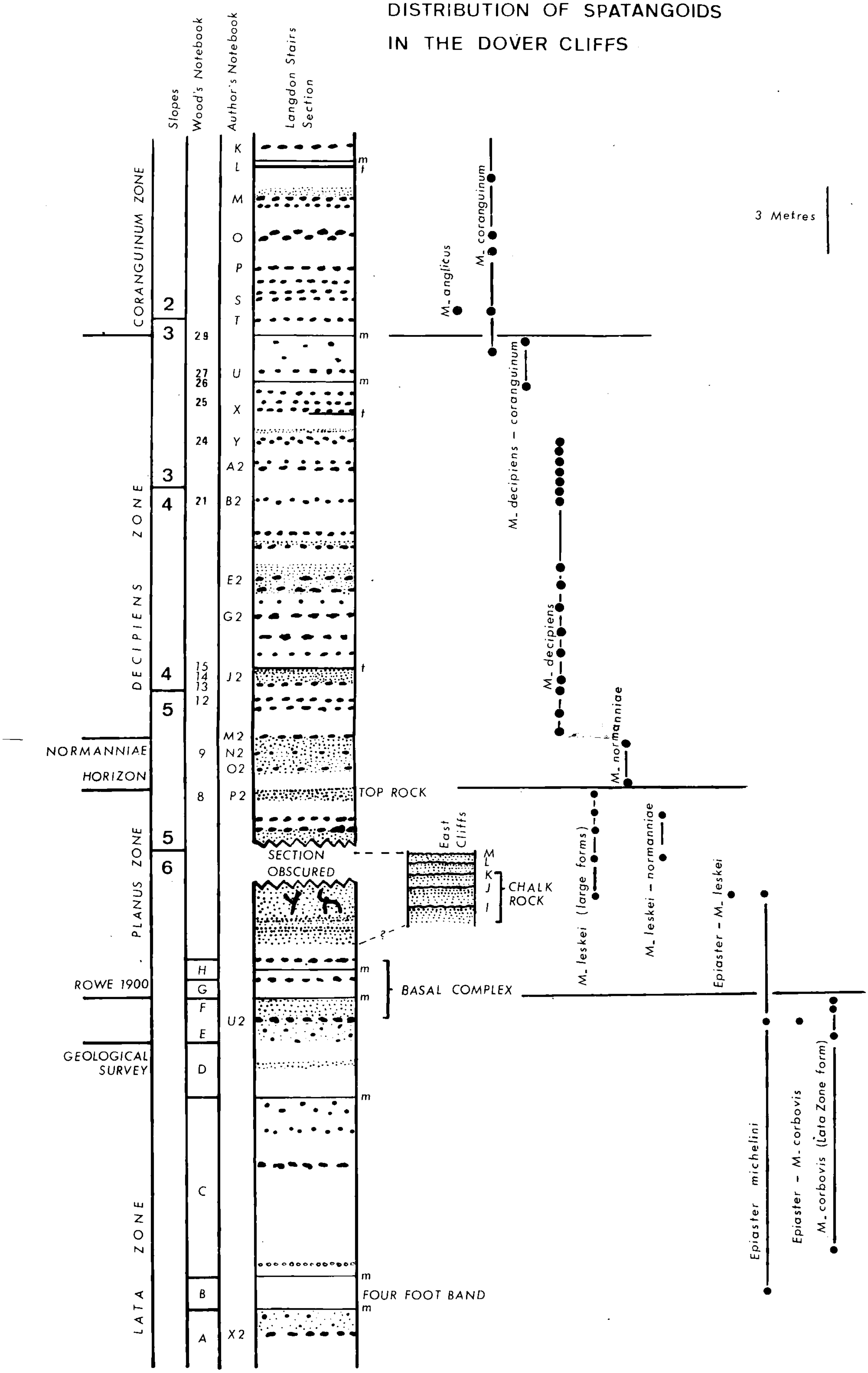
tebook

otebook

Stairs

FIG 19

DISTRIBUTION OF SPATANGOIDS IN THE DOVER CLIFFS



EXPLICATION OF THE SYMBOLS IN FIGURE 20

The symbols represent the following manuscript divisions of Rowe :-

Open Circle "*M. coranguinum* (Leske)"

Solid Circle "*M. coranguinum* (Leske) var. *latior*"

Solid Square "*M. coranguinum* in all respects, save that there is no fasciole"

Open Square "*M. coranguinum* nearing *Epiaster* shape, but in no other way resembling it"

and

"*M. coranguinum* still nearer to *Epiaster* shape, but in no other way resembling it"

Open Triangle "*M. coranguinum* nearing or actually reaching *Epiaster* shape, and having a feebly developed fasciole"

and

"*M. coranguinum* with anterior ambulacrum in process of modification, and the shape of *Epiaster* but with a slight but definite fasciole"

and

"*Epiaster gibbus* save for the anterior ambulacrum"

Solid Triangle "*Epiaster gibbus*"

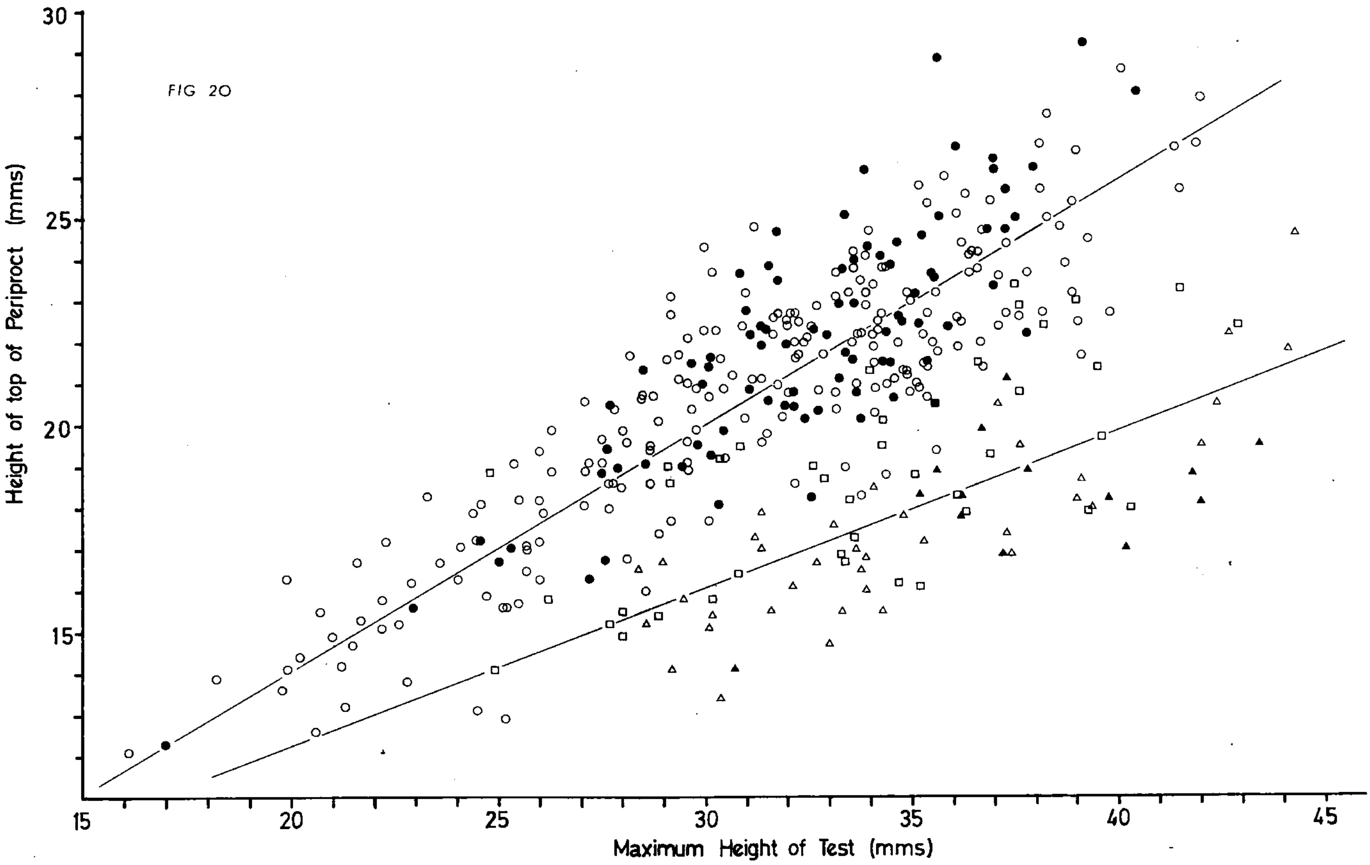


FIG 20
Height of top of Periproct (mms)
Maximum Height of Test (mms)
30
25
20
15
15
20
25
30
35
40
45

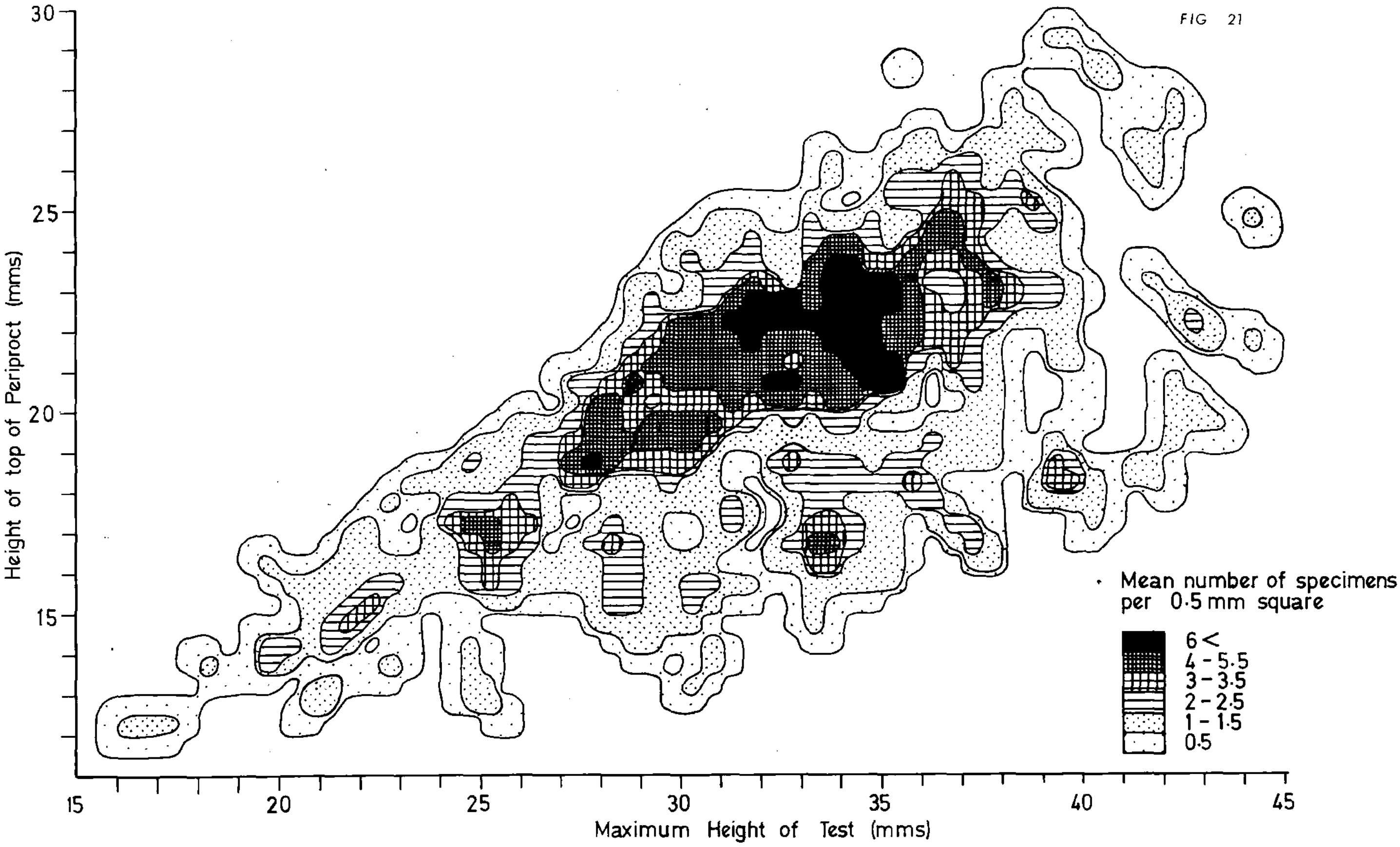


FIG 21
Height of top of Periproct (mms)
Maximum Height of Test (mms)
30
25
20
15
15
20
25
30
35
40
45
Mean number of specimens per 0·5 mm square
6<
4 - 5·5
3 - 3·5
2 - 2·5
1 - 1·5
0·5

FIG. 22

POSSIBLE CORRELATION OF THE TURONIAN AND SENONIAN OF THE SOUTH-EAST OF THE PARIS BASIN WITH SOUTHERN ENGLAND

	LAMBERT'S ZONES IN THE YONNE, 1902		SOUTHERN ENGLAND
CAMPANIAN	P	Magas pumilus	Mucronata Zone
	N	Galeola papillosa	Quadrata Zone
	M	Offaster pilula	Pilula Zone
SANTON	L	Marsupites ornatus	Uintacrinus & Marsupites Zones
	J	Conulus albogalerus	Coranguinum Zone
CONIAC	H	Inoceramus involutus	Decipiens Zone
	G	Terebratula semiglobosa	
TURONIAN	F	Prionotropis Neptuni	? Normanniae Horizon
	E	Holaster planus	? upper part of Planus Zone
	D	Cardiaster Peroni	Chalk Rock
	C	Terebratulina gracilis	Lata Zone
	B	Conulus subrotundus	Labiatus Zone
	A	Actinocamax plenus	Plenus Subzone

FIG. 23

STRATIGRAPHICAL DISTRIBUTION OF MICRASTERS IN THE SOUTH - EAST OF THE PARIS BASIN. Somewhat theoretical.

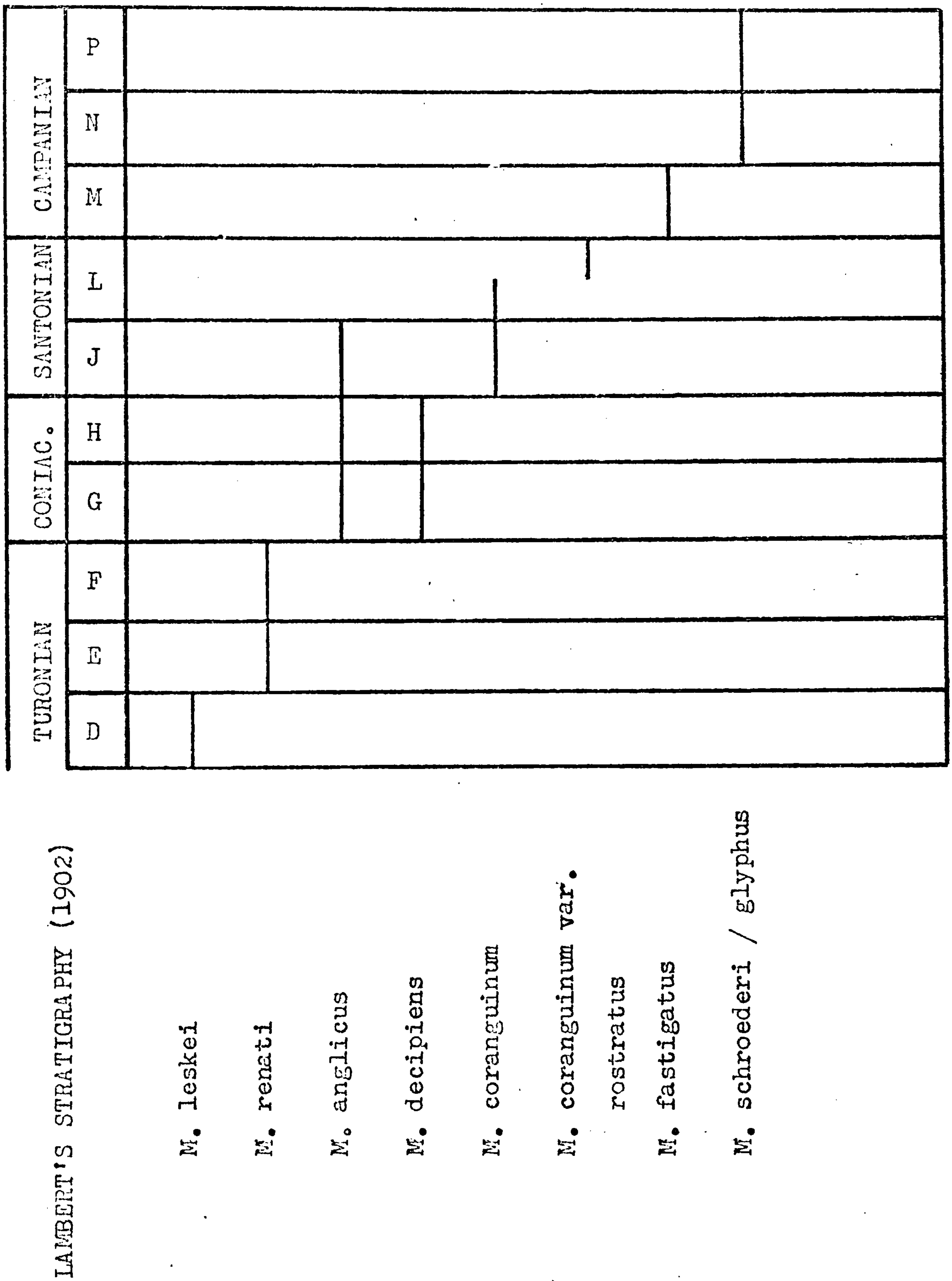


FIG. 24

STRATIGRAPHICAL DISTRIBUTION OF CERTAIN SPATANGOIDS IN TOURAINE. Based on de Grossouvre (1897).

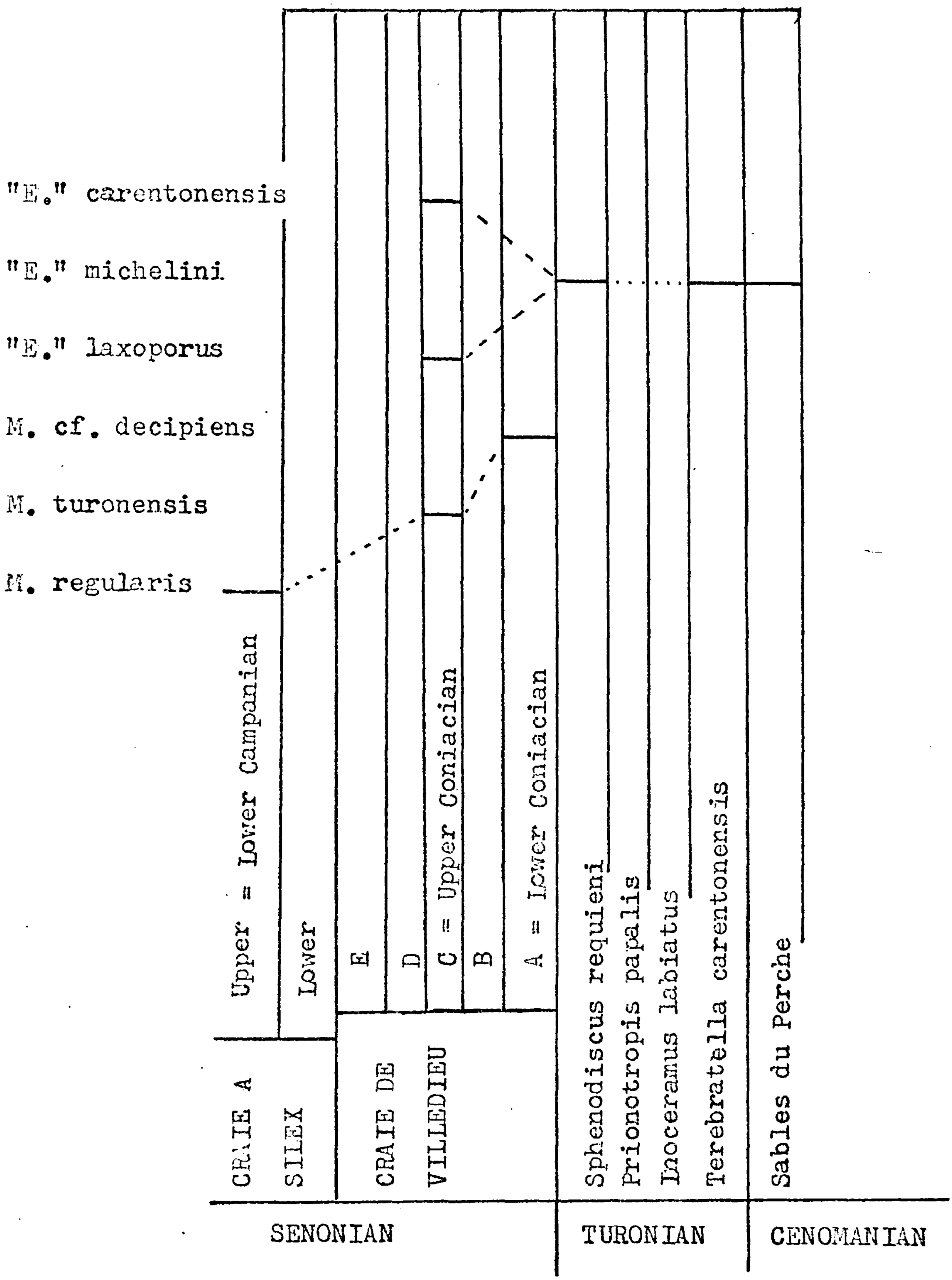


FIG. 25

STRATIGRAPHICAL DISTRIBUTION OF CERTAIN SPATANGOIDS IN AQUITAINE. Based on de Grossouvre (1897), showing Coquand's Substages and Arnaud's Zones.

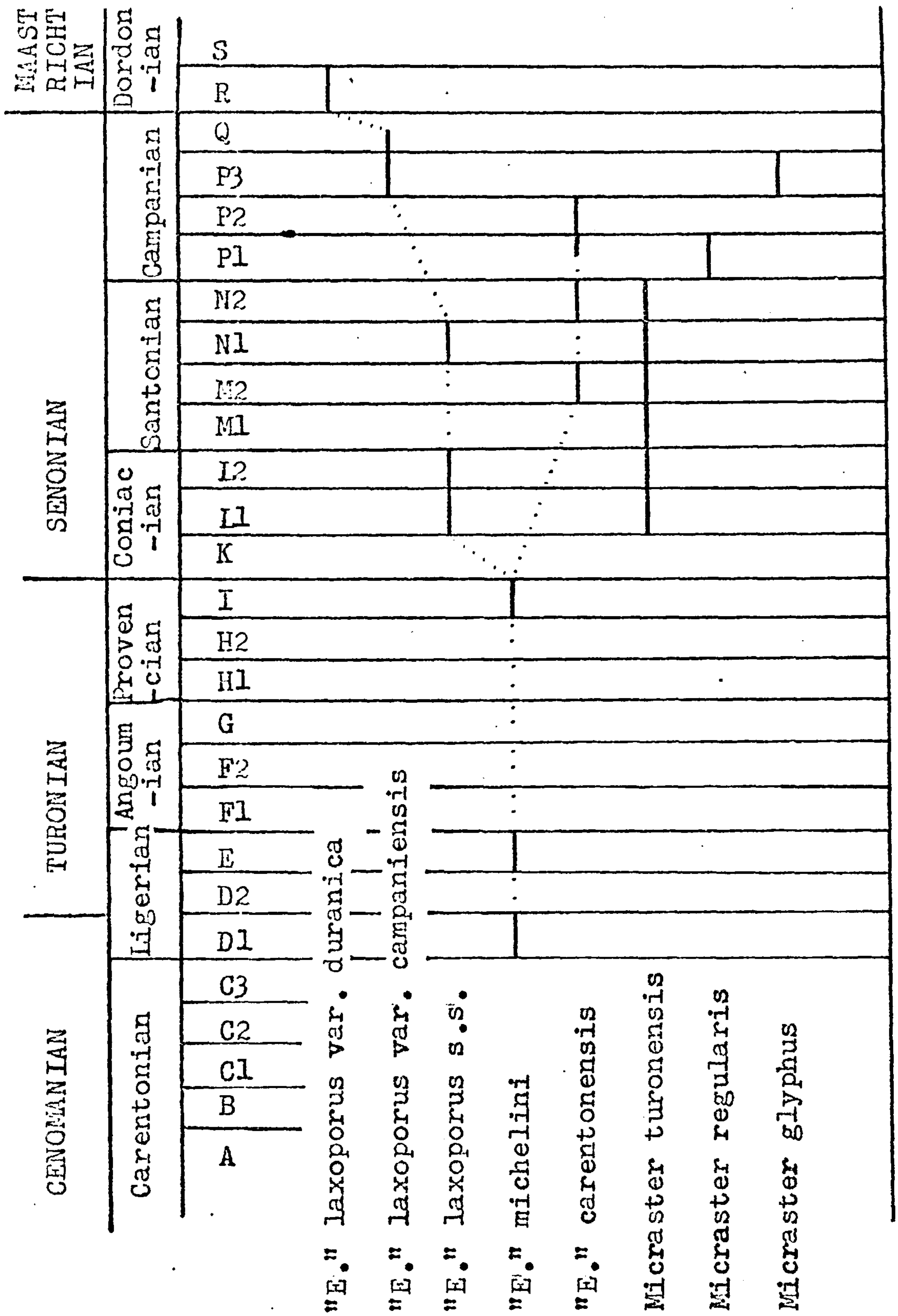


FIG. 26

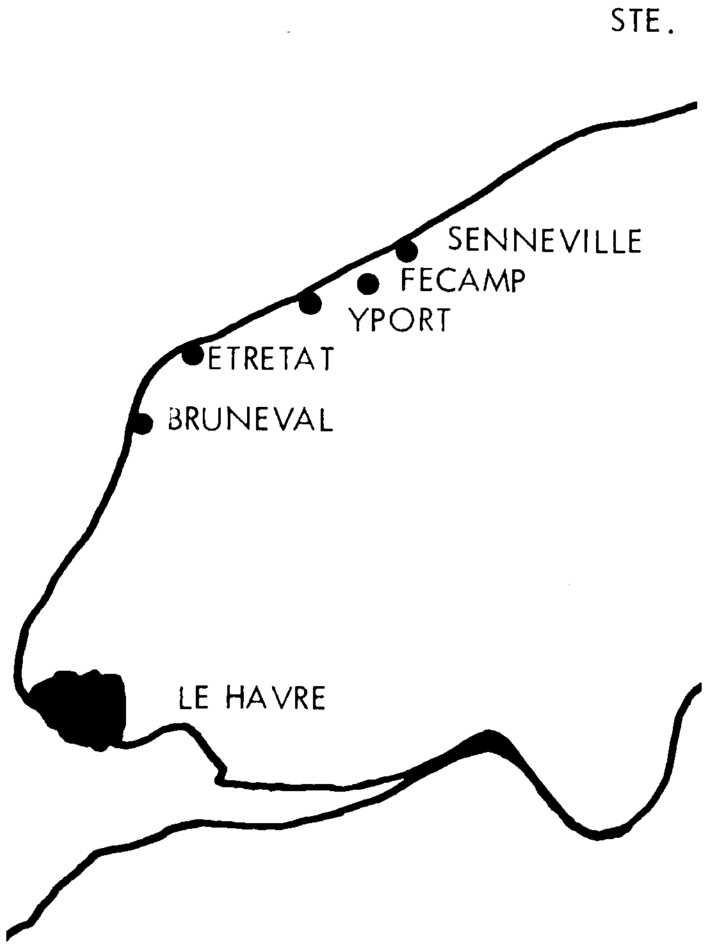
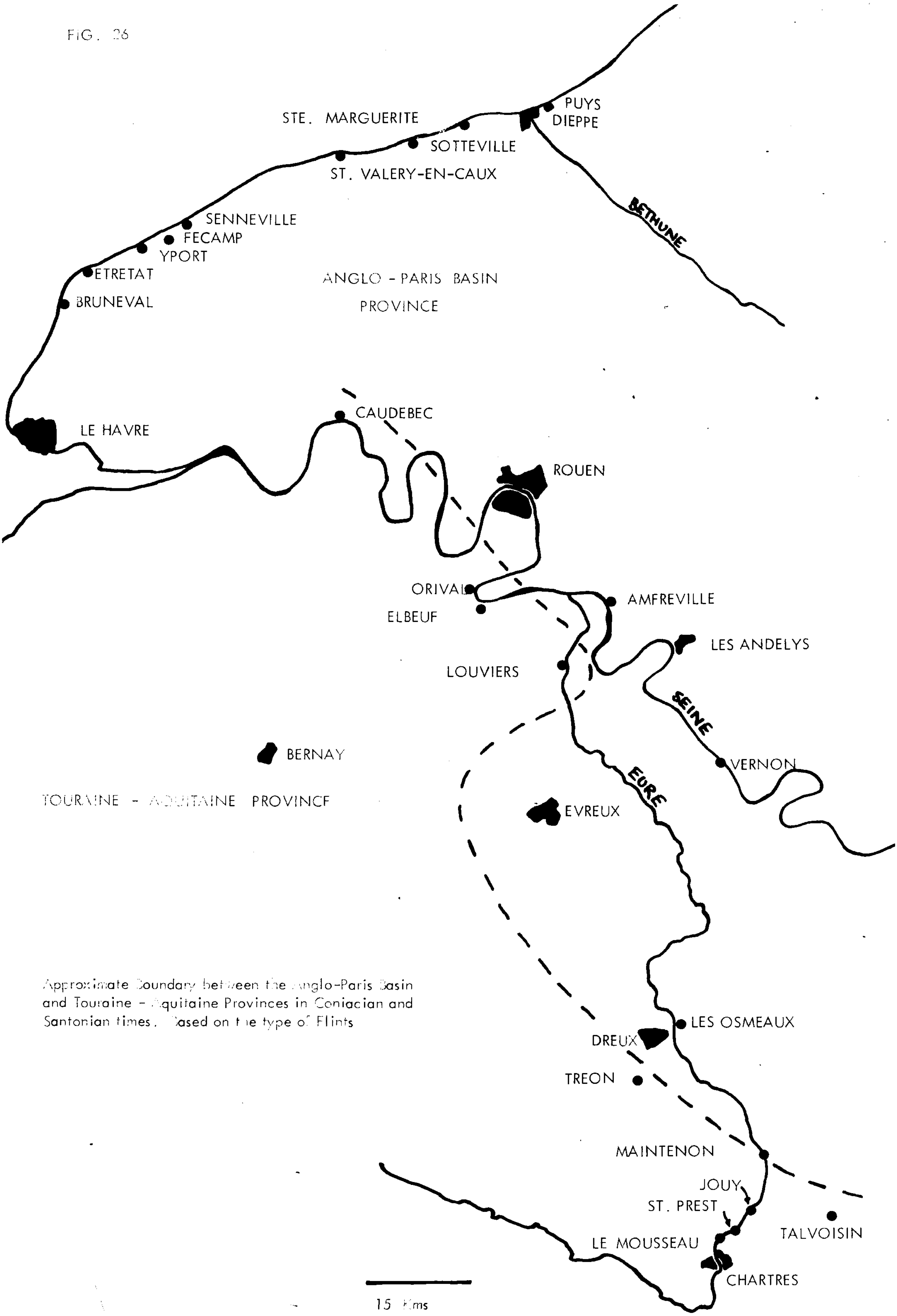


FIG. 26



Approximate boundary between the Anglo-Paris Basin and Touraine - Aquitaine Provinces in Coniacian and Santonian times. Based on the type of Flints

FIG. 27

SKETCH PLAN OF THE OLD QUARRY AT TERCIS (LANDES).

<u>Echinocorys</u> horizons determined by N.B. Peake.

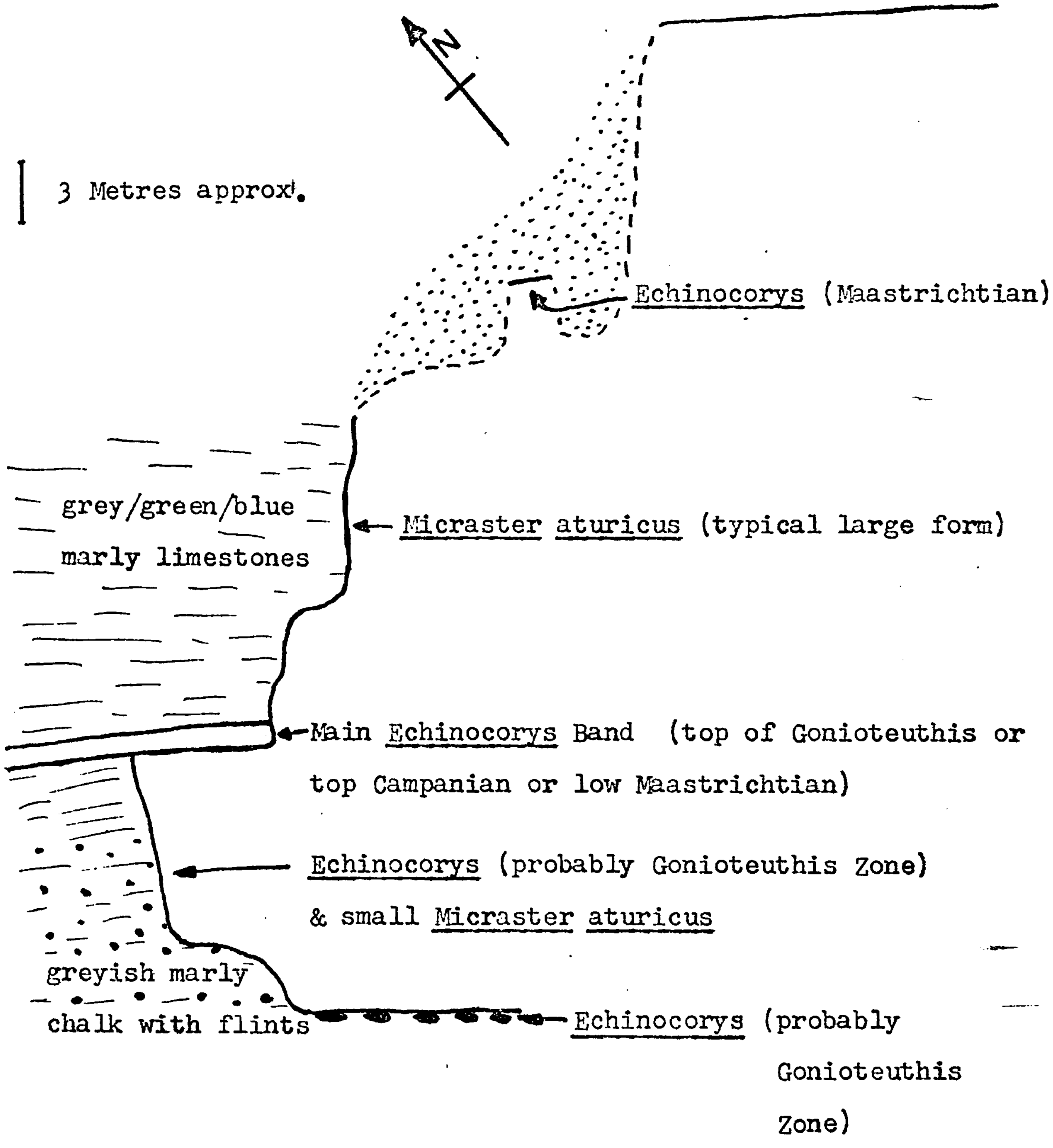


FIG. 28

Correlation of the evolutionary stages reached by the genus *Micraster* in the Turonian, Coniacian and Santonian of northern Germany and southern England.

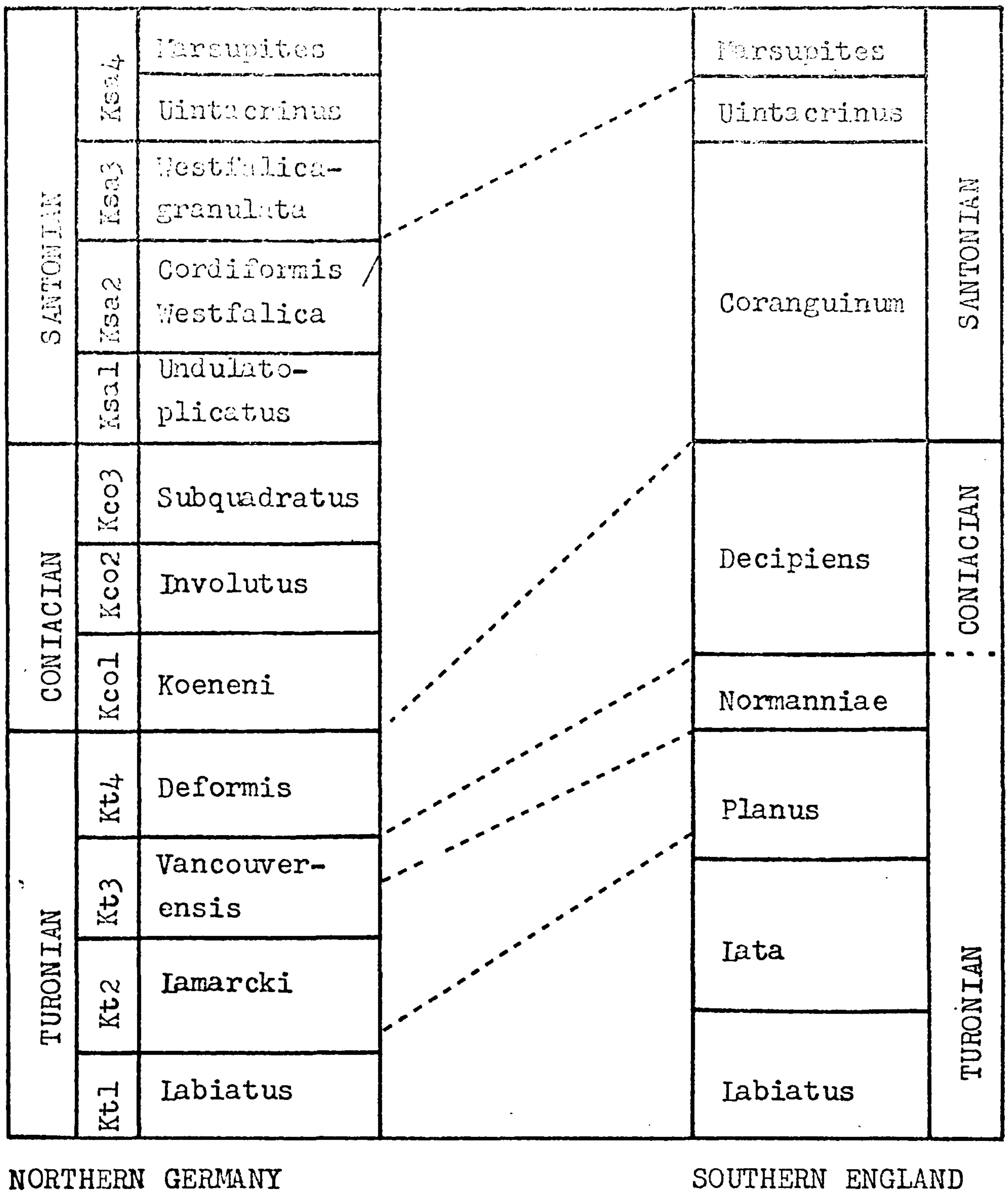


FIGURE 29

Number of pores in one row of Petal II

Open Triangles	Tunisian Micrasters *M. peini* & *M. solignaci* Santonian & Campanian Cotteau and Lambert Colls.
Solid Triangles	Pyrenean Province. *M. brevis*. Santonian B.M.(N.H.).
Open Circles	Touraine -Aquitaine Province. *M. turonensis*. Upper Coniacian and Santonian. Paris Collections.
Solid Cirlces	Anglo - Paris Basin Province. *M. ccranguinum*. Santonian. Westlake Collection.

Fig 29

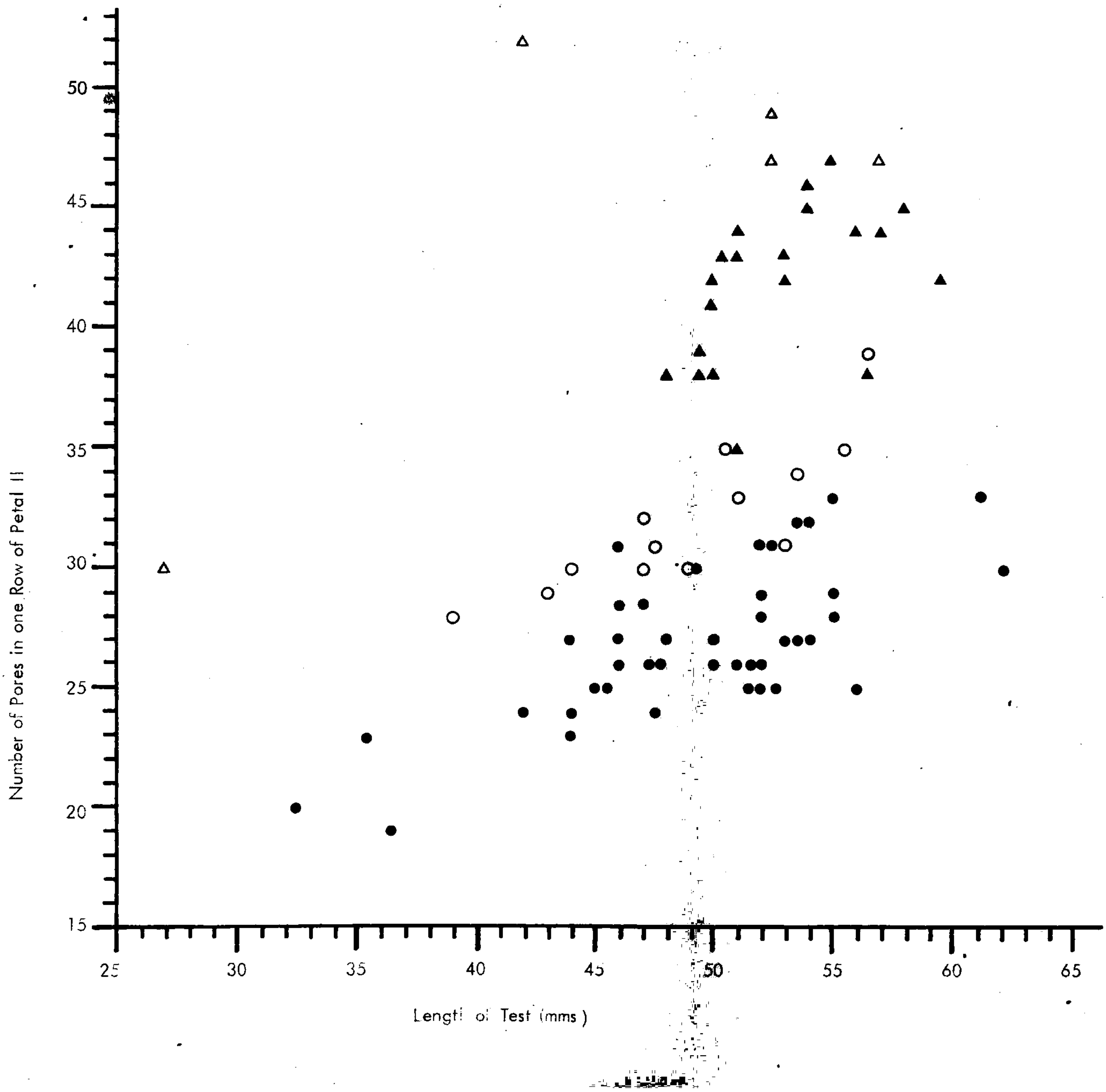

Number of Pores in one Row of Petal II
15
20
25
30
35
40
45
50
25
30
35
40
45
50
55
60
65
Length of Test (mms)

FIG. 30 Increase in the number of ocular plates touching the madreporite.

A Turonian

B Upper Coniacian

C Santonian

D Campanian

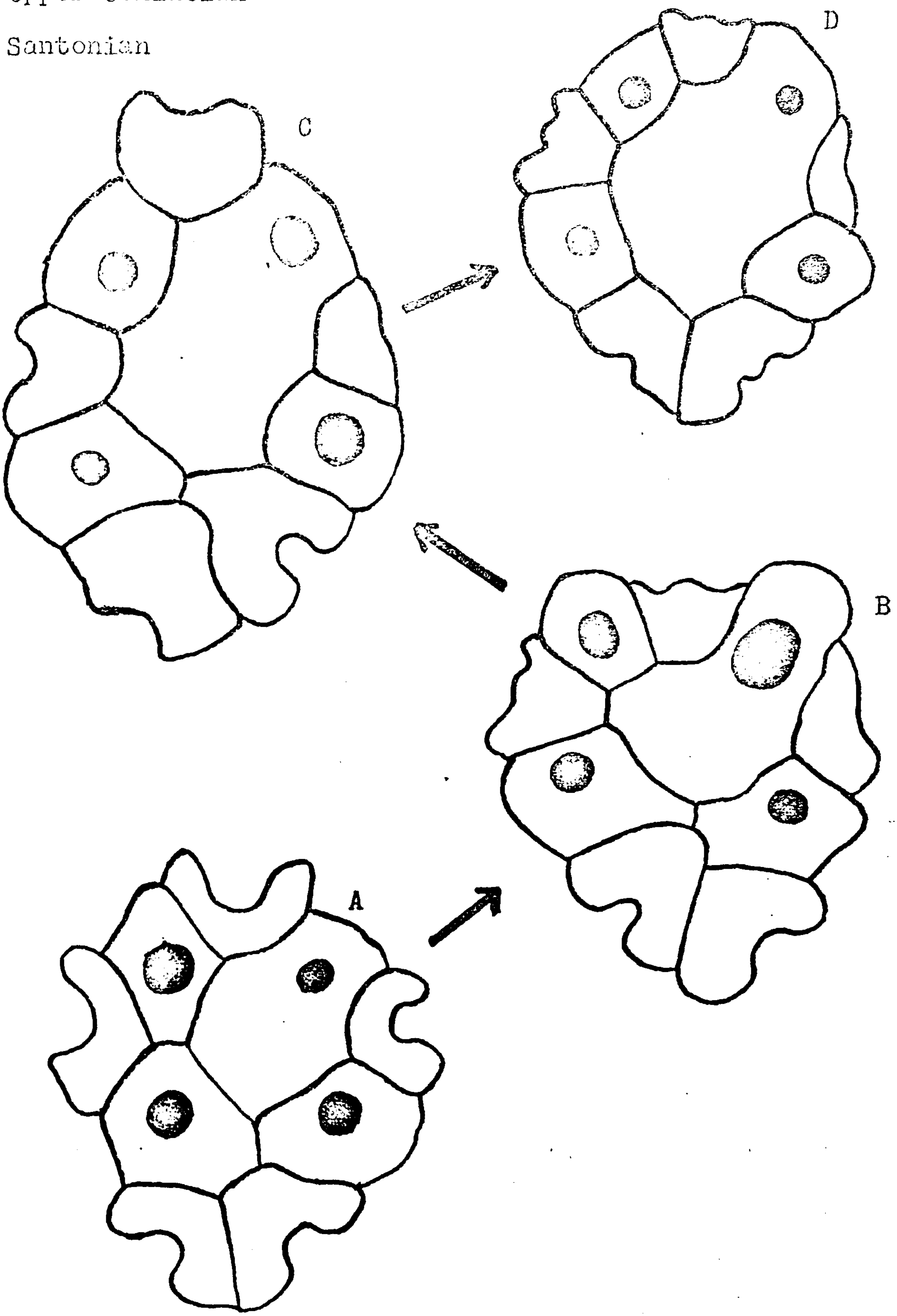


FIG. 31 Diagramatic representation of the withdrawal of the paired interambulacra from the peristome

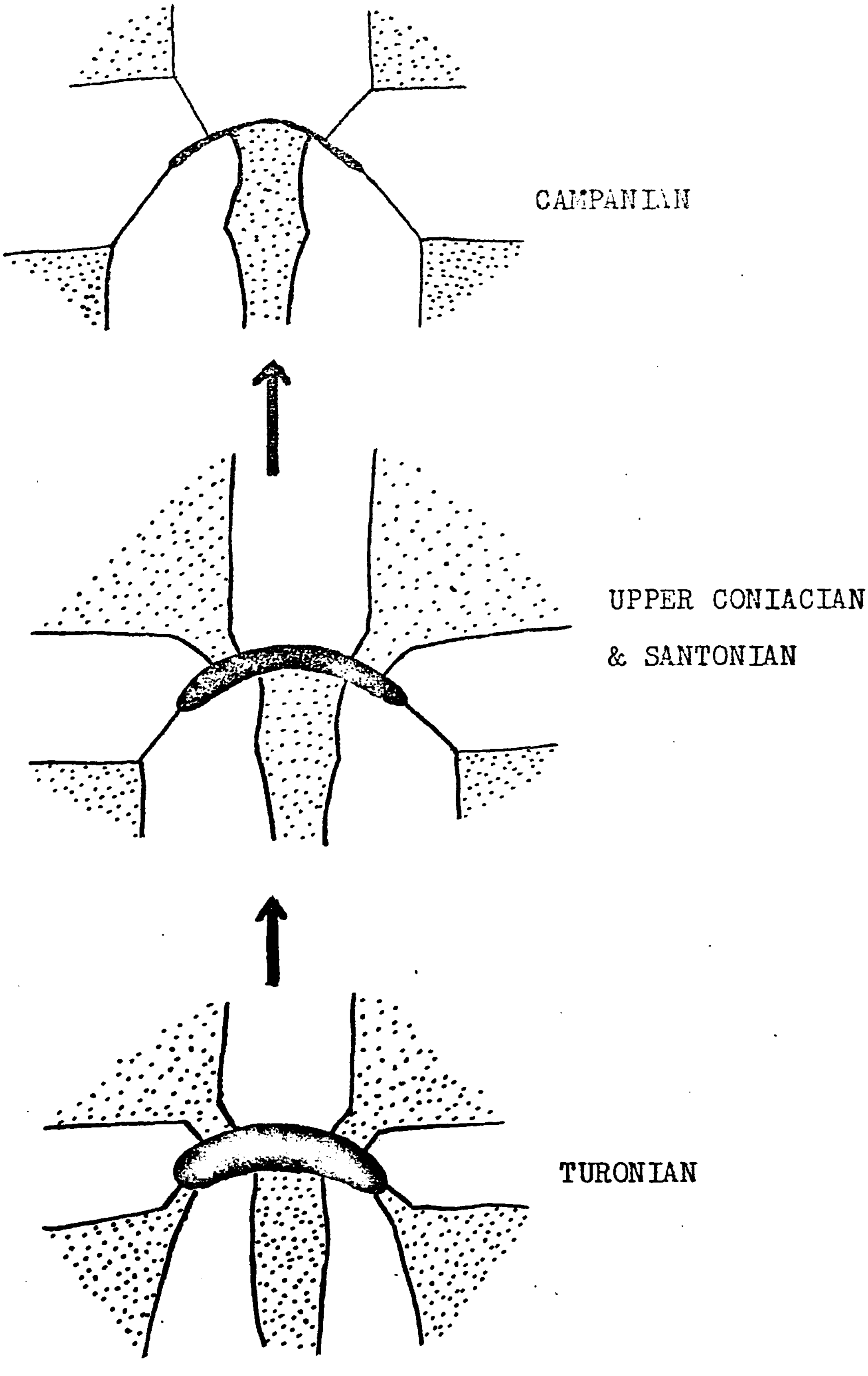


FIG. 32 Arrangement of the labral and sternal plates.

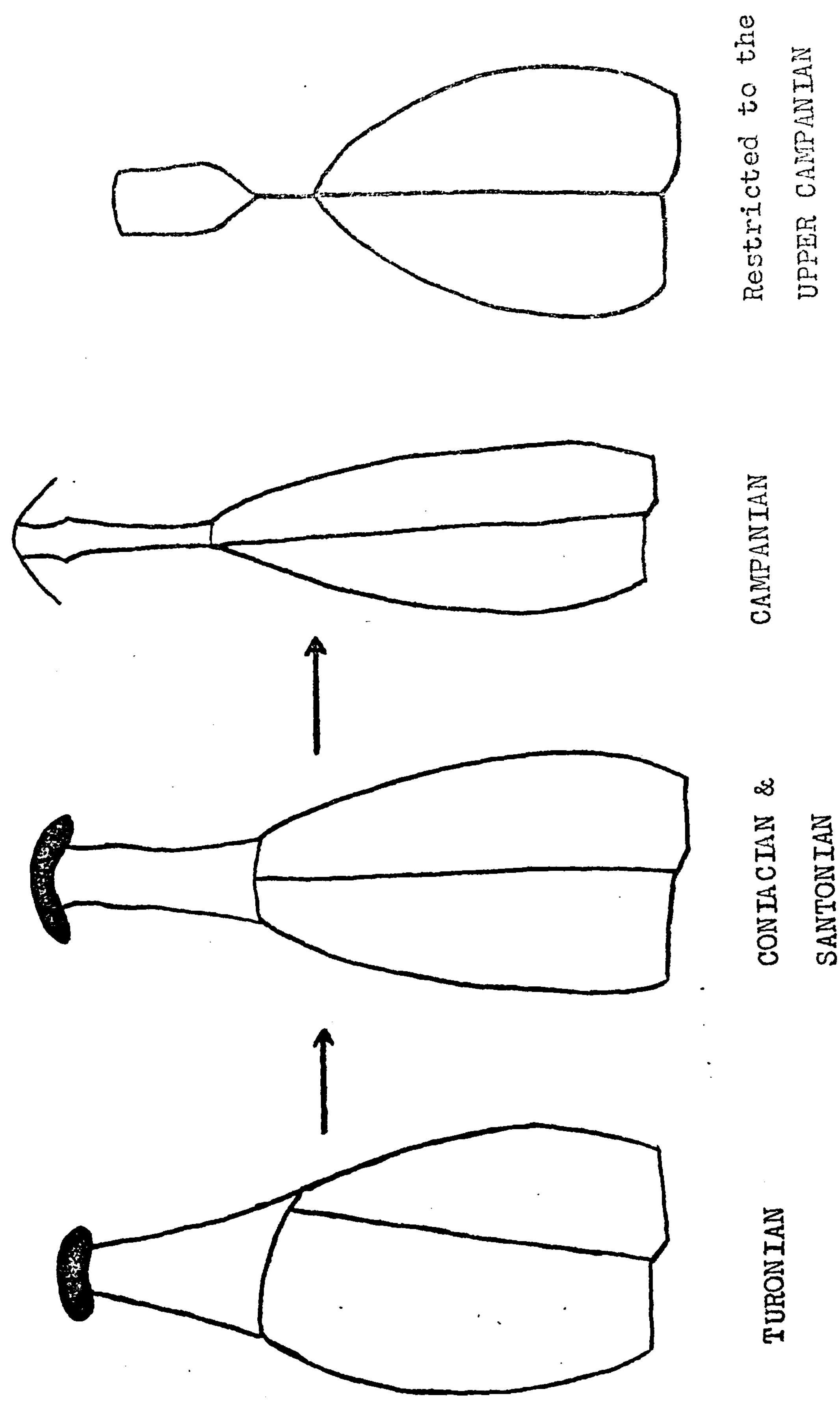
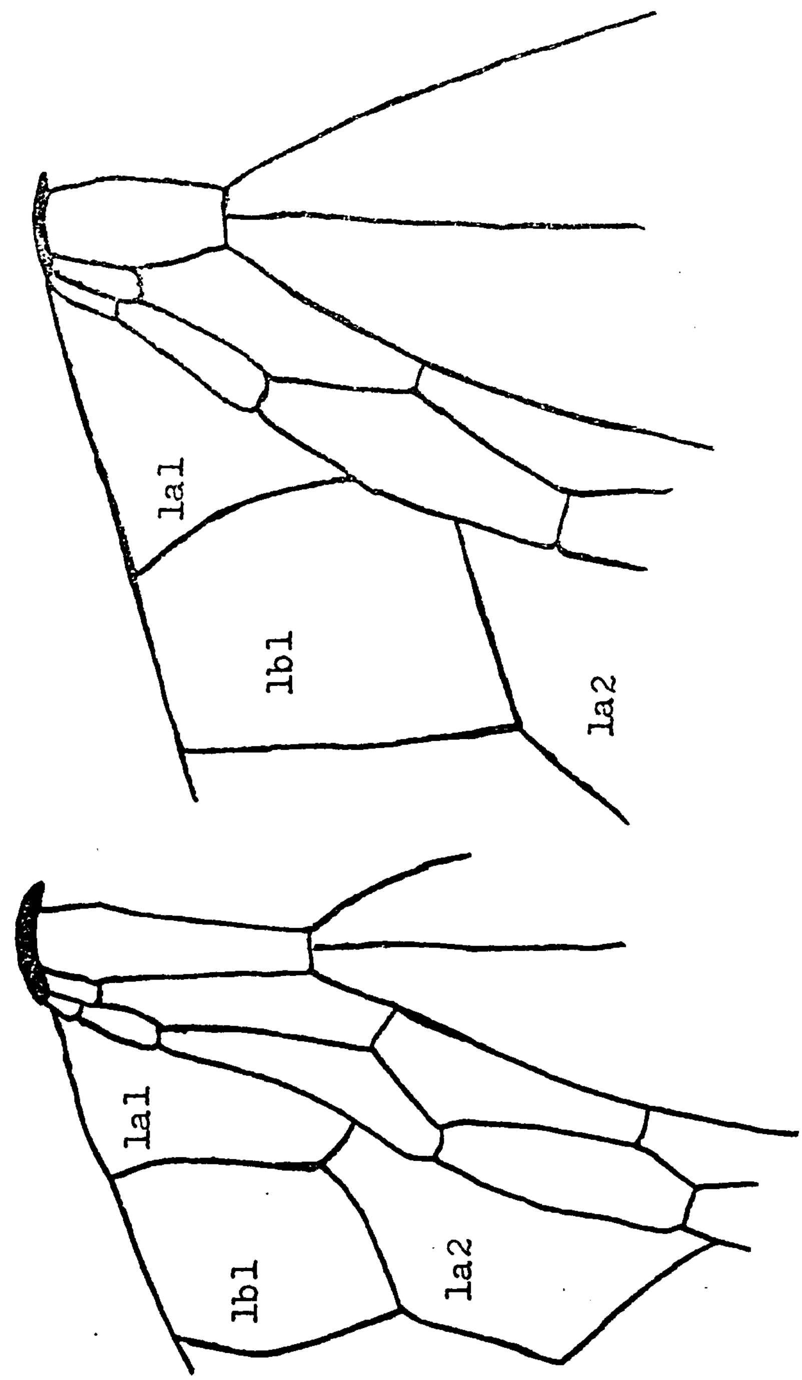


FIG. 33 Arrangement of plates in the right posterior paired interambulacrum.



Condition restricted to the Campanian

Condition occuring at all horizons

FIG. 35

Diplodetus idae: 23 specimens from the Köpinge Sandstone, Scania (Sweden).

Naturhistoriska Riksmuseet, Stockholm.

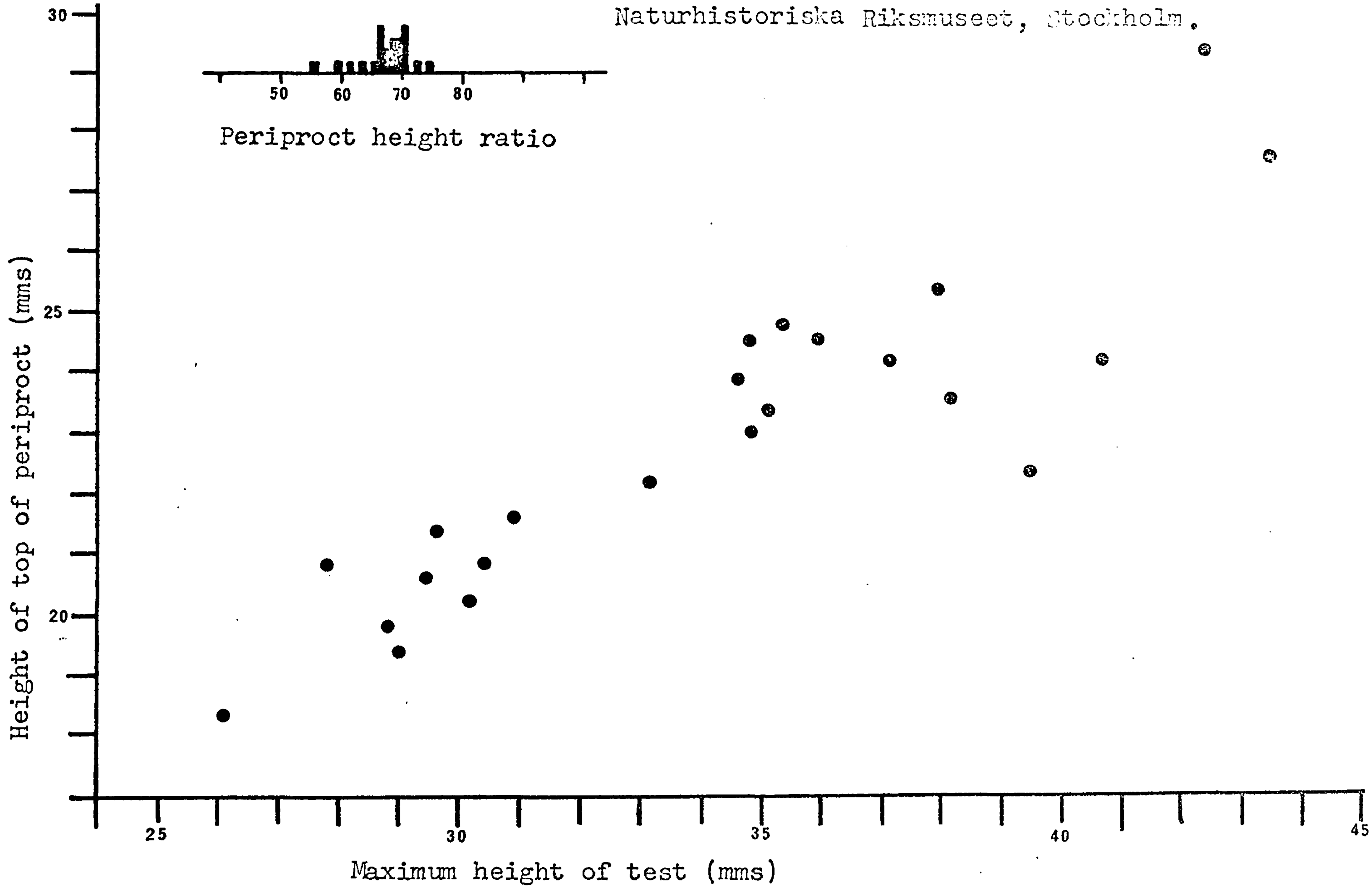


FIG. 36

DISTRIBUTION OF THE GENUS <u>DIPLODETUS</u>

	NORTH GERMANY	SWEDEN	BELGIUM	POLAND
DANIAN				D. DEPRESSUS
MAASTRICHTIAN			D. DUPONTI	
UPPER CAMPANIAN	D. SCHLUETERI D. CRETACEUS D. CORDIFORMIS	D. IDAE		
LOWER CAMPANIAN	D. CAVIFER D. MINOR			
UPPER SANTONIAN	D. RECKLINGHAUSENENSIS			

PLATES 1 - 42

PHOTOGRAPHIC PLATES 1 - 23

The original prints were of the magnifications stated. The length of the figured specimens is given because subsequent processing has varied the magnifications slightly. Unless otherwise stated the magnification is x 1.

LINE PLATES 24 - 42

Magnification x 22.

The madreporite (Genital Plate II) is stippled in plates 24 - 26.

PLATE I

<u>Micraster coranguinum</u> (Leske)

From the Lower Coniacian of the Staffhorst Mineshaft.

Spiegler Collection, Geol. Pal. Inst. Hamburg.

Length 51.3 mms.

A - C Oral, Apical and Lateral Views.

<u>Micraster coranguinum</u> var. <u>rostratus</u> (Mantell)

Senonian K, St. Martin (Yonne).

Lambert Collection.

Length 51.8 mms.

D - E Lateral and Apical Views.

F Petal II x 3.

G Petal III x 3.

1

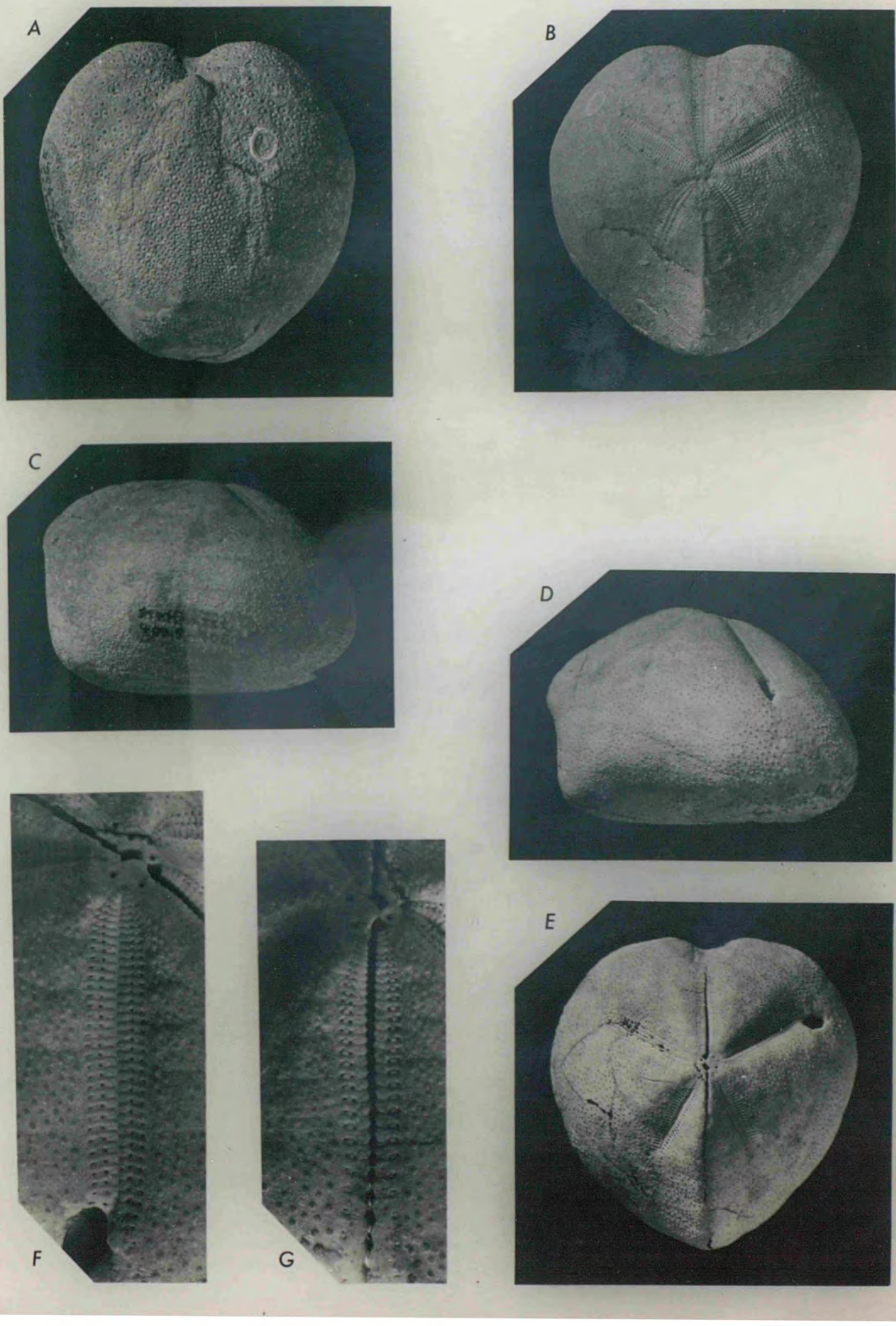


PLATE 2

<u>Micraster</u> <u>anglicus</u> (Coquand)

Senonian H, underground at Maillot (Yonne).

Lambert Collection.

Length 53.8 mms.

A - C	Oral, Apical and Lateral Views.
D	Petal III x 4.
E	Petal IV x 4.
F	Oral region x 4.
G	Apical System x 15.

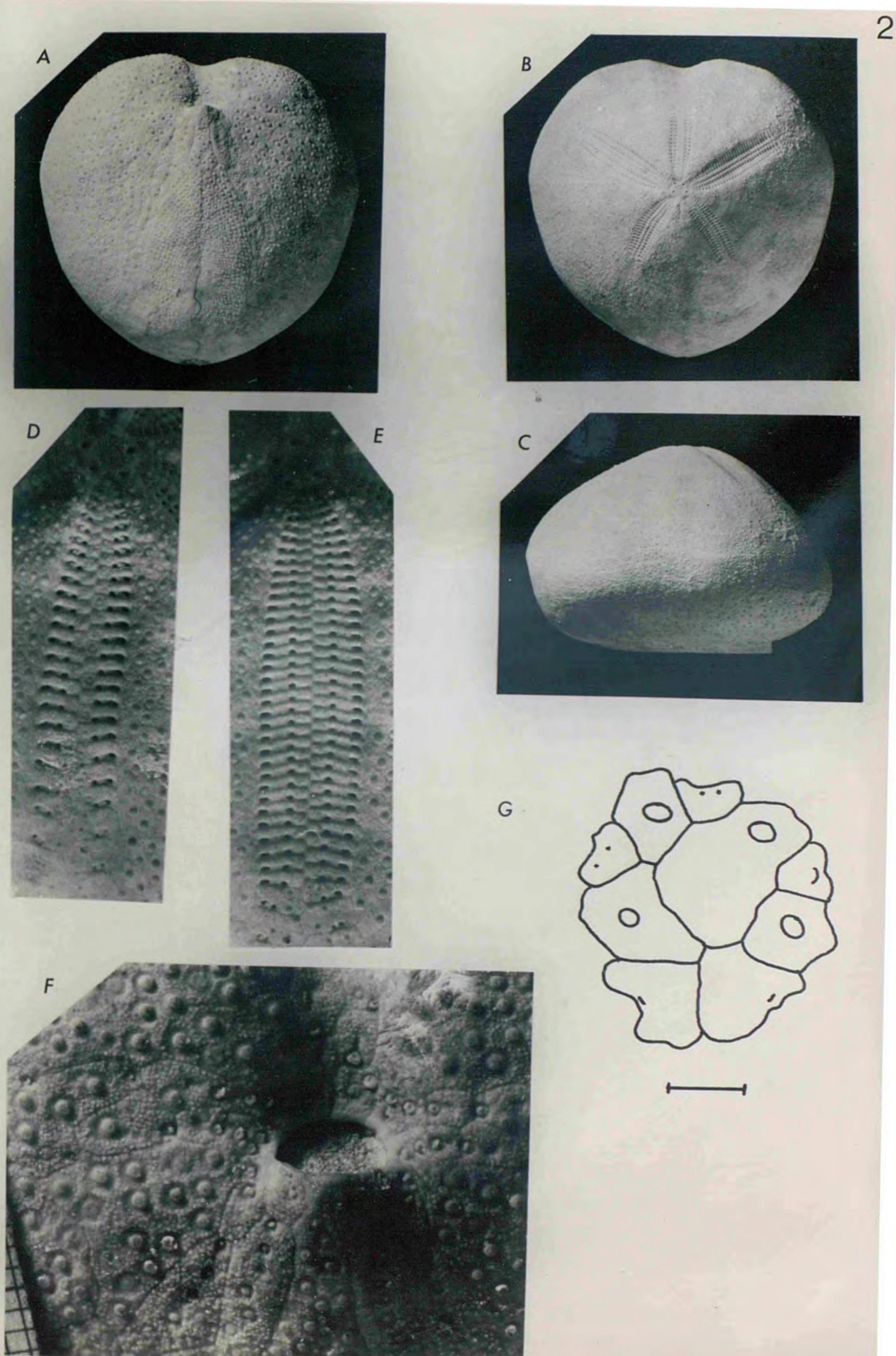

2
A
B
C
D
E
F
G

PLATE 3

Micraster decipiens (Bayle)

Senonian, Abbeville (Somme).

Lambert Collection no. 1040A.

Length 53.1 mms.

A - C Oral, Apical and Lateral Views.

D Oral region x 5.

E Petal III x 4.

F Petal IV x 4.

3

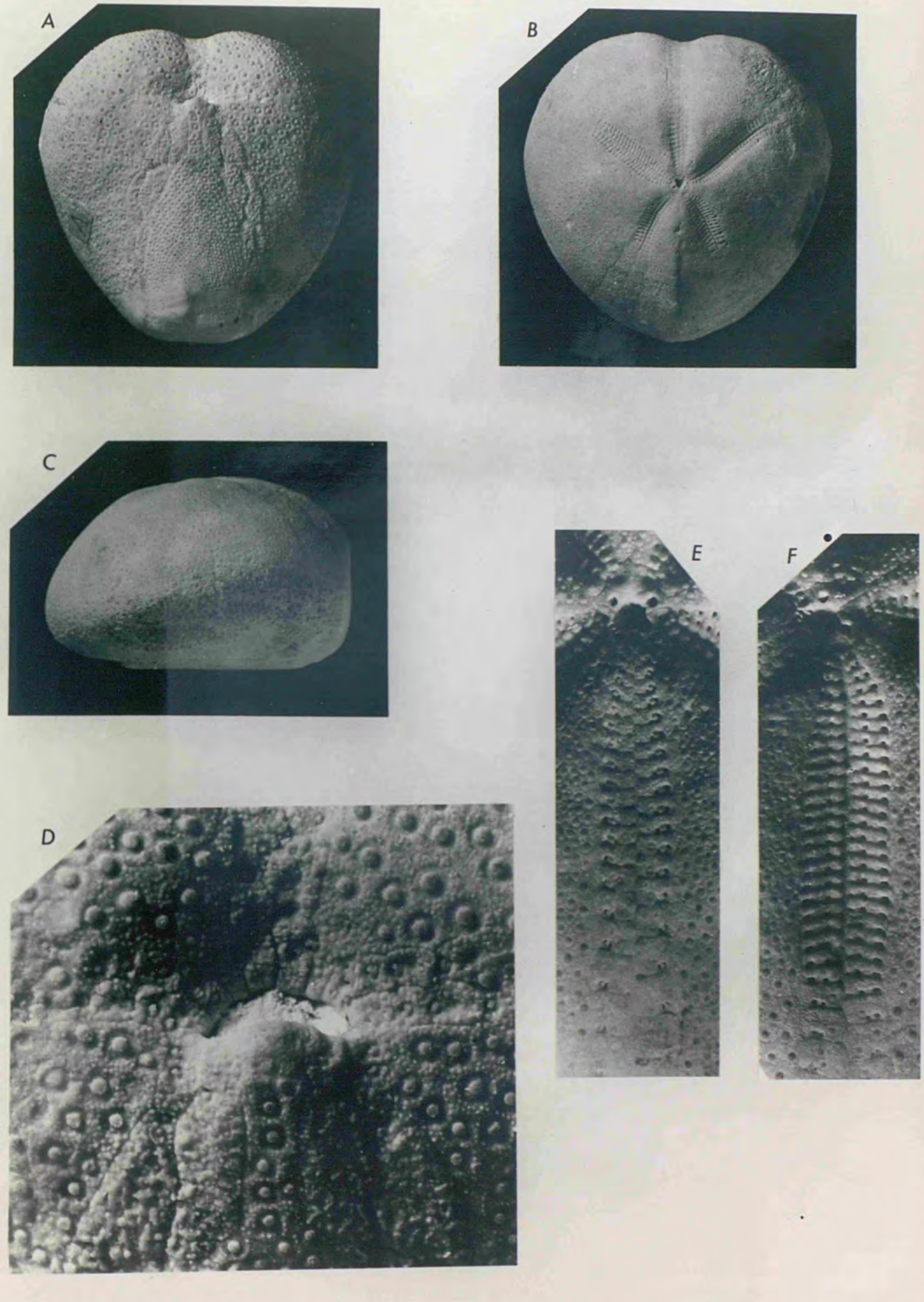


PLATE 4

<u>Micraster</u> <u>renati</u> (Gauthier)

Senonian F, underground at Cochepie (Yonne).

Lambert Collection.

Holotype of <u>Micraster</u> <u>icaunensis</u> Lambert.

Length 55 mms.

A - C Oral, Apical and Lateral Views.

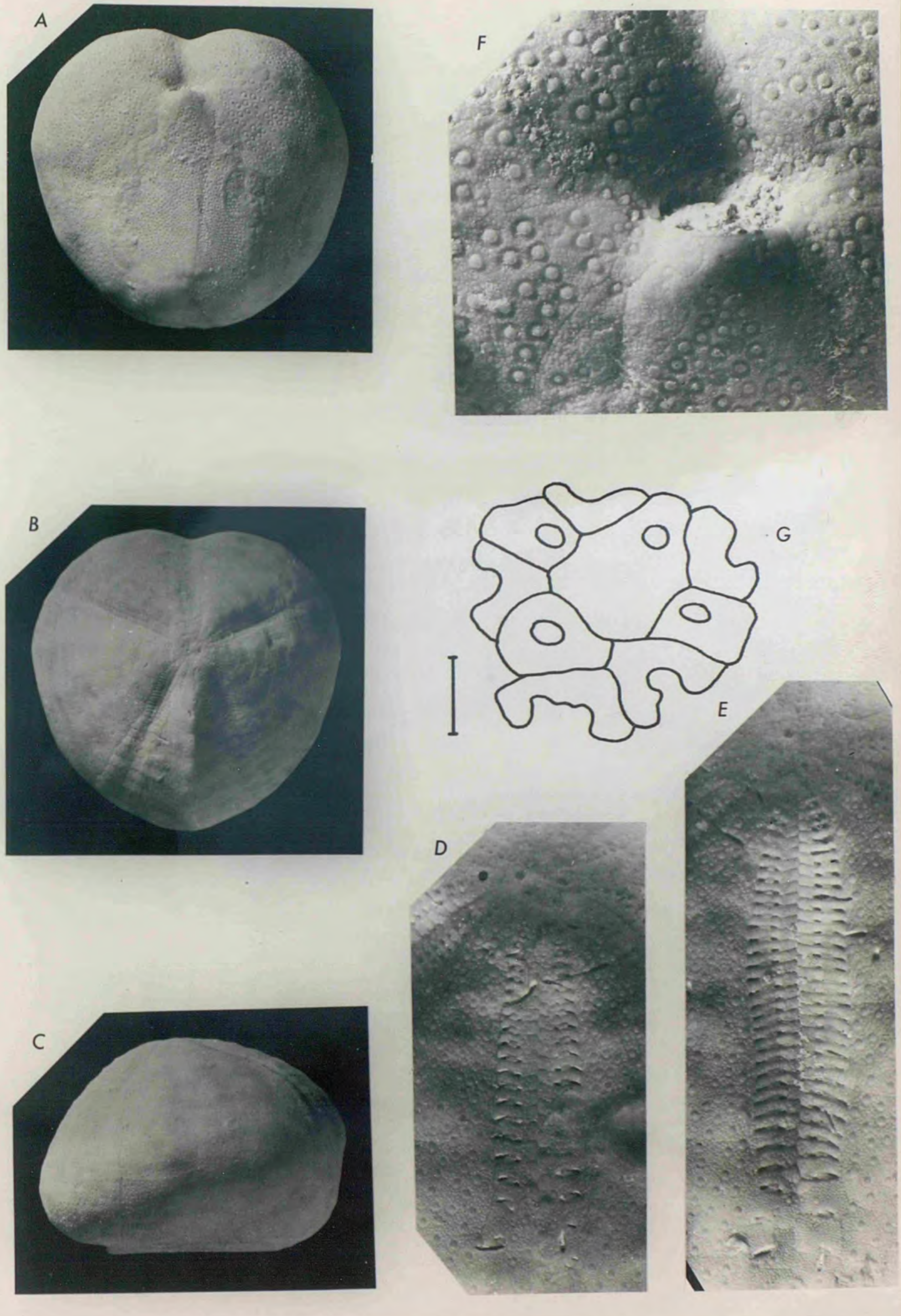
D Petal III x 4.

E Petal IV x 4.

F Oral region x 5.

G Apical system x 15.

4



/

PLATE 5

Micraster regularis Arnaud

Campanian, Tugéras - Jonzac (Charente - Maritime).

Mus. Hist. Nat. Paris.

Length 45.2 mms.

A - C Oral, Apical and Lateral Views.

D Petal III x 4.

E Petal IV x 4.

Micraster schroederi Stolley.

Senonian C, St. Aignan (Yonne).

Lambert Collection.

Length 54 mms.

F - H Oral, Apical and Lateral Views.

I Petal IV x 5.

J Petal III x 5.

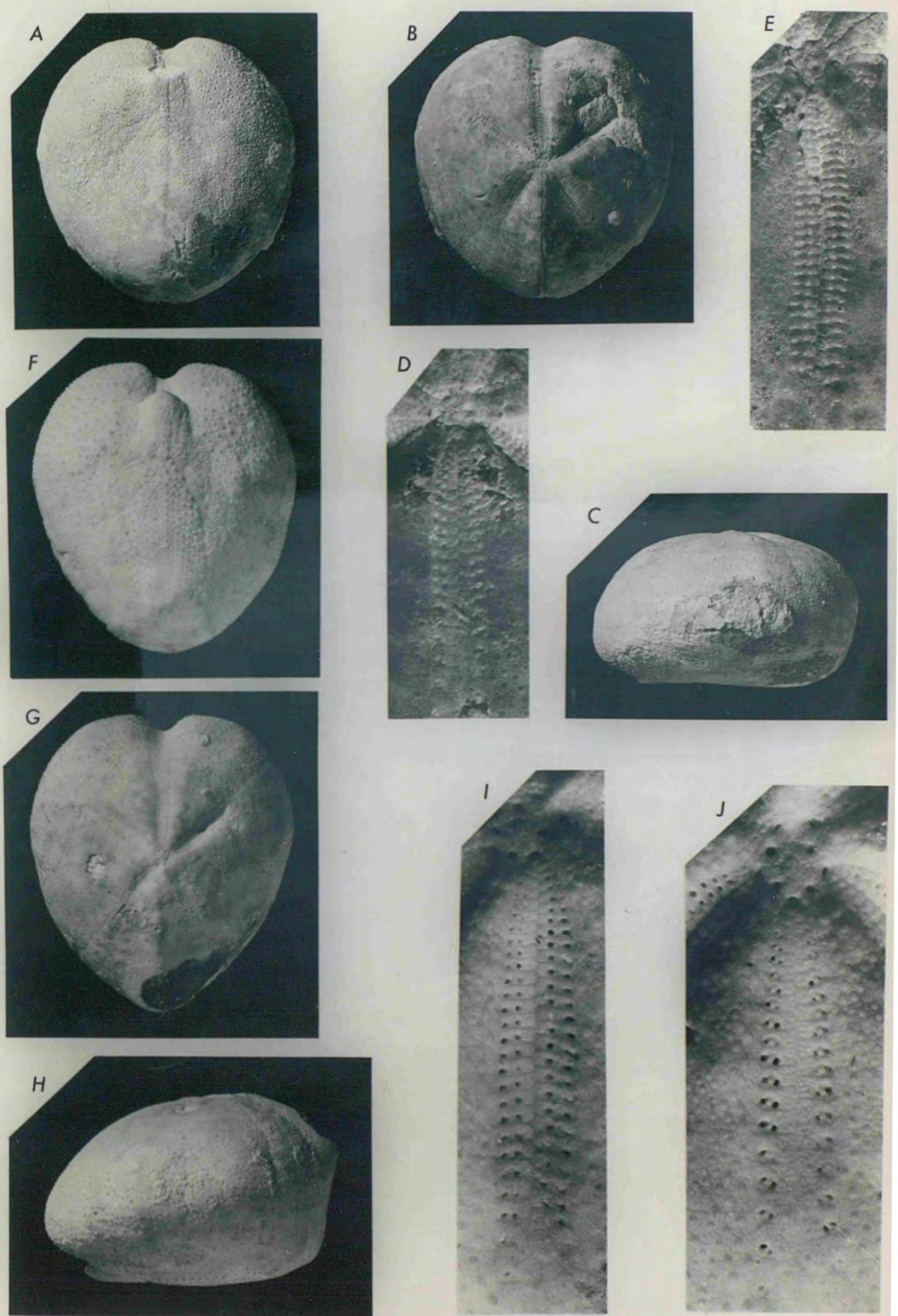

A
B
E
F
D
C
G
I
J
H

PLATE 6

Micraster corcolumbarium Desor

Campanian, Montesquieu (Spain).

Lambert Collection.

The Neotype.

Length 31.7 mms

A - C Oral, Apical and Lateral Views.

D Petal III x 4.

E Petal IV x 4.

Micraster mengaudi (Lambert)

The Holotype from Cabo Menor.

Lambert Collection.

Length 47.9 mms.

F Petal III x 3.

G Petal II x 3.

H - J Lateral, Oral and Apical Views.

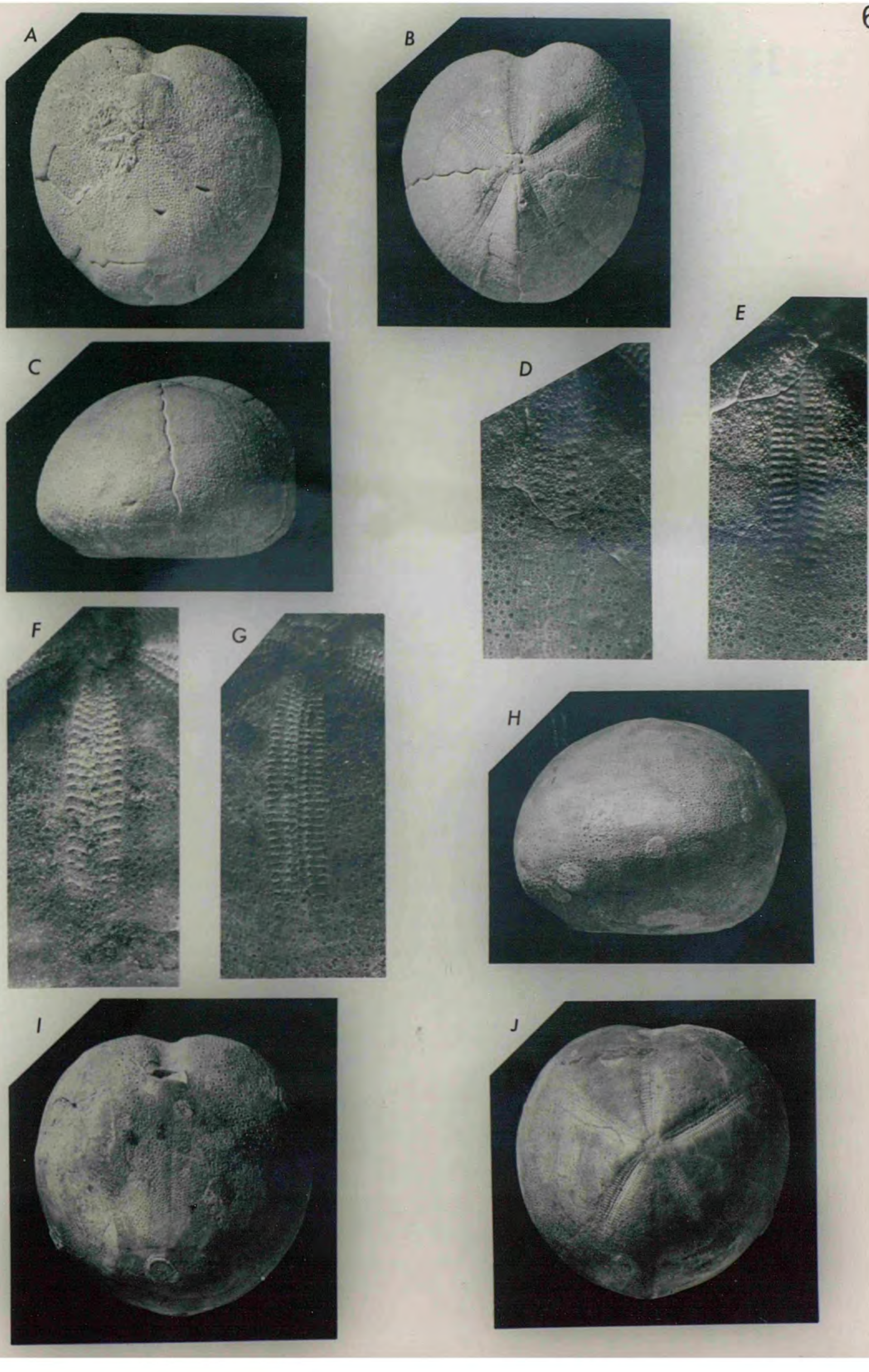

A
B
C
D
E
F
G
H
I
J

PLATE 7

Micraster aturicus Hébert

Campanian, Ermitage de Seira (Spain).

Lambert Collection.

Length 54.2 mms.

A - C Oral, Apical and Lateral Views.

D Petal IV x 4.

Micraster solignaci sp. nov.

Campanian, Koudiat Melhab (Tunisia).

Lambert Collection.

Holotype.

Length 52.6 mms.

E Apical View.

F Lateral View.

G Petal III x 3.

H Petal II x 3.

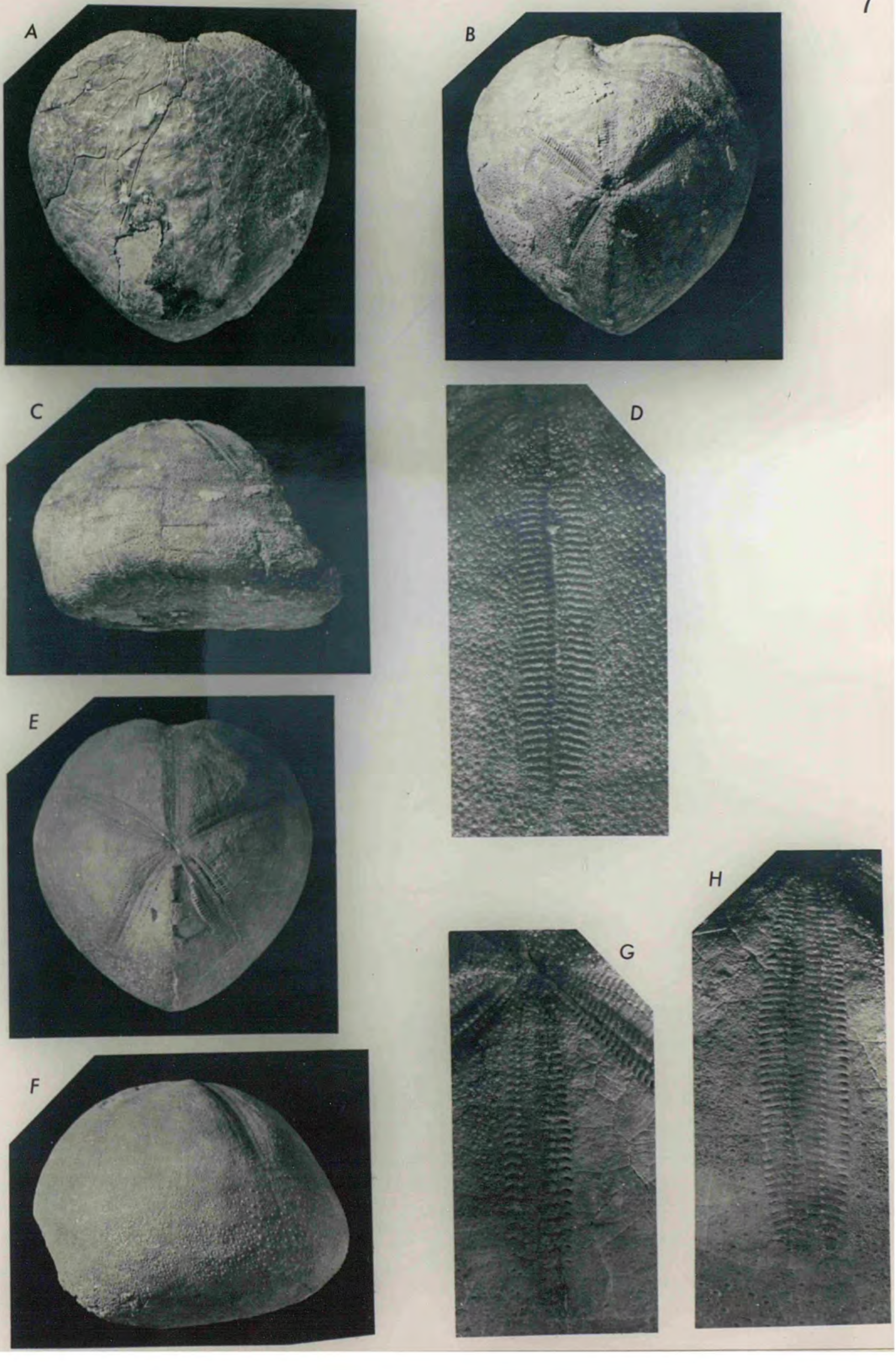

A
B
C
D
E
F
G
H

PLATE 8

Micraster peini Coquand

Santonian, Kanguet Merouna (Tunisia).

Lambert Collection. One of two specimens numbered 984 T.

Length 57.1 mms.

A - C Oral, Apical and Lateral Views.

D Petal I x 3.

E Petal III x 3.

Micraster peini Coqhand

Kanguet Merouna (Tunisia).

Cotteau Collection.

F Petal III x 4.

G Apical region x 6.

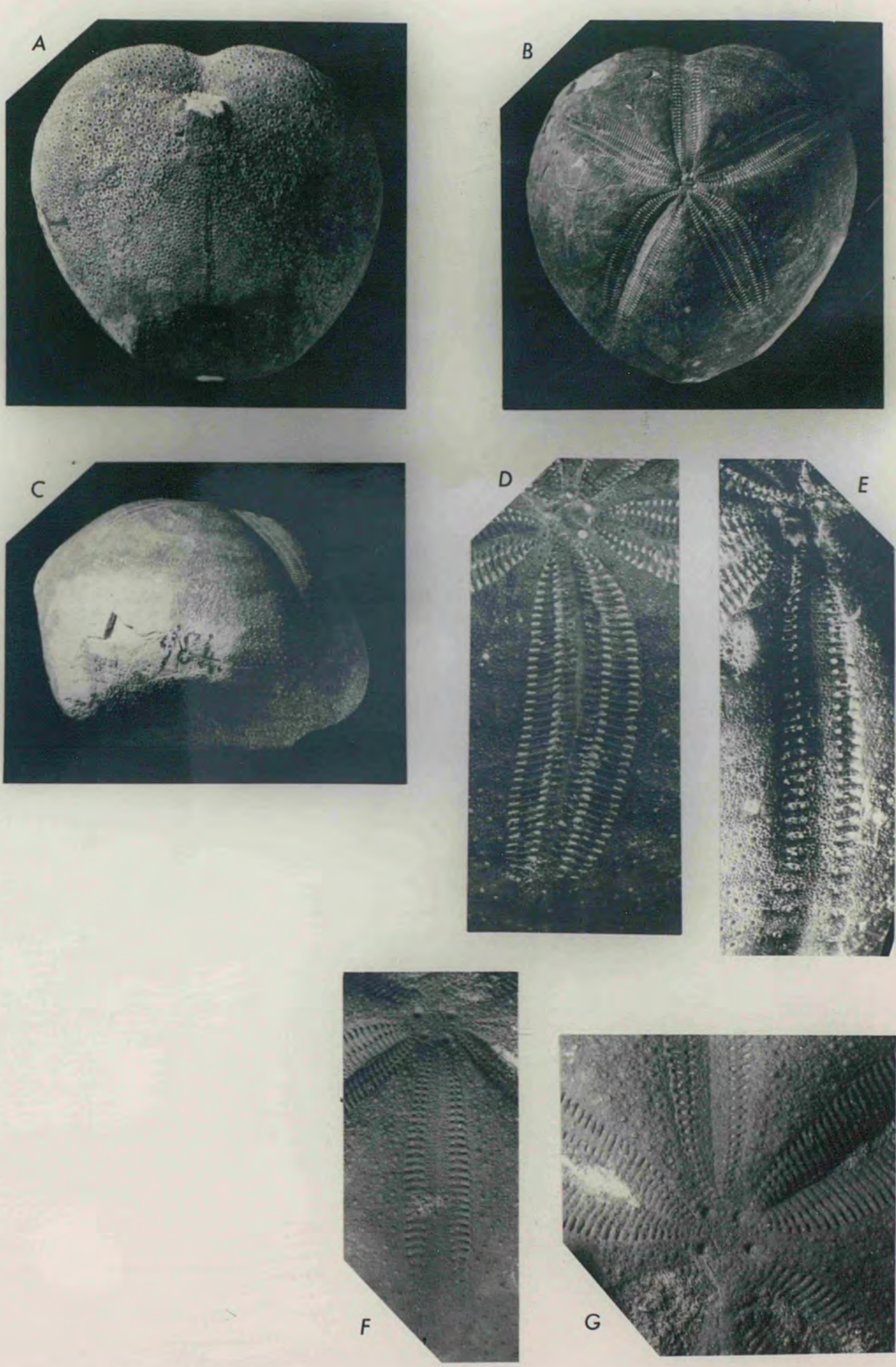

A
B
C
D
E
F
G

PLATE 9

Micraster grimmensis Nietsch

Upper Campanian, Wolsu (U.S.S.R.).

Museum Ziemi (Warsaw) no. Ee - 641

Ex Moskvin Collection.

Length 33.6 mms.

A - C Oral, Apical and Lateral Views. x 1.5.

D Petal III x 4.

E Petal II x 4.

Micraster coravium Poslavskaia

Lower Campanian, U.S.S.R..

Muzeum Ziemi (Warsaw) no. Ee - 640

Ex Moskvin & Poslavskaia Collection.

Length 37.2 mms.

F - H Oral, Apical and Lateral Views x 1.5

I Petal III x 6.

J Petal II x 6.

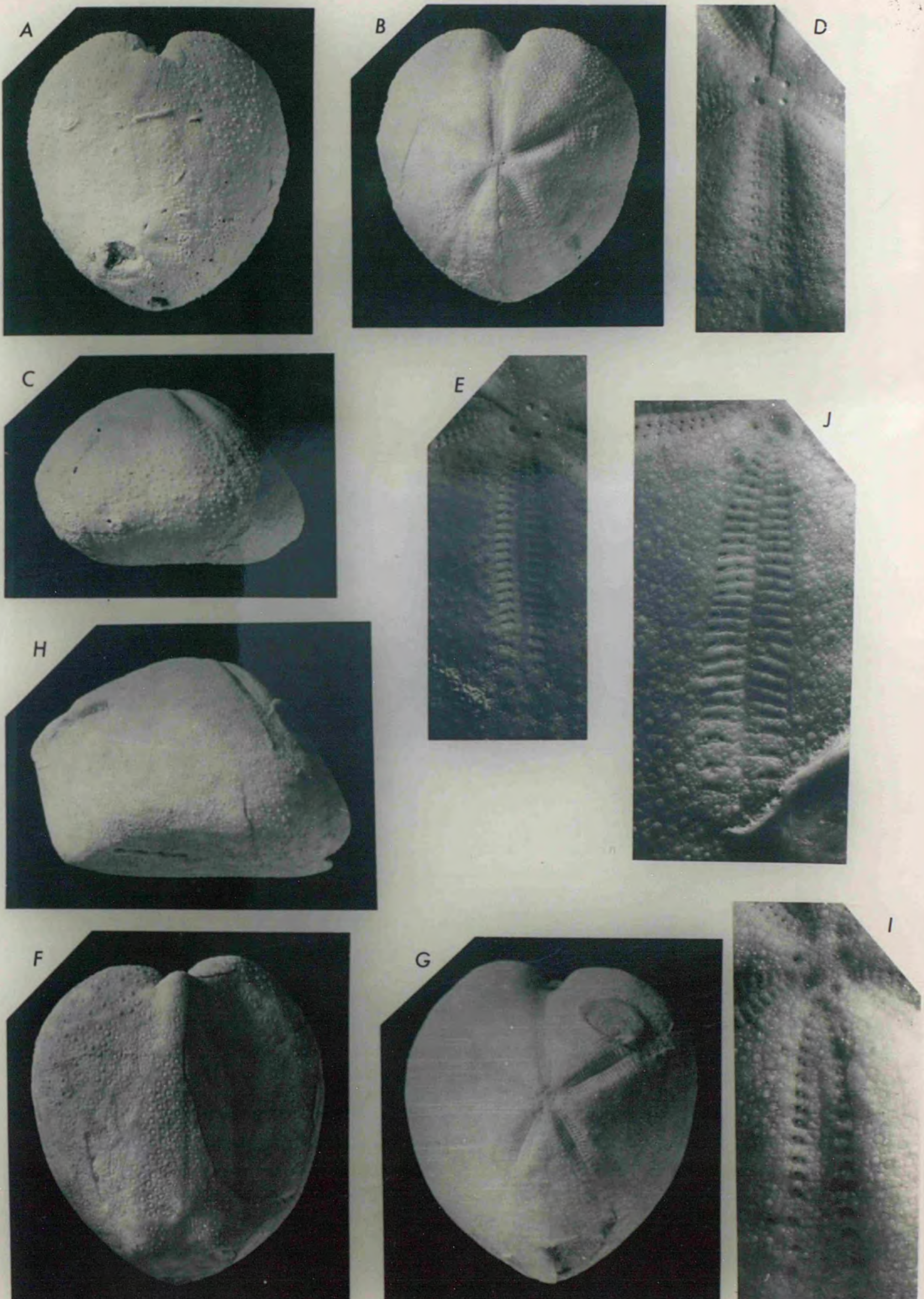

A
B
D
C
E
J
H
I
F
G

PLATE IO

<u>Micraster</u> <u>fastigatus</u> Gauthier

Senonian M, Muizon (Marne).

Lambert Collection.

Length 54 mms.

A - C	Oral, Apical and Lateral Views.
D	Petal II x 4.
E	Petal III x 4.
F	Apical system x 15.

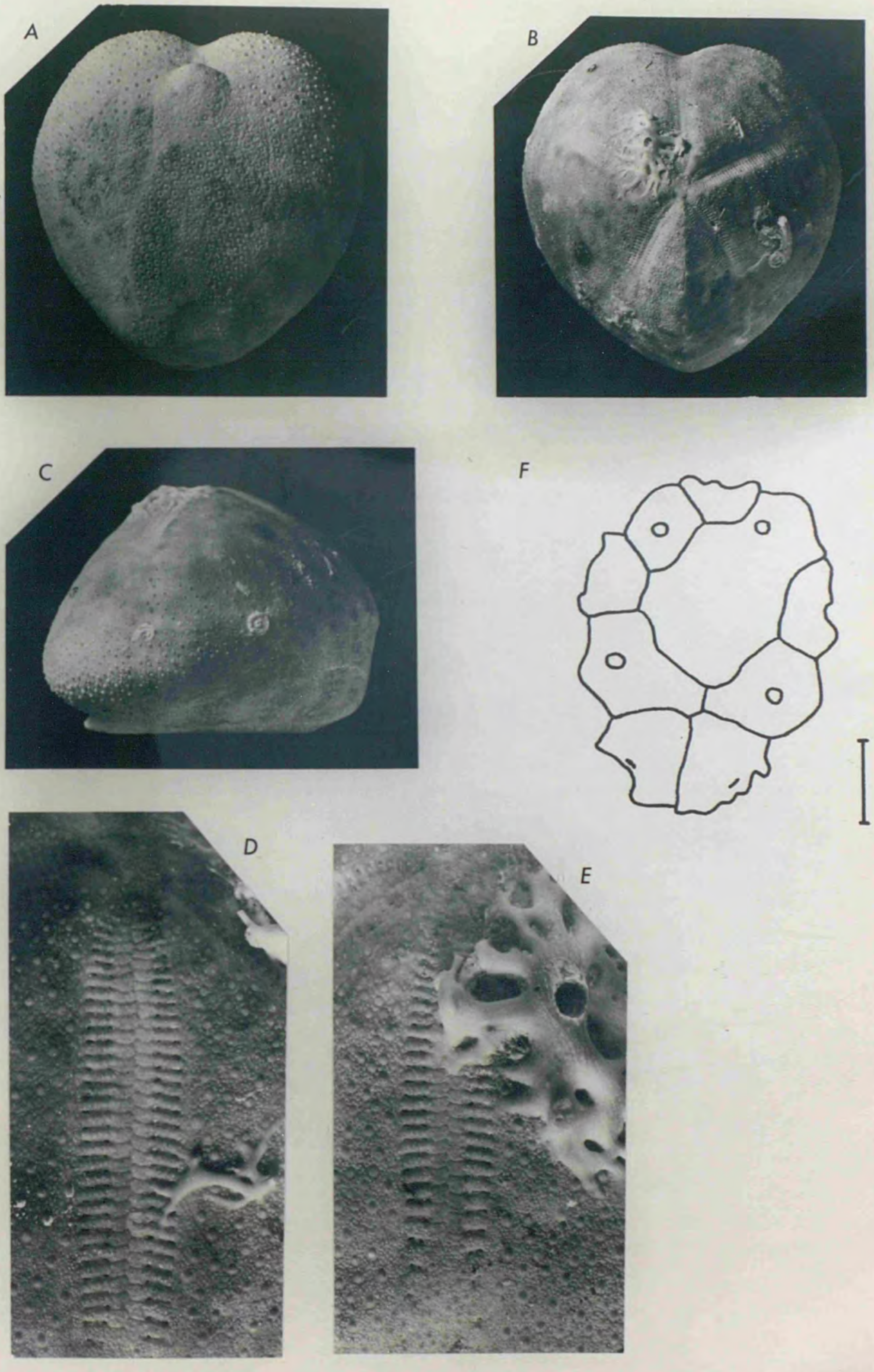

A
B
C
F
D
E

PLATE 11

Plaster casts from the Collection of L. Agassiz and E. Desor.

X 88 _Micraster anglicus_ (Coquand)

White Chalk, England.

Length 63.2 mms.

A - C Oral, Apical and Lateral Views.

S 55 _Micraster coranguinum_ (Leske)

White Chalk, England.

Length 45.6 mms.

D - F Oral, Apical and Lateral Views.

Q 36 _Micraster fastigatus_ Gauthier

Chalk, France.

Length 36.6 mms.

G - I Oral, Apical and Lateral Views.

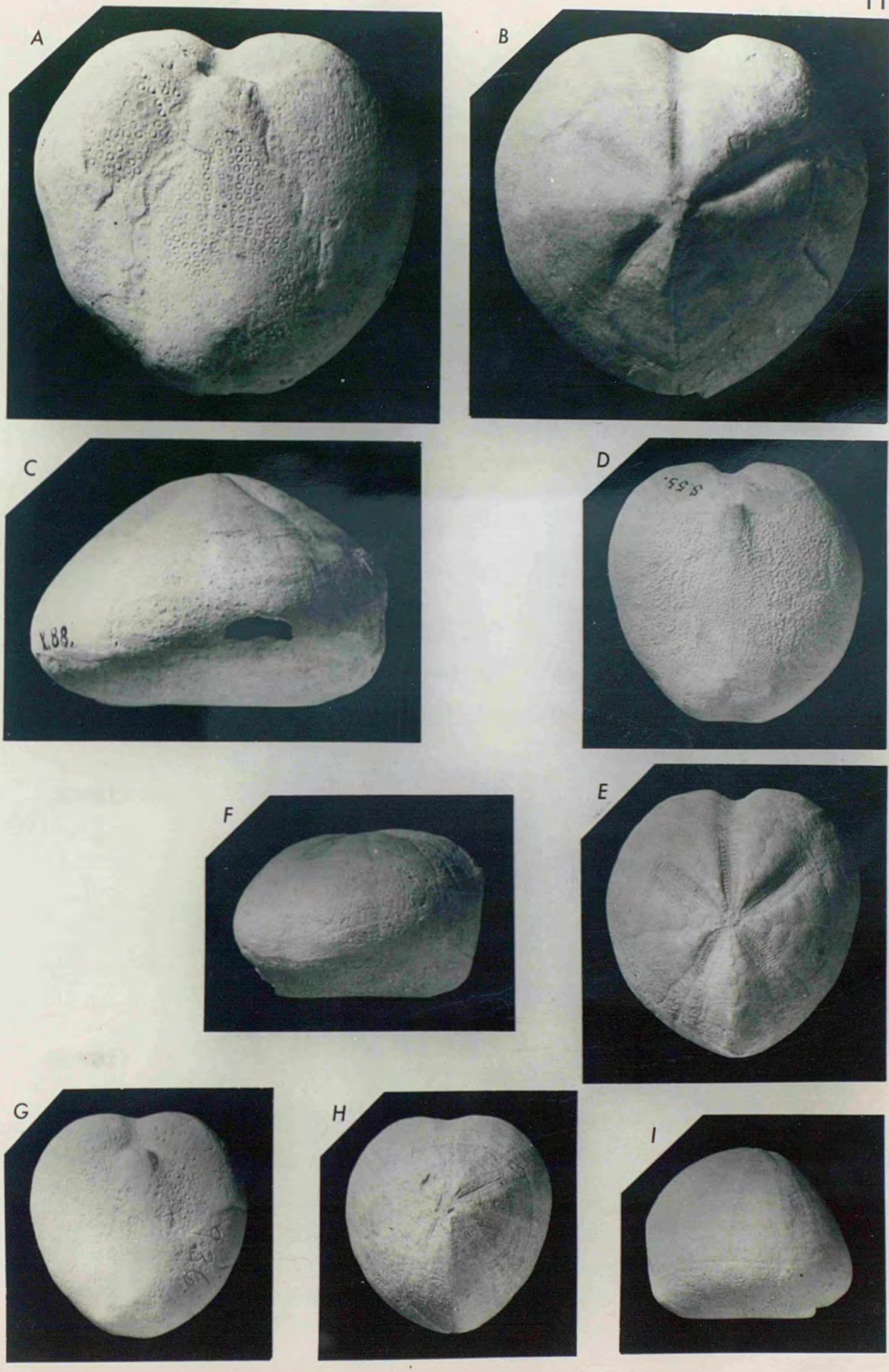

A
B
C
D
E
F
G
H
I

PLATE 12

Plaster casts from the Collection of L. Agassiz and E. Desor.

X 92 *Micraster decipiens* (Bayle)

Craie marneuse, Rouen.

Length 48.2 mms.

A - C Oral, Apical and Lateral Views.

R 69 *Micraster brevis* Desor

Craie à Hippurites, Sougraigne near Bains de Rennes.

Length 43 mms.

D - F Oral, Apical and Lateral Views.

T 49 "*Epiaster*" *michelini* (Agassiz)

Turonian, Touraine.

Length 39.7 mms.

G - H Lateral and Apical Views.

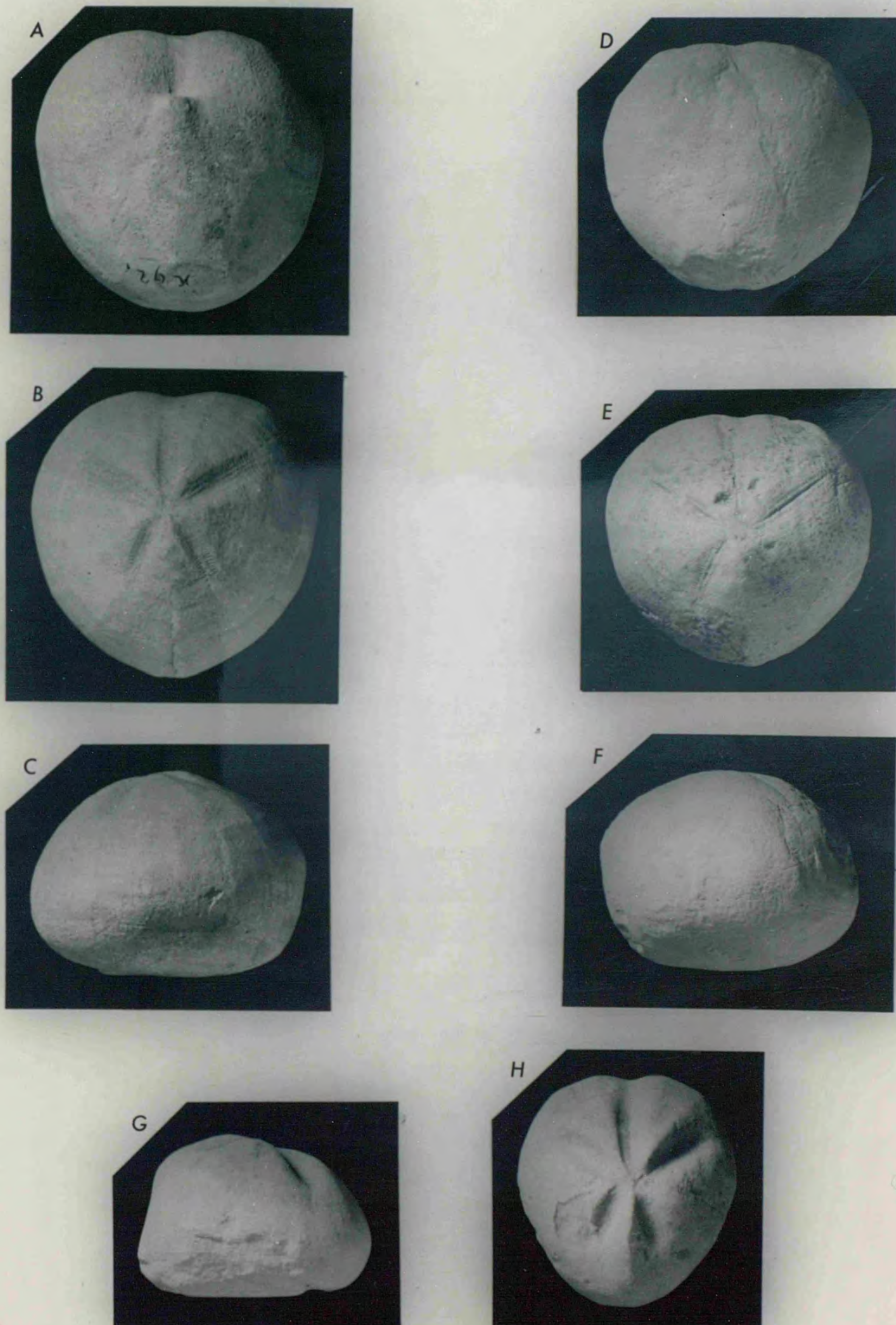

A
B
C
D
E
F
G
H

PLATE 13

<u>Micraster</u> <u>heberti</u> de Lacvivier

Santonian (?), Loredo (Santander).

Lambert Collection.

Length 57.4 mms.

A - C Oral, Apical and Lateral Views.

D Petal III x 3.

E Petal IV x 3.

<u>Diplodetus</u> <u>idae</u> (Cotteau)

Upper Campanian (Köpinge Sandstone), Köpinge (Sweden).

Naturhistoriska Riksmuseet Stockholm Ee 7715.

Length 59.6 mms.

F Oral View.

<u>Diplodetus</u> <u>duponti</u> (Lambert)

Lower Maastrichtian, Kunraed (Belgium).

Musée Royal d'Histoire Naturelle, Brussels

I.G. 5185

G Petal III x 4.

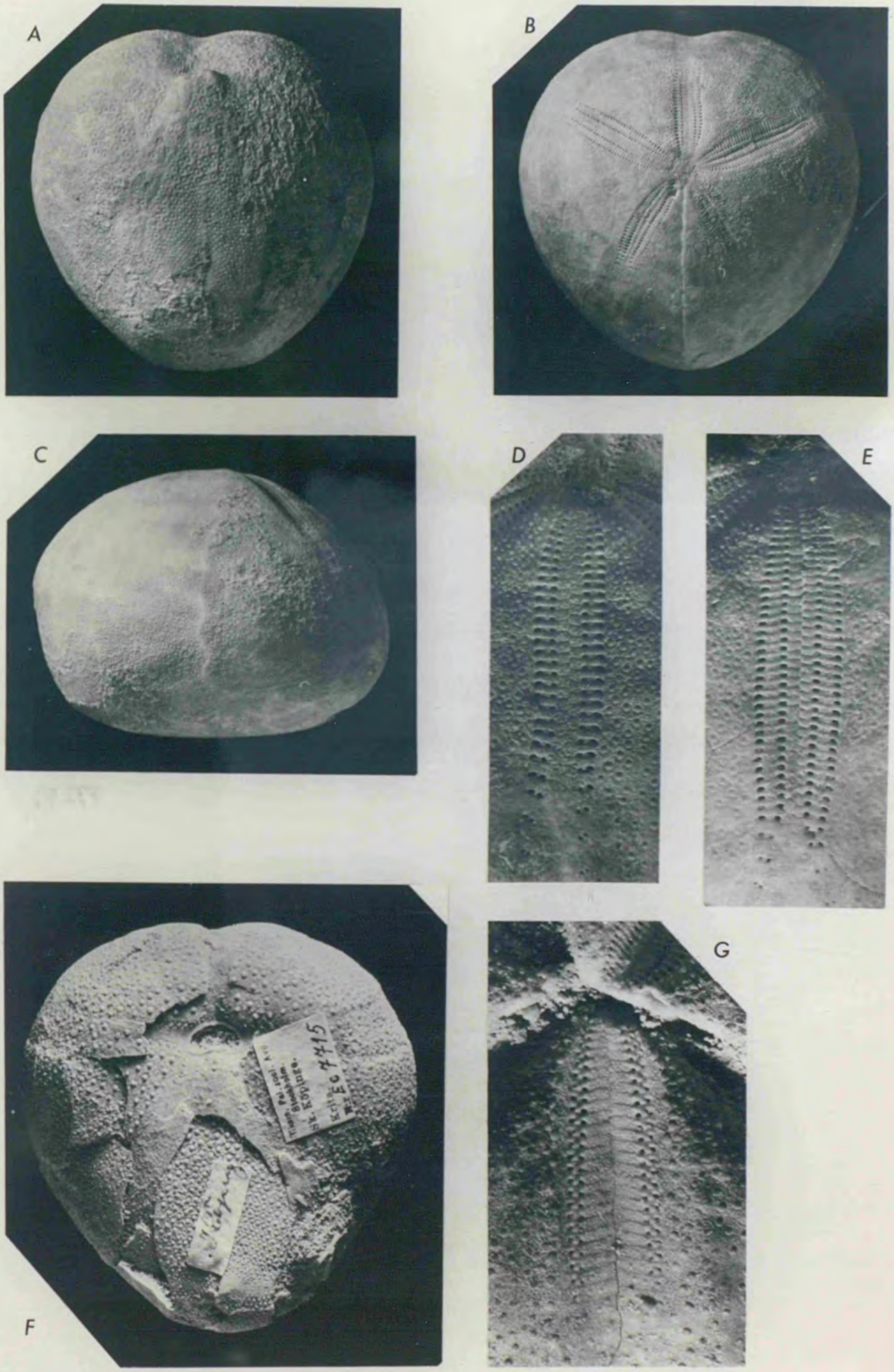

A
B
C
D
E
F
G

PLATE 14

Micraster gosseleti Cayeux

"Cortestudinarium" Zone, Ennequin (Lille).

Lambert Collection (ex Parent Collection).

Length 51.4 mms.

A - C Oral, Apical and Lateral Views.

Micraster gourdoni Cotteau

Senonian, Egea (Aragon).

Lambert Collection.

Holotype of _Micraster dallonii_ Lambert.

Length 64.2 mms.

D - F Oral, Apical and Lateral Views.

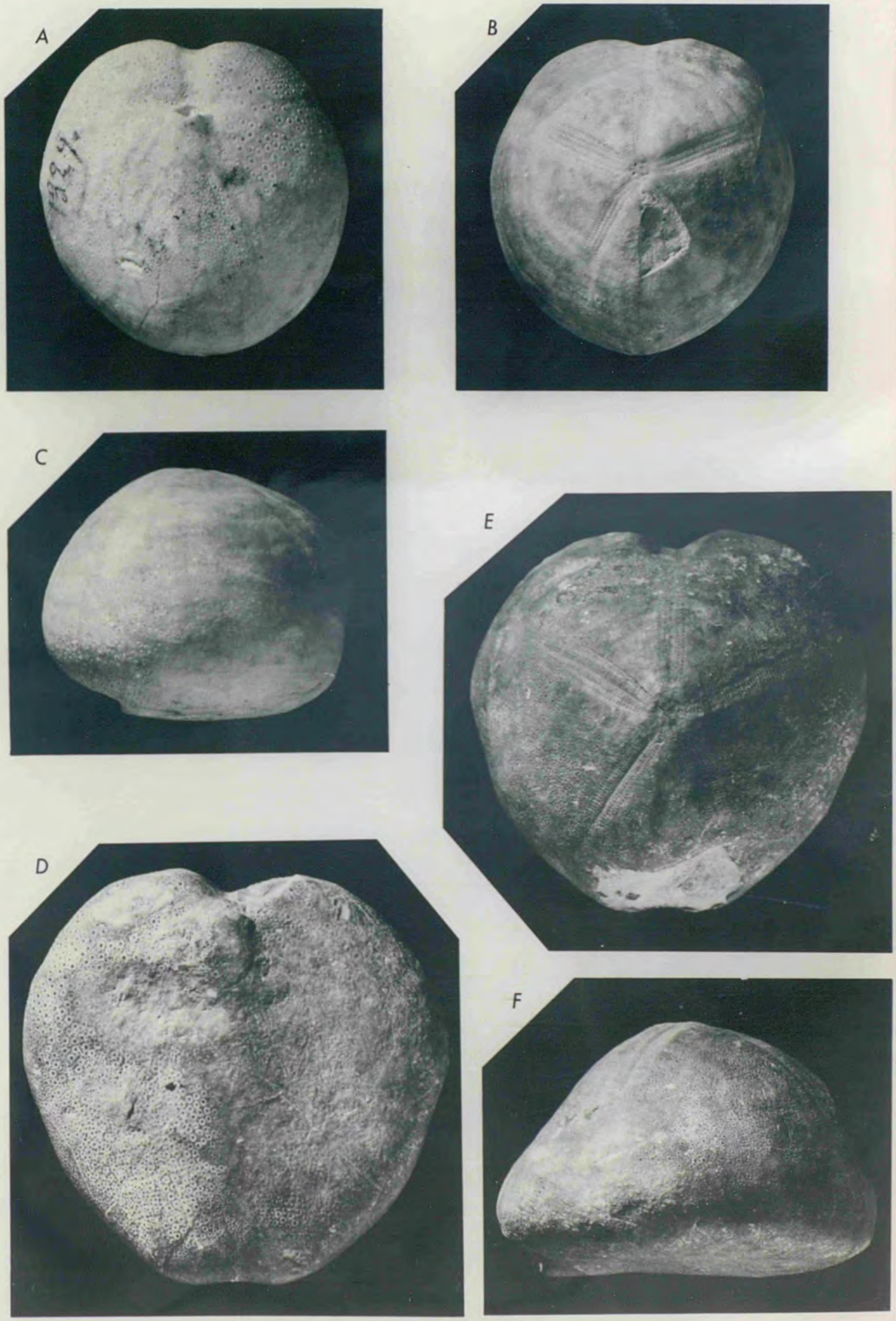

A
B
C
D
E
F

PLATE 15

Micraster brongniarti Hébert

Upper Campanian, Meudon (Paris).

Musée d'Histoire Naturelle, Paris.

? Holotype.

Length 53.4 mms.

A - C   Oral, Apical and Lateral Views.

D   Petal III x 4.

E   Petal IV x 4.

Micraster renati (Gauthier)

Senonian F, St.-Julien-du-Sault (Yonne).

Lambert Collection.

Length 50.7 mms.

F - H   Lateral, Oral and Apical Views.

I   Petal II x 5.

15

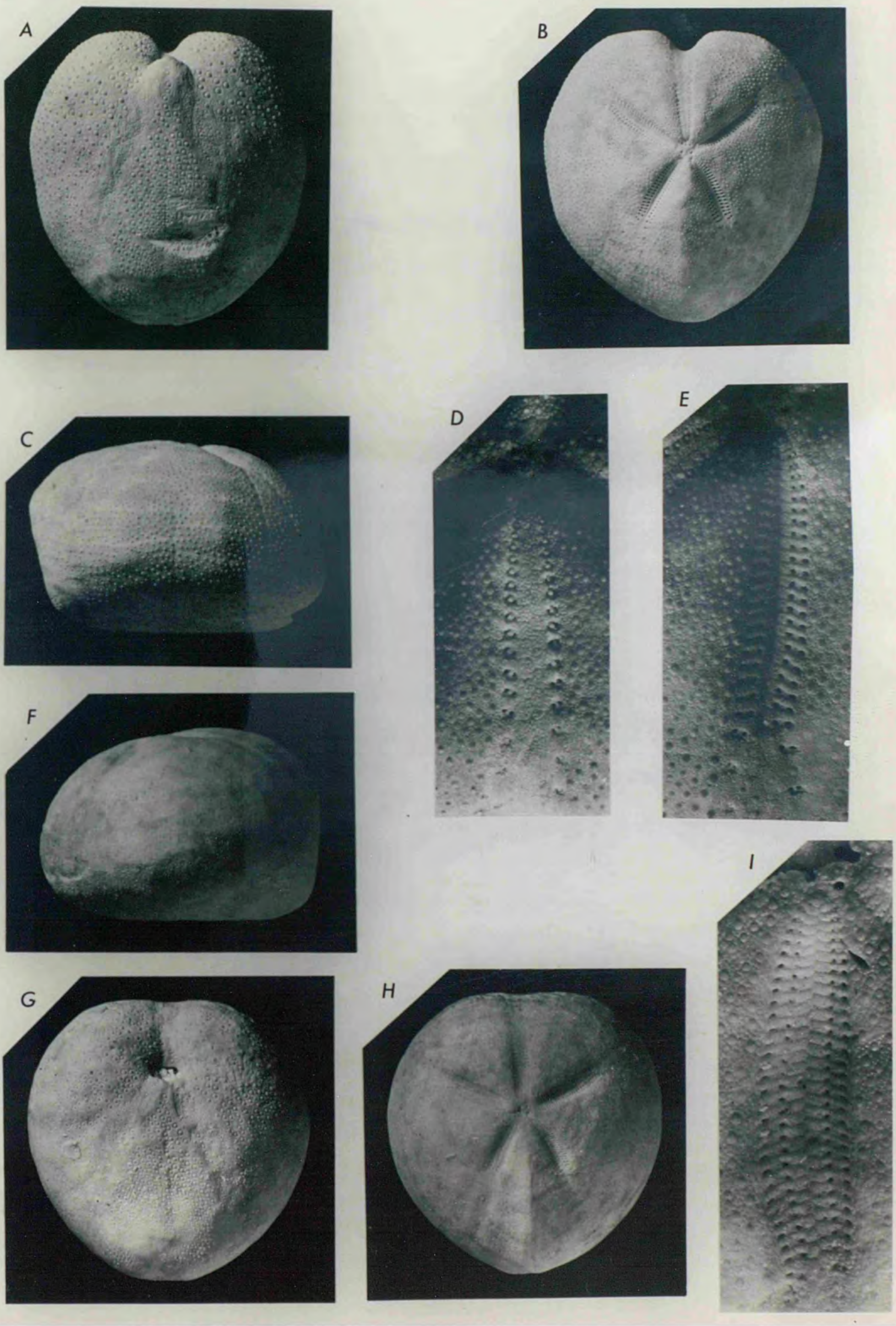


PLATE 16

Micraster stolleyi Lambert

Upper Senonian, La Palarea (near Nice).

Lambert Collection.

Lambert's Neotype of Micraster gibbus (Lamarck).

Length 52.2 mms.

A - C Oral, Apical and Lateral Views.

D Petal III x 4.

E Petal II x 4.

"Epiaster" laxoporus (d'Orbigny)

Craie de Villedieu, Villedieu (Loir et Cher).

Cotteau Collection.

Length 27.1 mms.

F - H Oral, Lateral and Apical Views x 1.5.

16

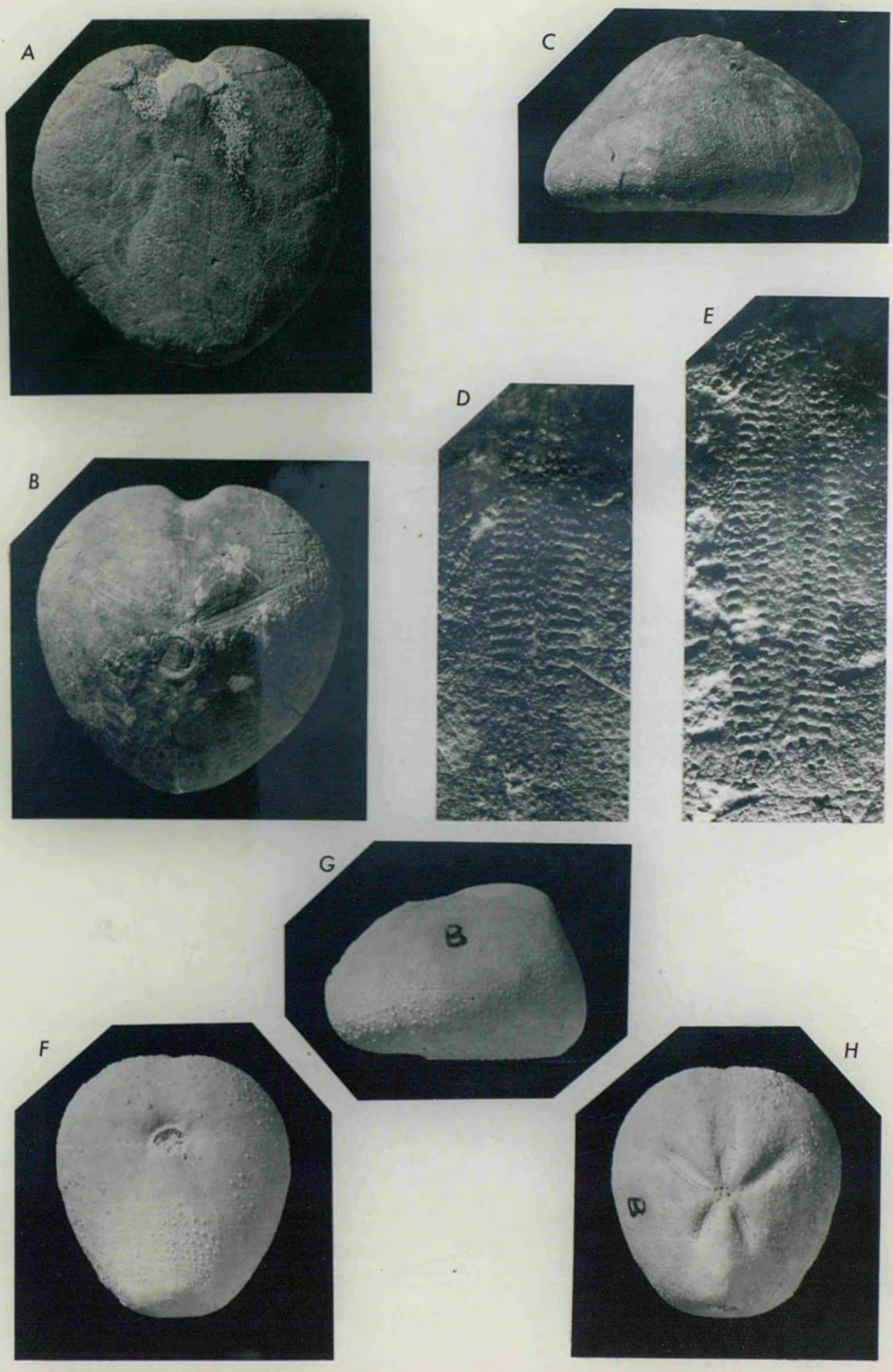


PLATE 17

Micraster turonensis (Bayle)

Craie de Villedieu, Villedieu (Loir et Cher).

De Grossouvre Collection.

Length 56.4 mms.

A - C	Oral, Apical and Lateral Views.
D	Oral region x 3.
E	Petal IV x 4.
F	Petal III x 4.

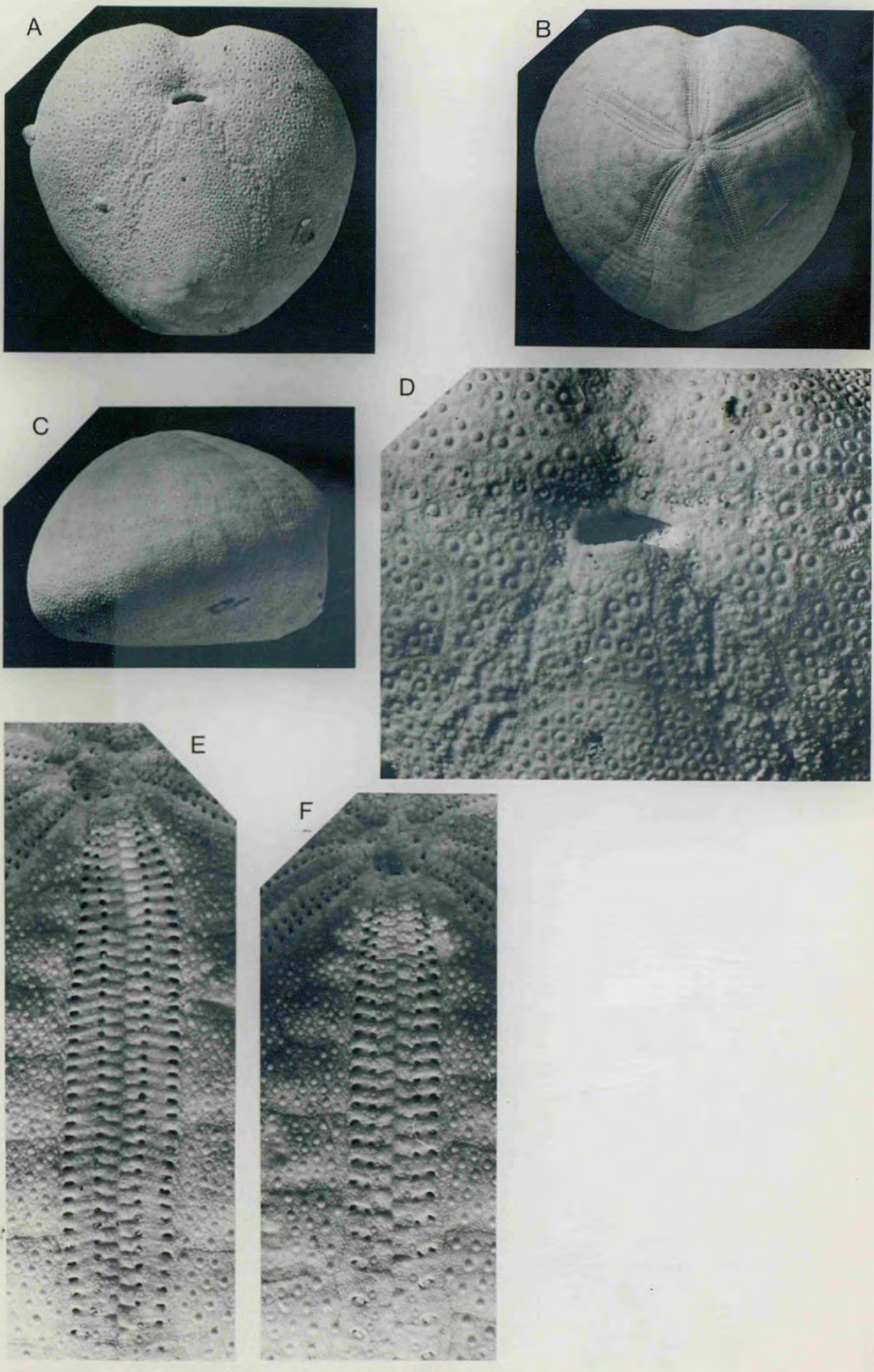

A
B
C
D
E
F

PLATE 18

Micraster sismondai Lambert

Upper Senonian, La Palarea near Nice.

Lambert Collection.

Holotype. Length 56.9 mms.

A - C Oral, Apical and Lateral Views.

D Petal II x 4.

E Petal III x 4.

Micraster douvillei Lambert

Santonian (?), Santa Marina (Santander).

Lambert Collection. Length 57.9 mms.

F - H Apical, Lateral and Oral Views.

Holotype from the same locality.

Lambert Collection.

I Petal III x 4.

J Petal II x 4.

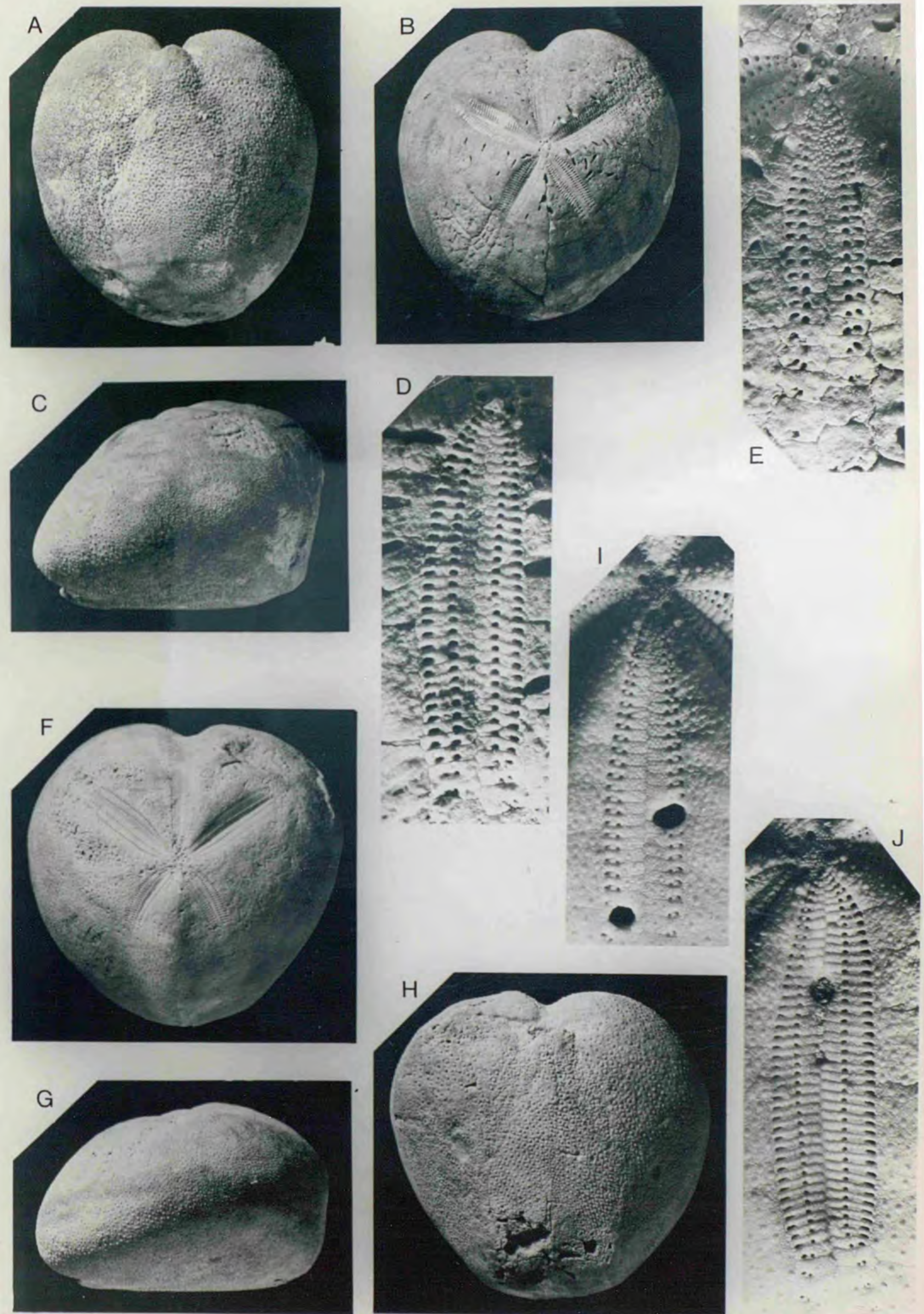

A
B
C
D
E
F
G
H
I
J

PLATE 19

Micraster normanniae Bucaille

Setques (Pas-de-Calais).

De Grossouvre Collection.

Length 50 mms.

A - C Oral, Apical and Lateral Views.

Micraster normanniae Bucaille

Neufchâtel (Seine Maritime).

De Grossouvre Collection.

D Petal II x 4.

E Petal III x 4.

Micraster coranguinum var. *simpsoni* var. nov.

Echinocorys tectiformis Horizon, Saltdean (Sussex).

R. Simpson Collection.

Holotype.

Length 46 mms.

F _ H Lateral, Apical and Oral Views.

I Petal IV x 4.

J Petal III x 4.

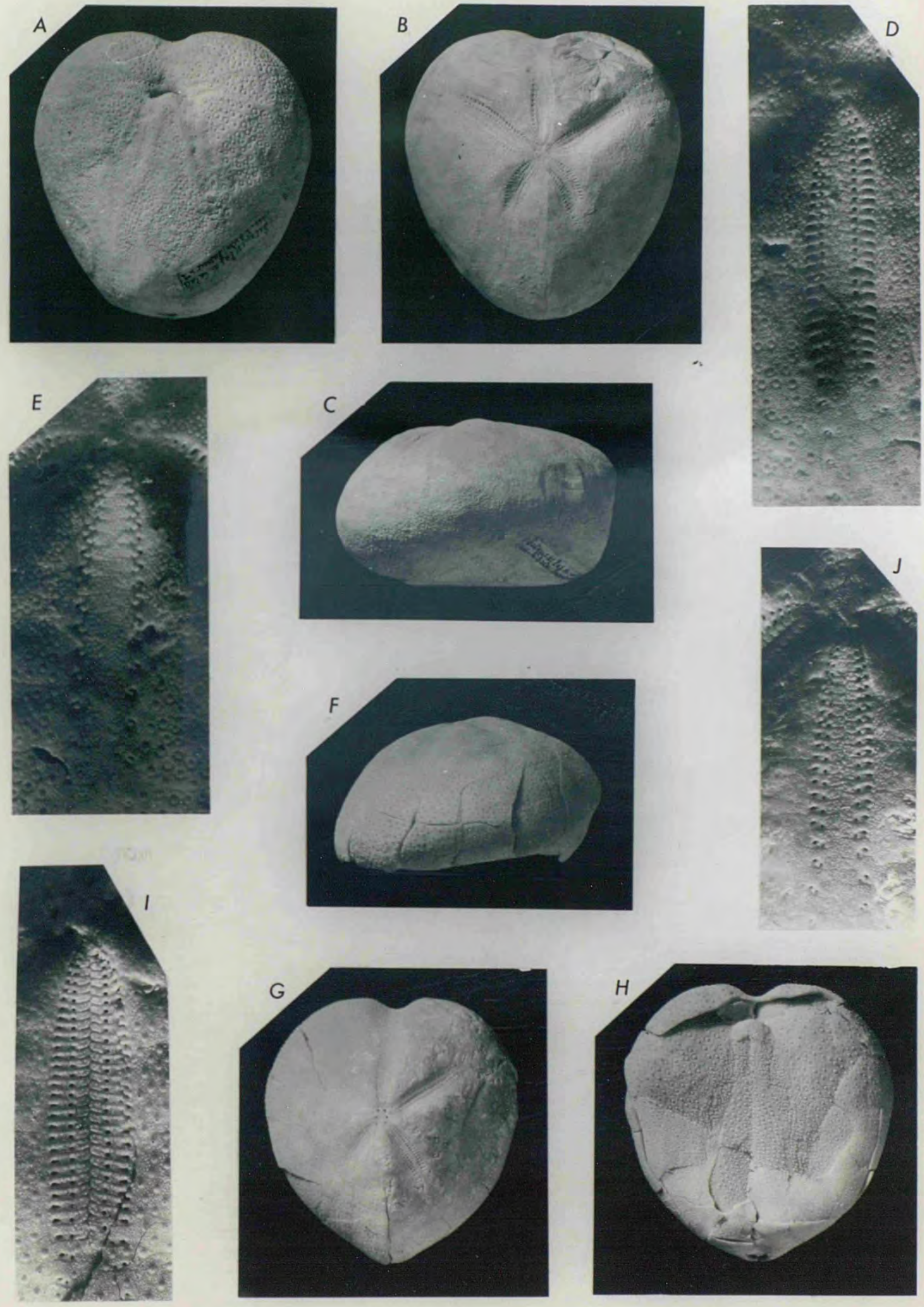

A
B
D
E
C
J
F
I
G
H

PLATE 20

<u>Micraster</u> <u>gibbus</u> (Lamarck)

Craie d'Obourg, Harmignies (Belgium).

Musée Royal d'Histoire Naturelle, Brussels

specimens numbered I.G. 6435.

A Oral View.

B Lateral View.

Another specimen

C Apical View.

<u>Micraster</u> <u>glyphus</u> Schlüter

Mucronata Zone, Darup (Westfalia).

Schlüter Collection.

Labelled "Darup 1869"

Length 73 mms.

D Oral View.

E Apical View.

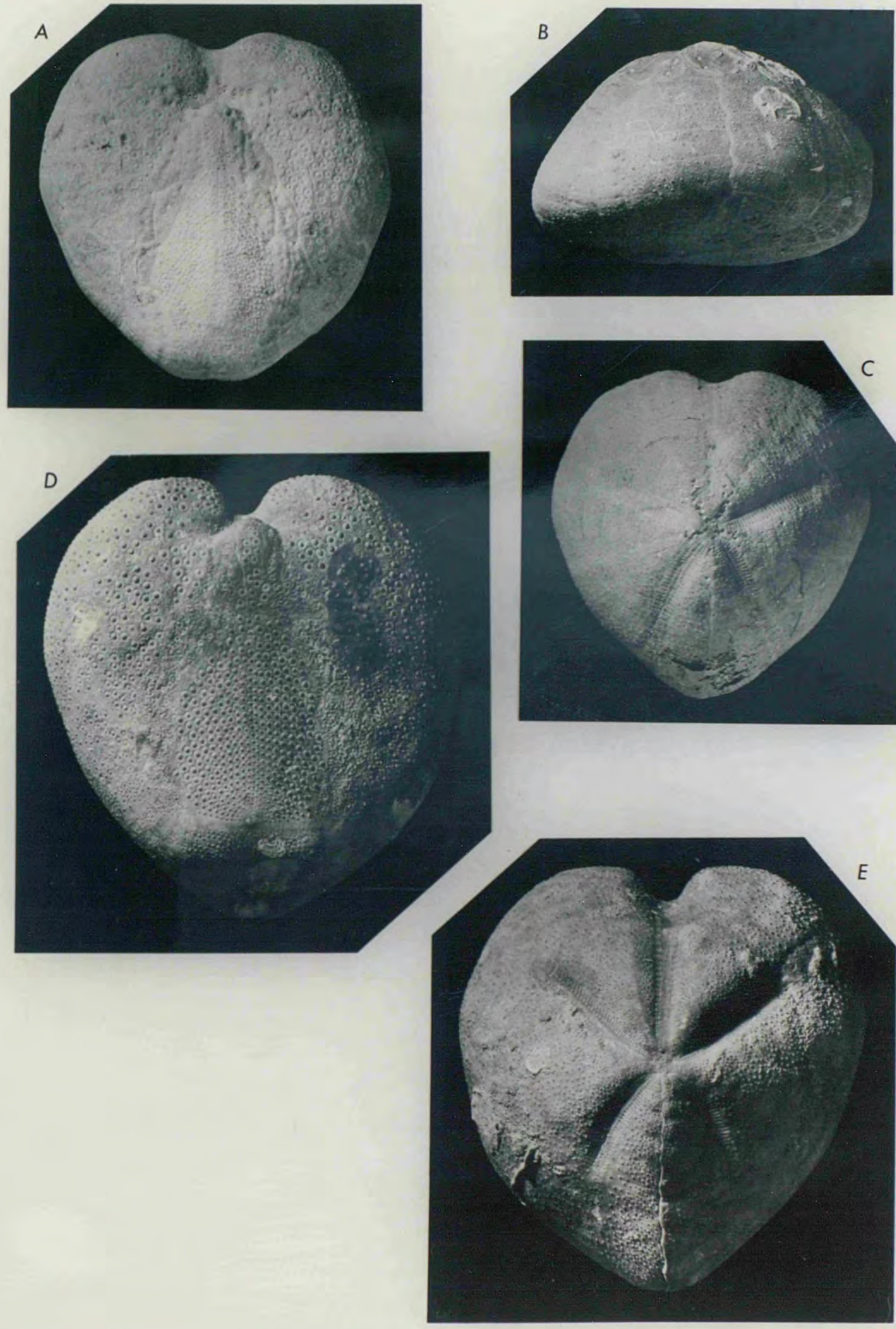

A
B
C
D
E

PLATE 21

"*Epiaster*" *michelini* (Agassiz)

Cenomanian, Briollay

Cotteau Collection.

Length 43.3 mms.

A - C Oral, Apical and Lateral Views x 1.5.

D Petal III x 5.

E Petal IV x 5.

"*Epiaster*" *michelini* (Agassiz)

Turonian, Briollay

Cotteau Collection

Length 39.6 mms.

F Lateral View x 1.75

21

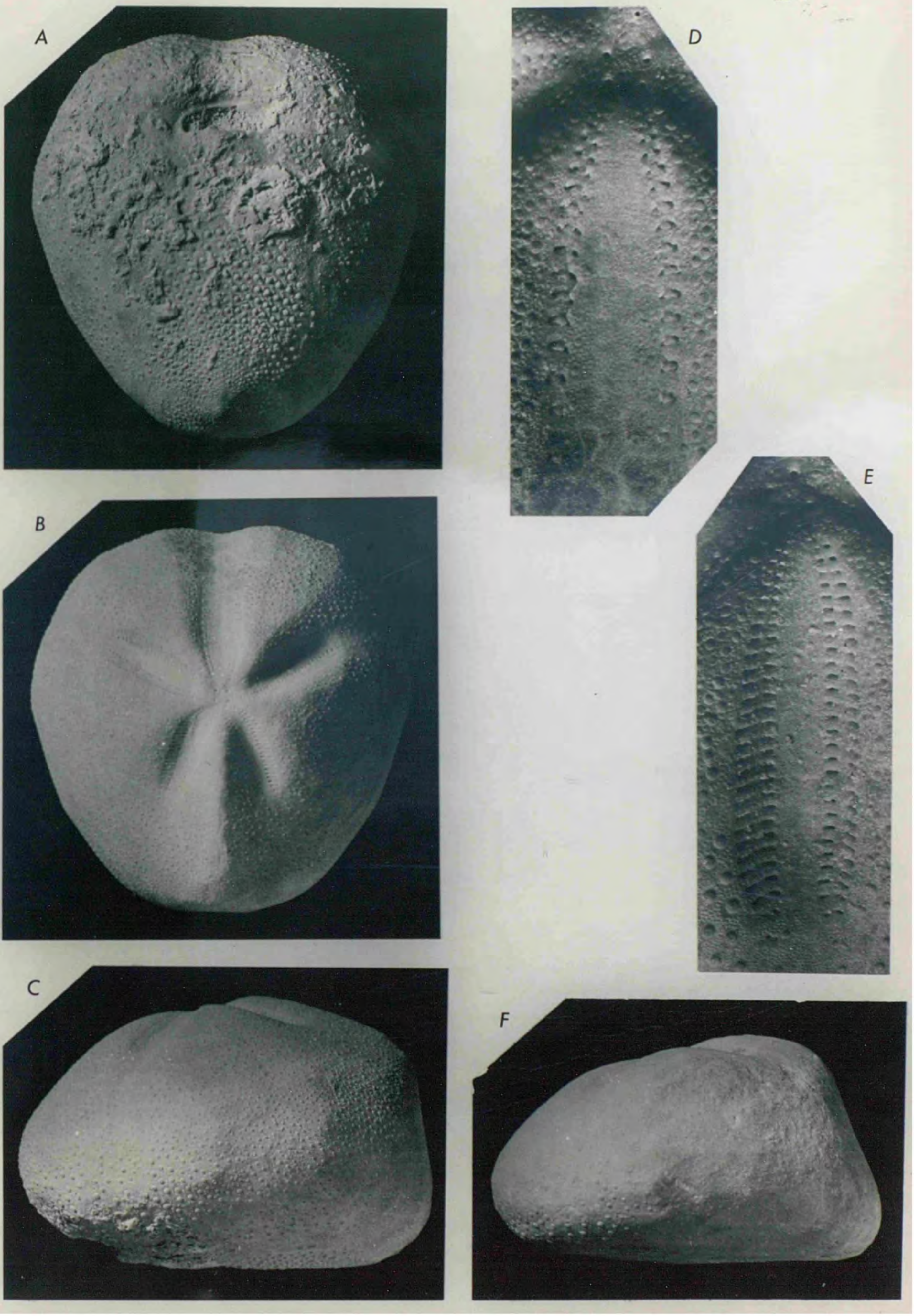


PLATE 22

Micraster westlakei sp. nov.

Mucronata Zone, Tichbourne Farm (Hants).

Westlake Collection no. 3321

Length 61.5 mms.

A Oral View.

Holotype from the same locality

Westlake Collection no. 3320

Length 63 mms.

B Apical View.

C Lateral View.

Micraster turonensis var. intermedius Bucaille

Senonian, Elbeuf (Seine Maritime).

Lambert Collection (ex Bucaille Collection)

Length 44.6 mms.

D - F Lateral, Oral and Apical Views.

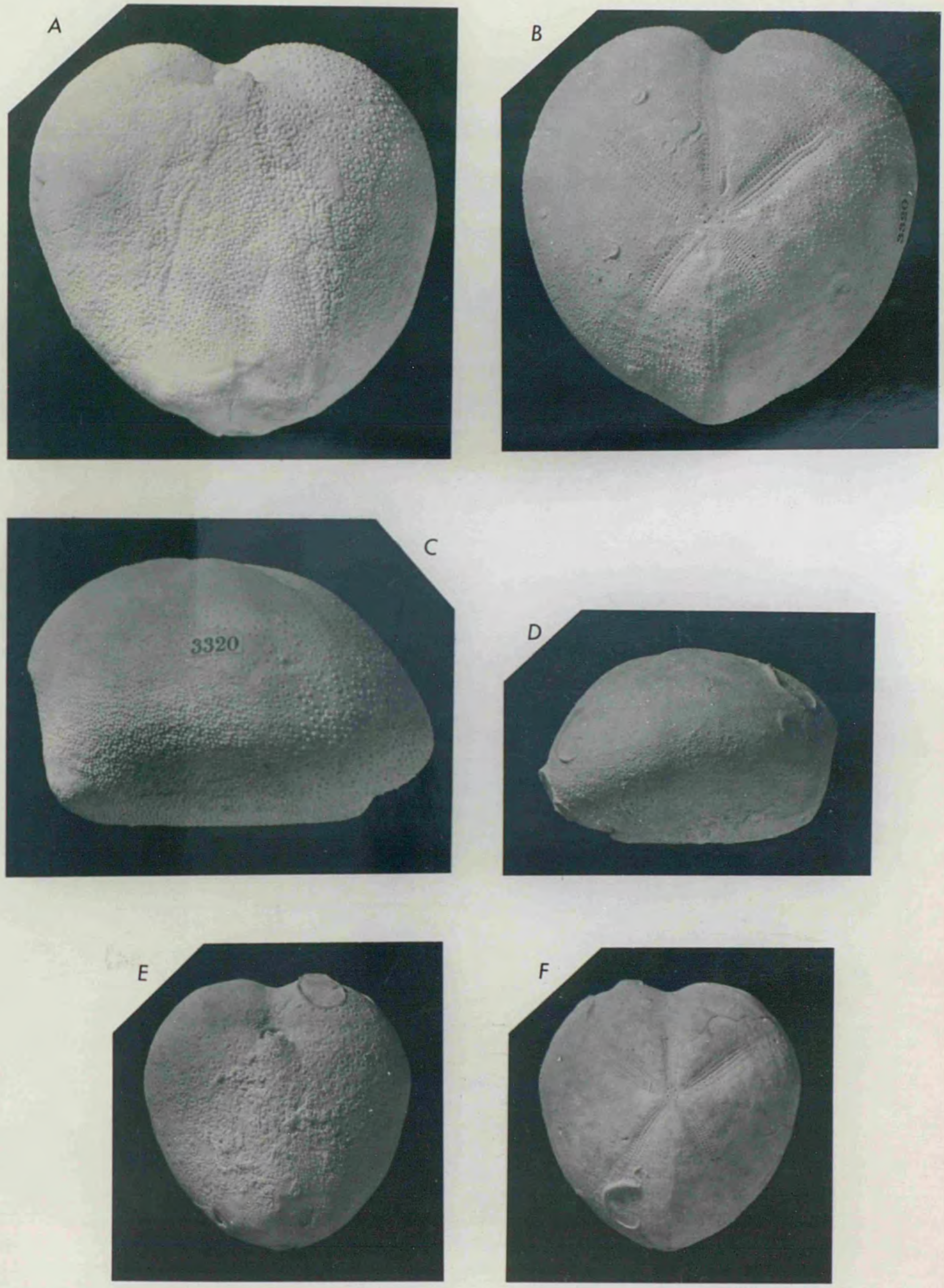

A
B
3320
C
3320
D
E
F

PLATE 23

<u>Micraster</u> <u>turonensis</u> var. <u>coniacensis</u> Lambert

Senonian, Rocher de l'Epinette (Ile d'Oléron).

Lambert Collection.

Length 34.5 mms.

A - C Oral, Apical and Lateral Views.

<u>Micraster</u> <u>bucailli</u> Parent

"Cortestudinarium" Zone, Kiplingcotes (Yorks).

C.W. & E.V. Wright Collection no. 24732.

D Oral View x 1.

<u>Micraster</u> <u>corbovis</u> Forbes (Aberrant form)

Planus Zone, Kiplingcotes (Yorks).

C.W. & E.V. Wright Collection no. 478.

E Oral View x 1.

23

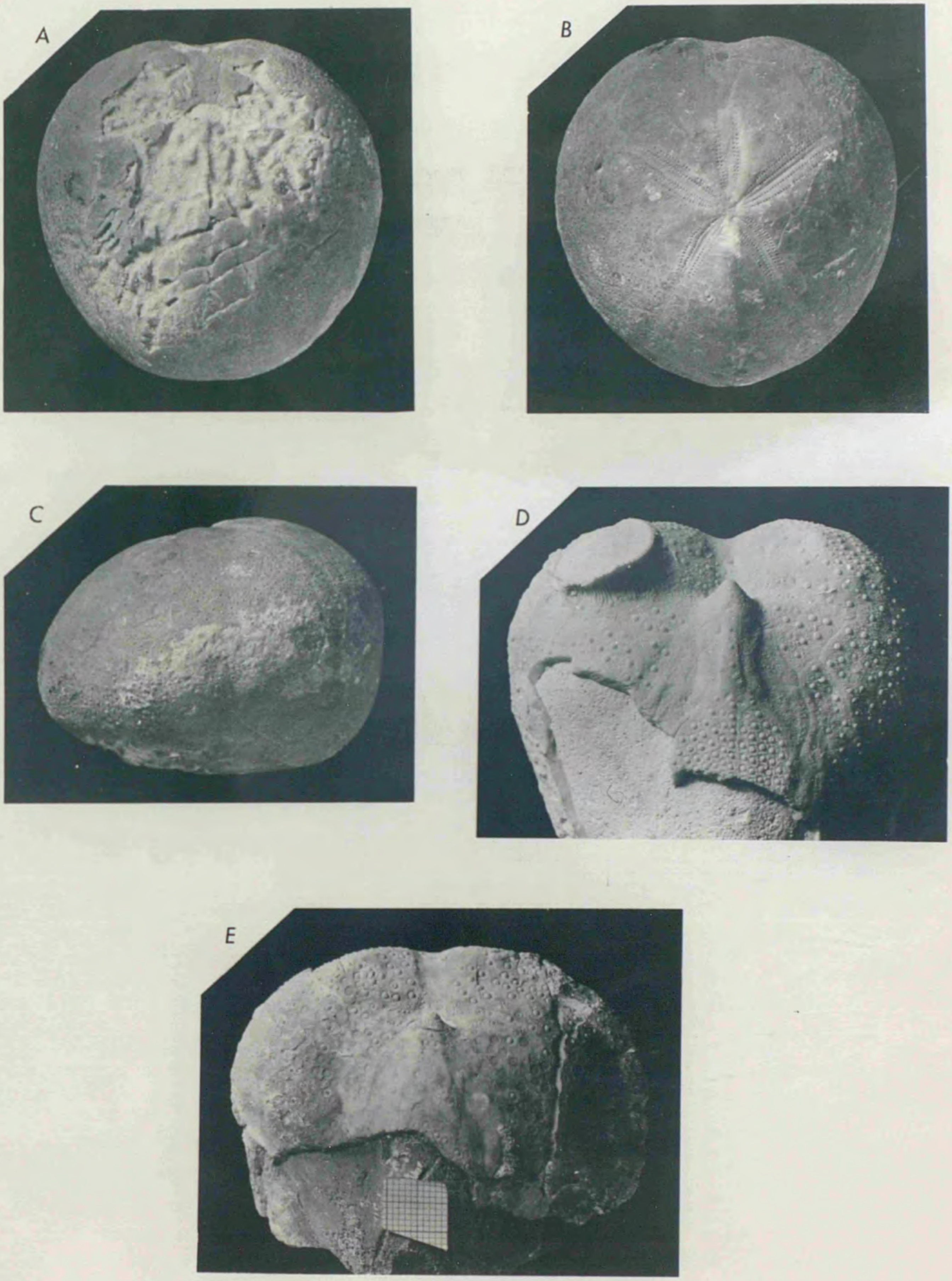


PLATE 24

Apical systems of the "*Epiaster*" Group.

a) "*Epiaster*" *michelini* (Agassiz). Cenomanian of Briollay
Cotteau Collection.

b) "*Epiaster*" *michelini* (Agassiz). Turonian of Briollay
Cotteau Collection.

c) "*Epiaster*" *laxoporus* (d'Orbigny). Senonian of
Villedieu. Cotteau Collection.

d) "*Epiaster*" *laxoporus* (d'Orbigny). Senonian of
Villedieu. Cotteau Collection.

e) "*Epiaster*" *carentonensis* (Lambert). Senonian of
Villedieu. Lambert Collection, no. 538.

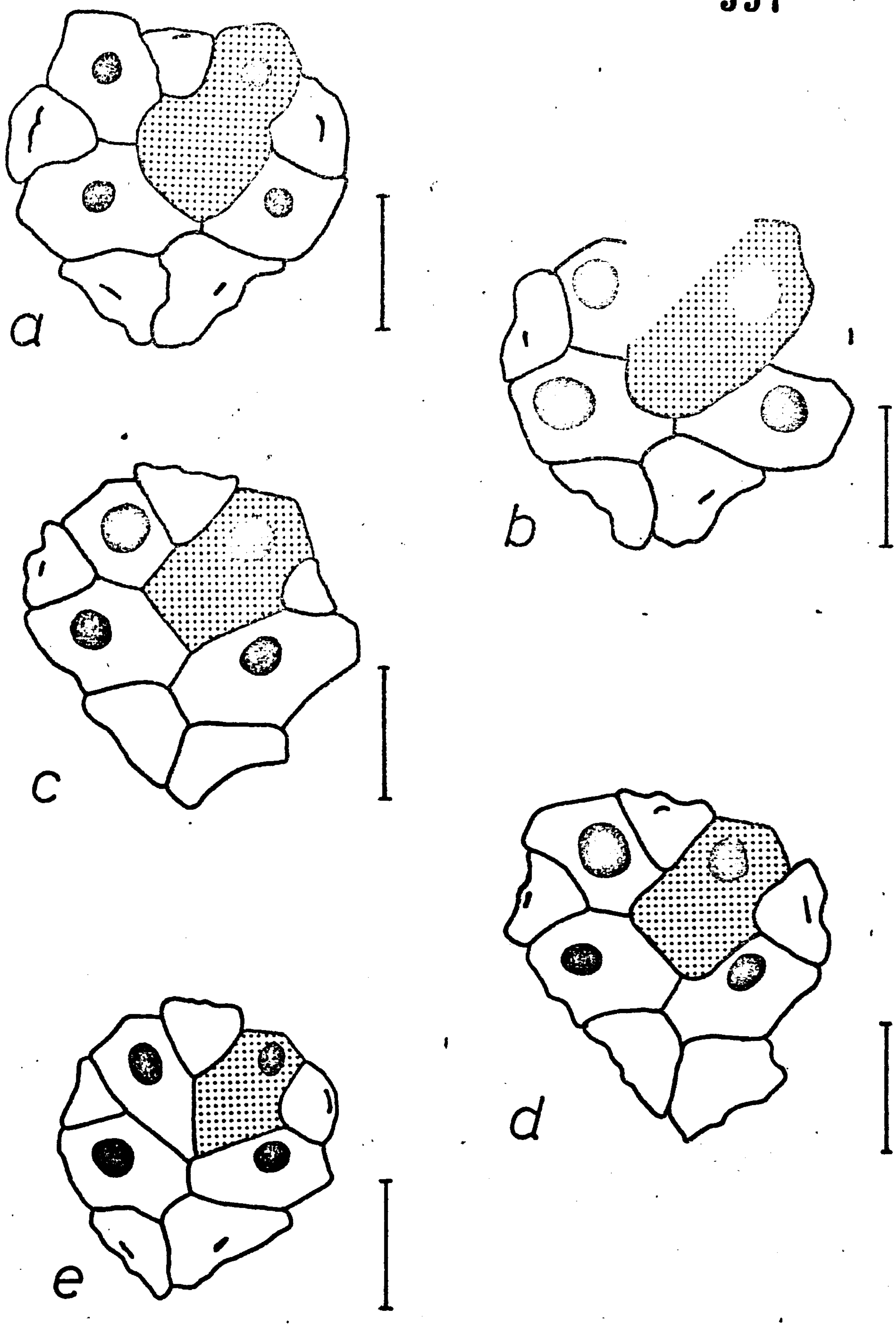

a
b
c
d
e

PLATE 25

Apical systems of Tunisian Micrasters.

a) Micraster peini Coquand. Djebel Touireuf.
Lambert Collection.

b) Micraster peini Coquand. Kanghuet Mazouna
Santonian. Lambert Collection.

c) Micraster peini Coquand. Kanghuet Mazouna
Cotteau Collection.

d) Micraster solignaci sp. nov. Campanian of
Koudiat Melhab. Lambert Collection.

25

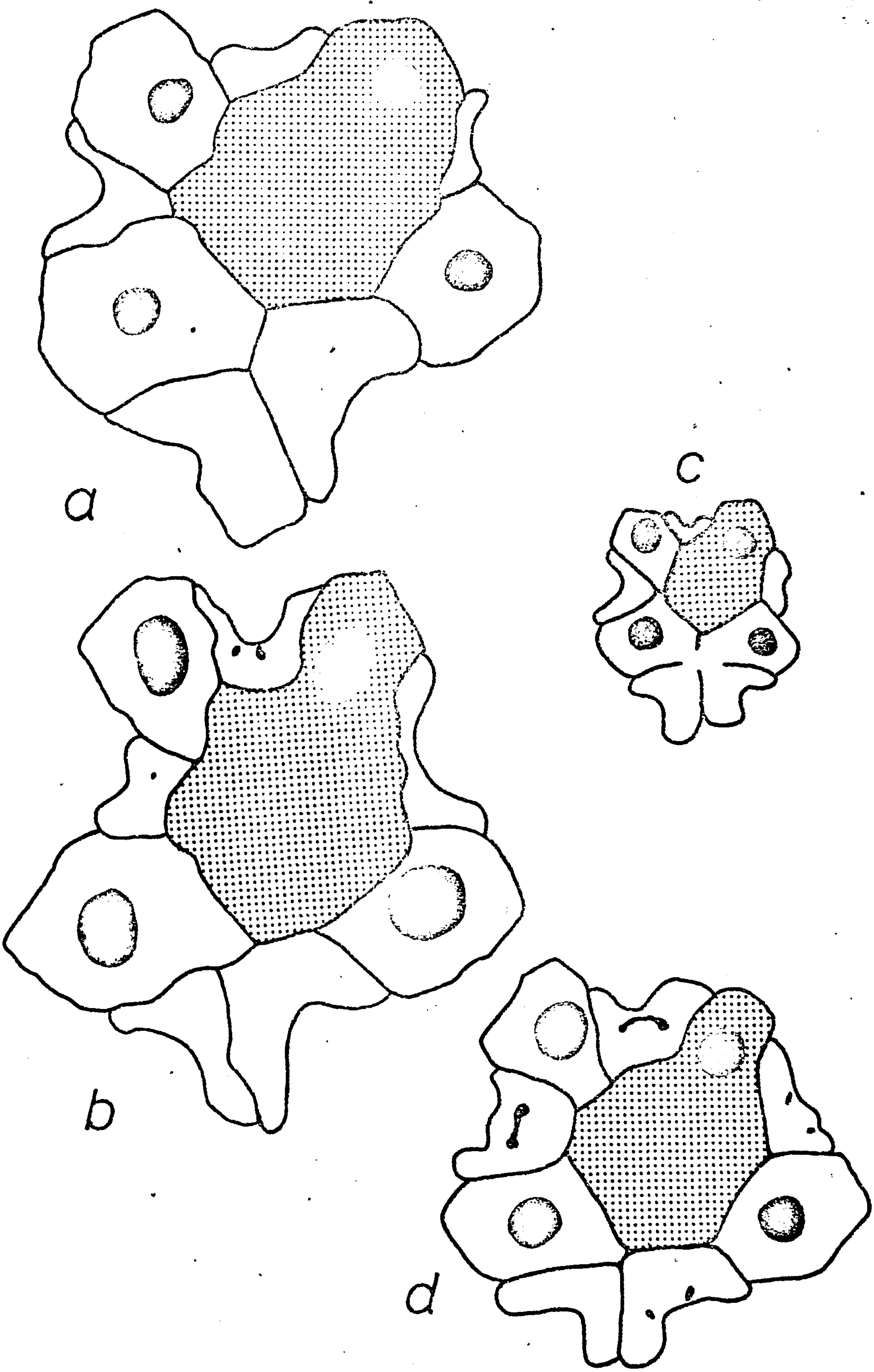
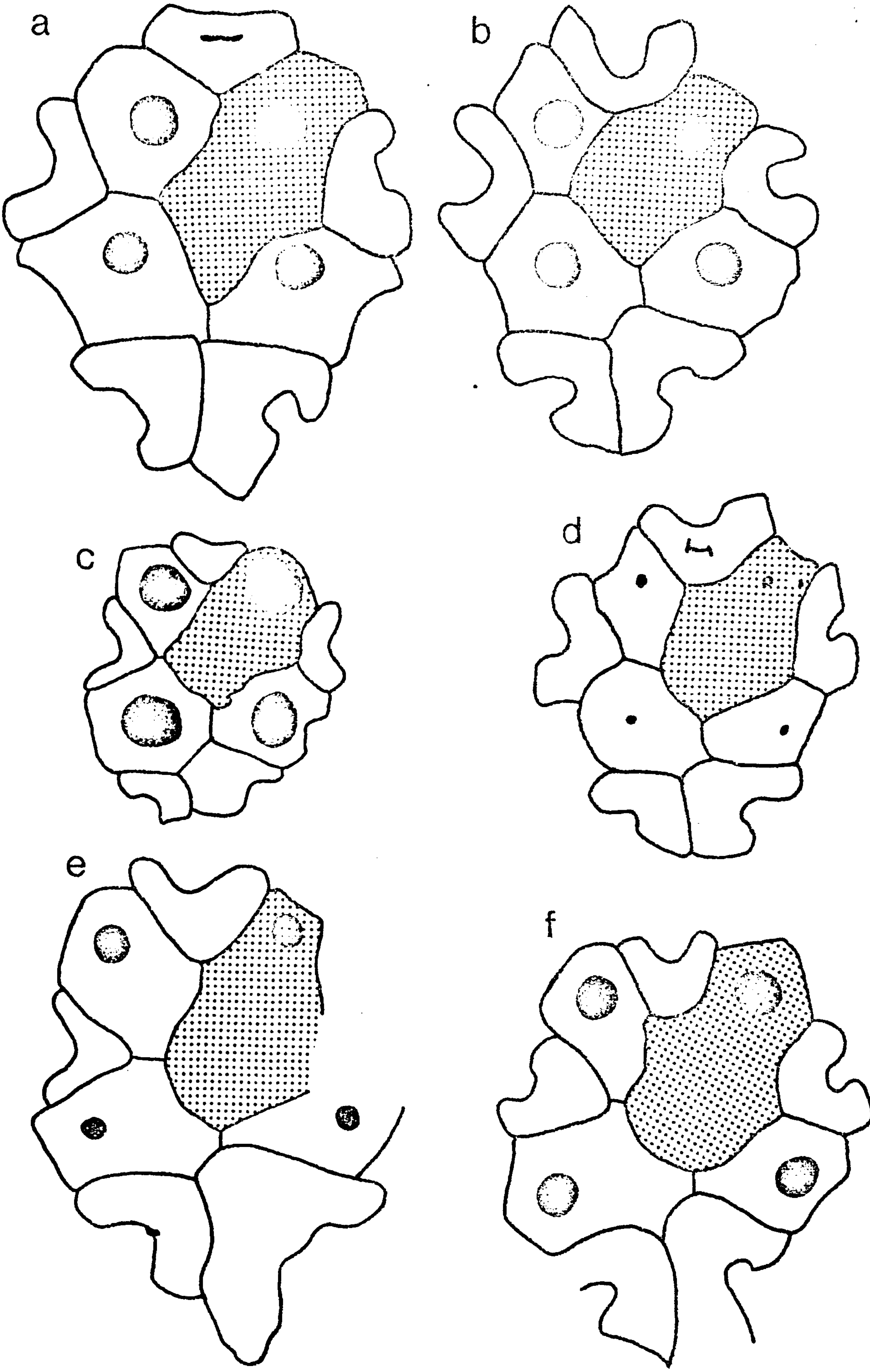


PLATE 26

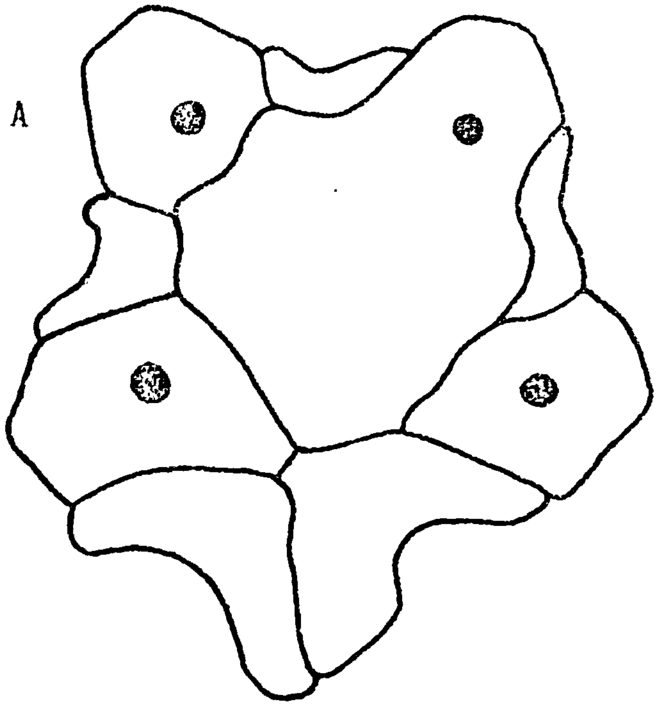
Apical Systems

Figs. a - c   Micraster leskei Desmoulins from the Planus Zone of Underwood Hall Cambridgeshire. Author's Collection nos. 4, 3, 6 respectively.

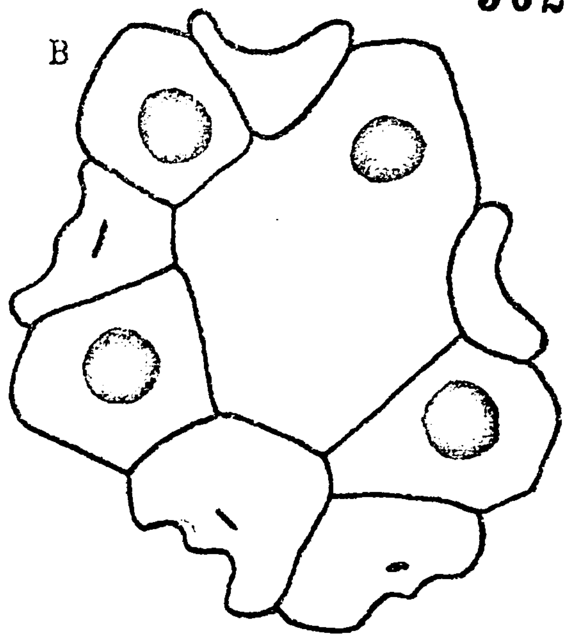
Figs. d - f   Micraster borchardi Hagenow from the Lamarcki Zone of Wüllen near Ahaus Westfalia. Author's Collection nos. 249, 250, 259 respectively.


a
b
c
d
e
f

A



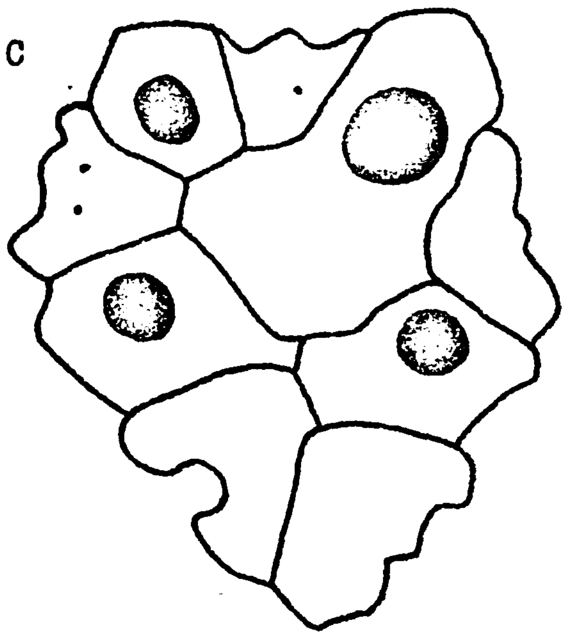
B



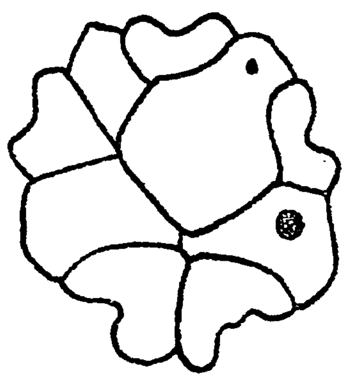
A <u>M</u>. <u>turonensis</u> (Bayle)
Villedieu
De Grossouvre Collection

B <u>M</u>. <u>turonensis</u> (Bayle)
Couture
Peron Coll. no. 553

C

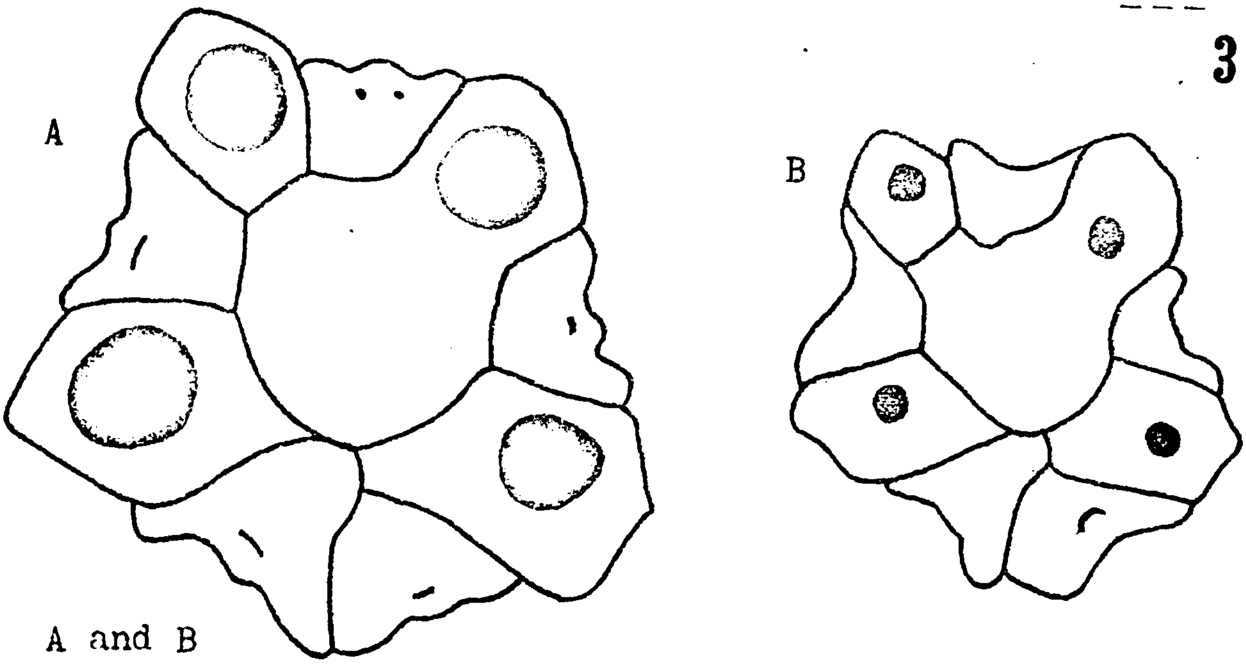


D



C <u>M</u>. <u>turonensis</u> (Bayle)
Villedieu
Lambert Collection

D <u>M</u>. <u>turonensis</u>
var. <u>coniacensis</u> Lambert
Senonian
Rocher de l'Epinette
(Ile d'Oléron)
Lambert Collection

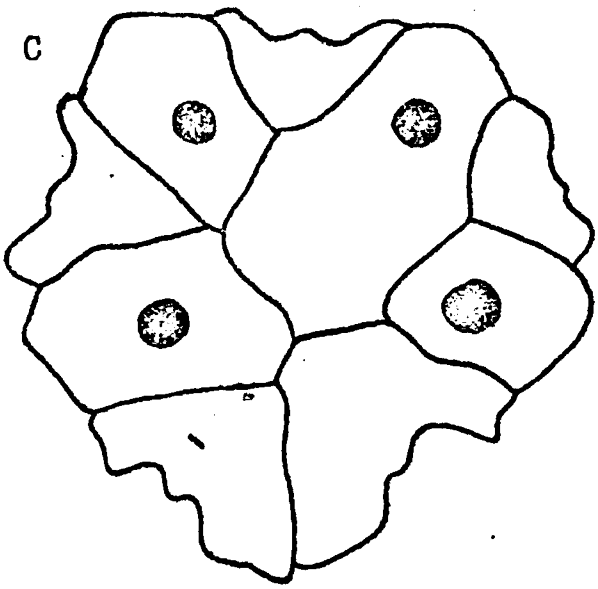


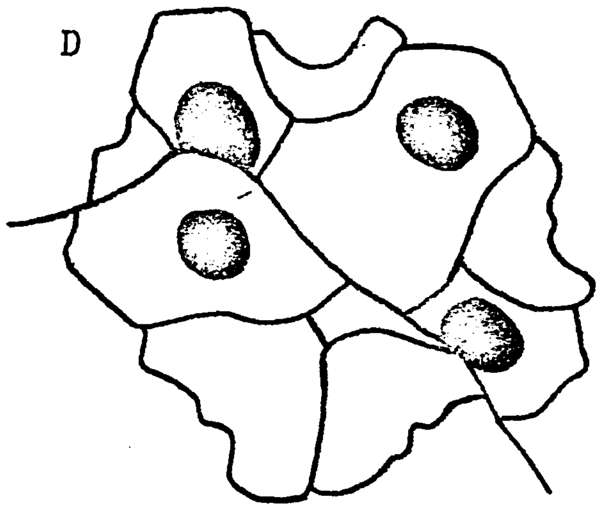
A and B

M. turonensis var. intermedius Bucaille

Senonian, Elbeuf, det. Bucaille

2 specimens from the Lambert Collection





C M. renati (Gauthier)

Turonian E

Saint-Julien-du-Sault

Lambert Collection

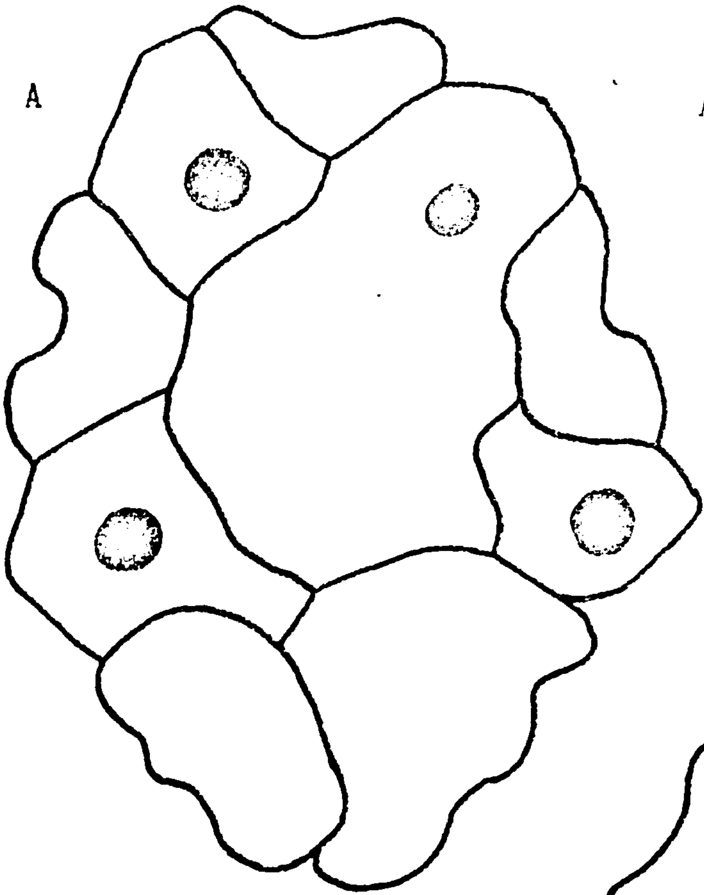
D M. renati (Gauthier)

Senonian F

Saint-Julien-du-Sault

Lambert Collection

A



A *M. westlakei* sp. nov.

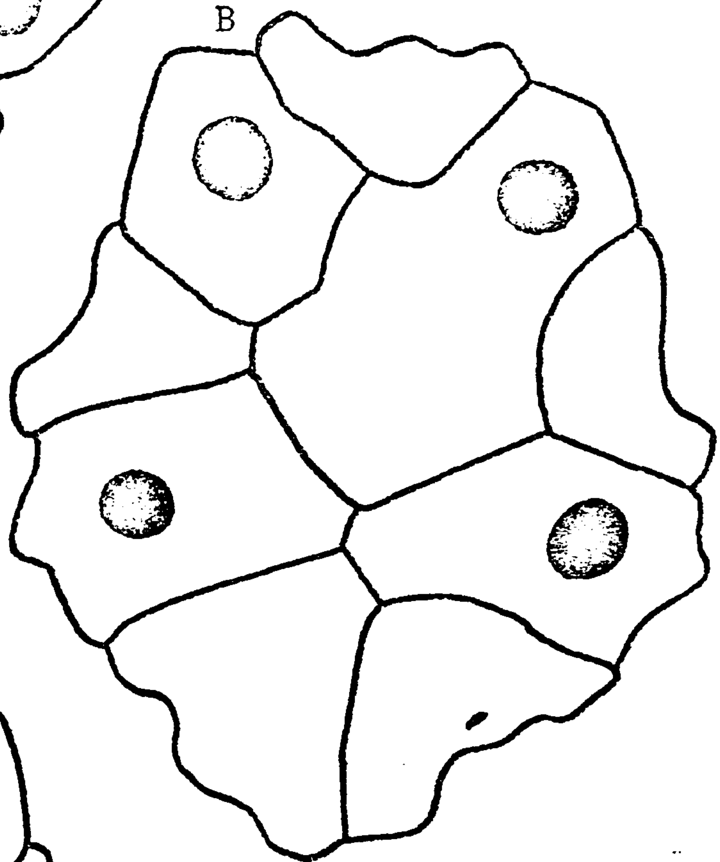
The holotype

Mucronata Zone

Tichbourne Farm (Hants)

Westlake Coll. no. 3320

B

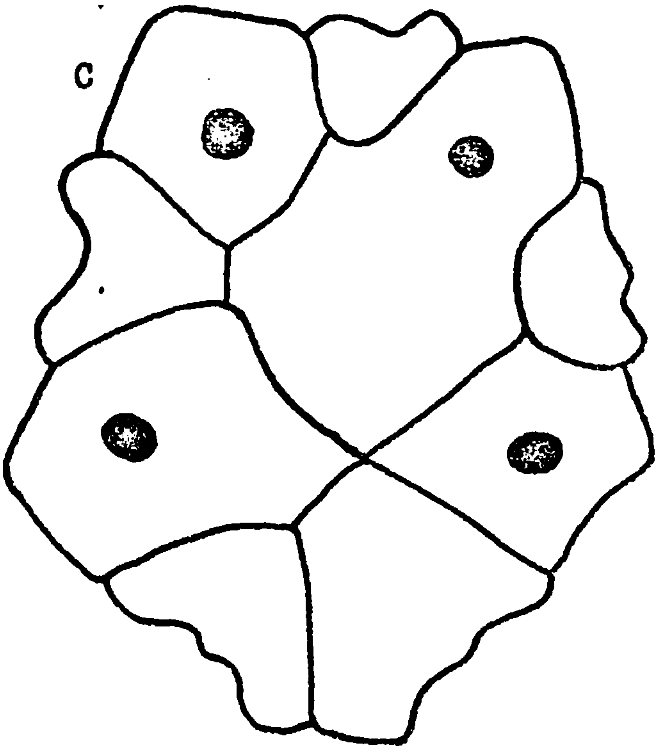


B *M. westlakei* sp. nov.

Locality and horizon as A

Westlake Coll. no. 3321

C



C *M. coranguinum* var. *rostratus*

Senonian K

St. Martin (Yonne)

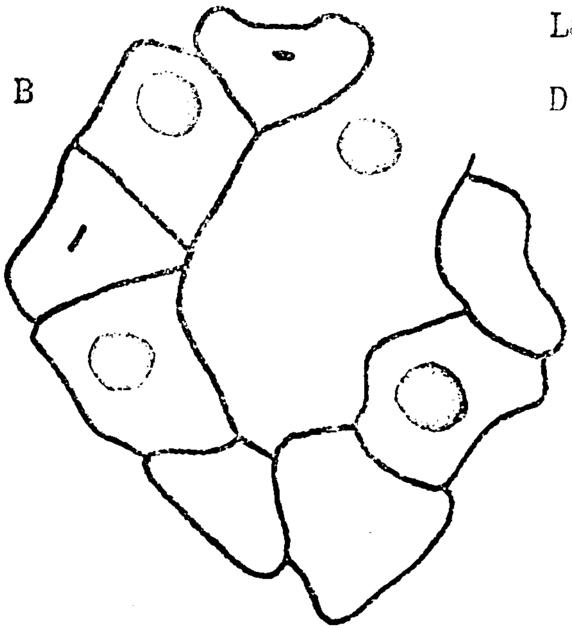
Lambert Collection

A M. coranguinum (Leske) ---

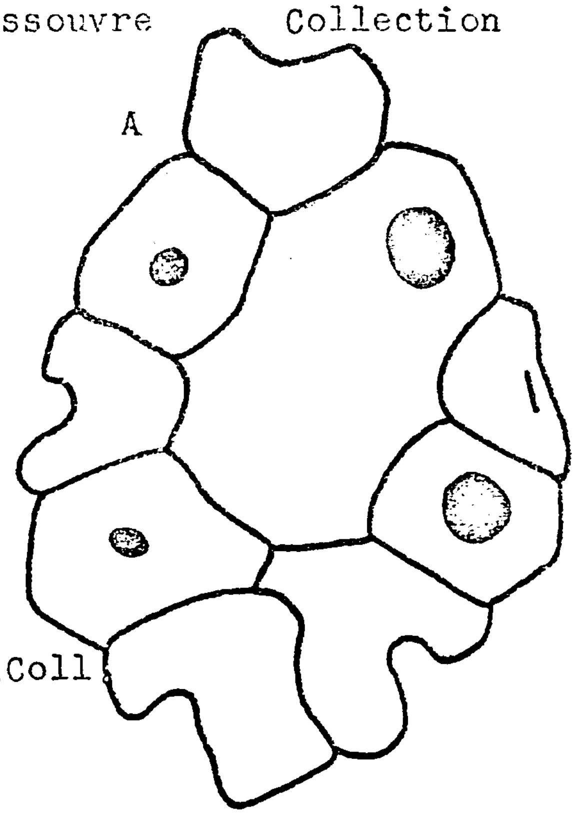
La Ferté (Abbeville)

De Grossouvre Collection

B



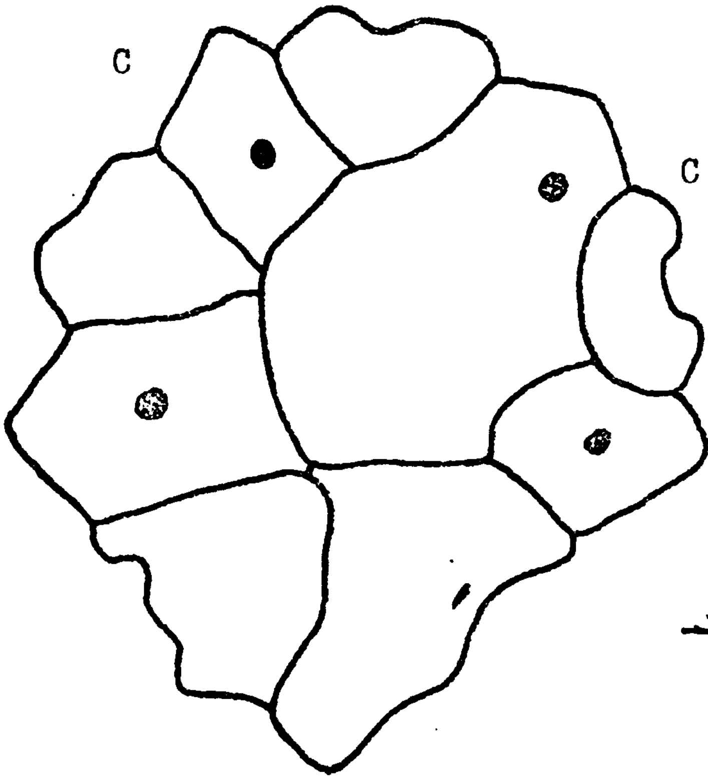
A



B M. coranguinum (Leske)

Hardivillers (Oise), de Gross.Coll.

C

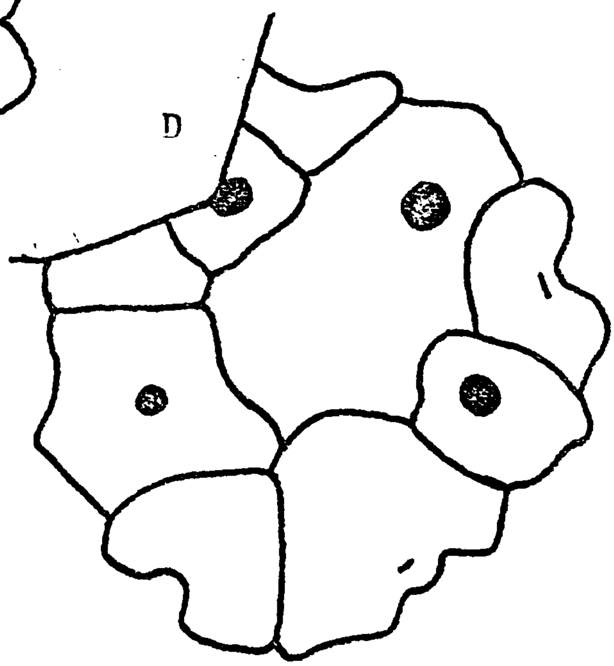


C M. coranguinum (Leske)

La Ferté (Abbeville)

De Grossouvre Collection

D



D M. coranguinum var. simpsoni

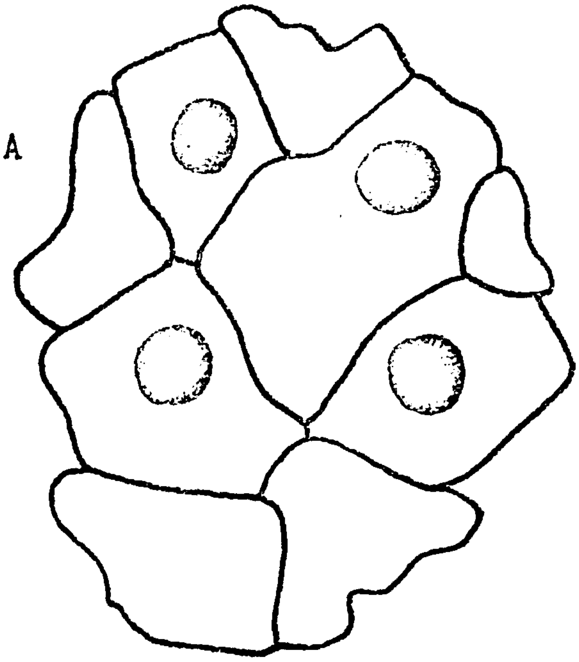
var. nov.

Tectiformis Belt

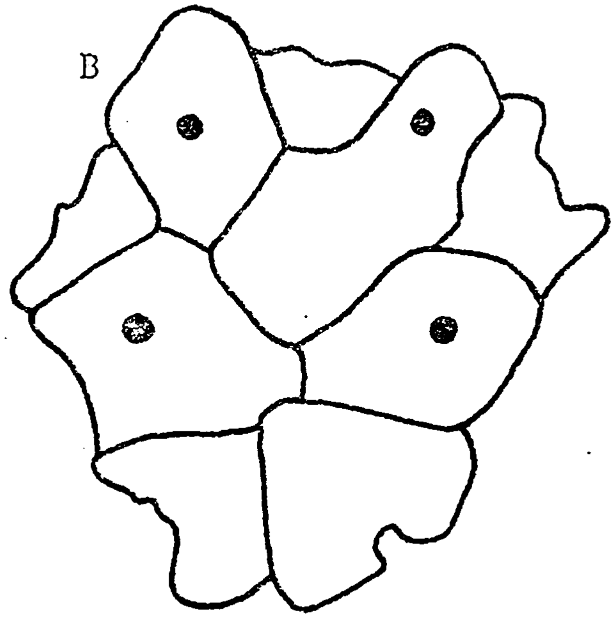
Saltdean (Sussex)

Simpson Collection no. S43, the holotype

A



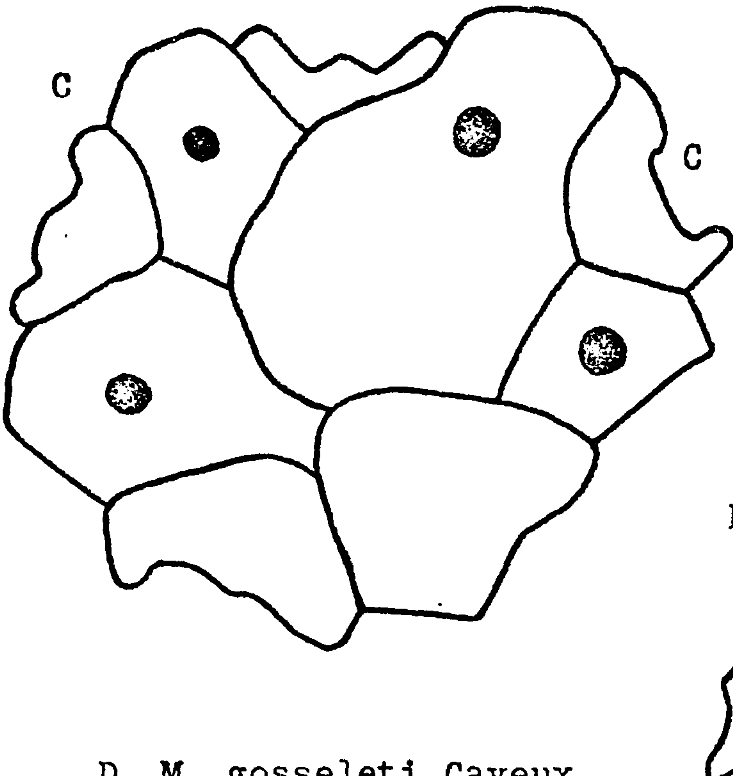
B



A *M. normanniae* Bucaille
Etaples (Pas - de - Calais)
Lambert Coll. no. 849

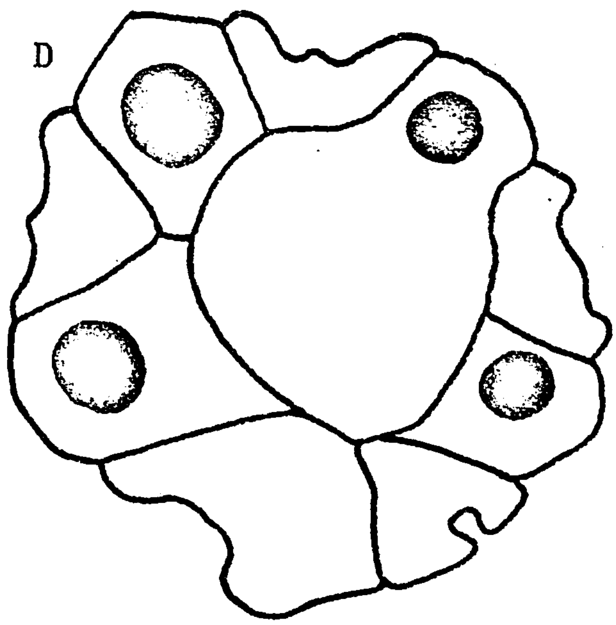
B *M. normanniae* Bucaille
Neufchâtel
De Grossouvre Collection

C



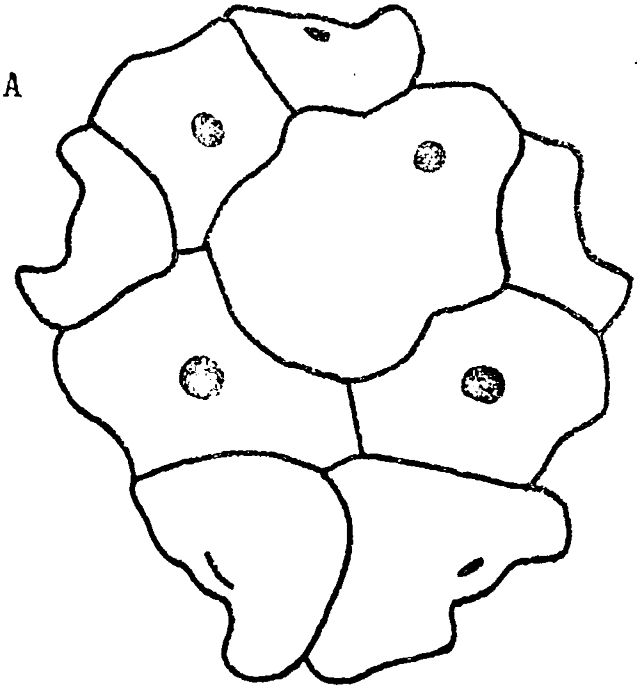
C *M. gosseleti* Caveux
Lumbres (Pas-de-Calais)
Lambert Collection
Coniacian

D



D *M. gosseleti* Caveux
Ennequin (Nord)
Lambert Collection
Coniacian

A



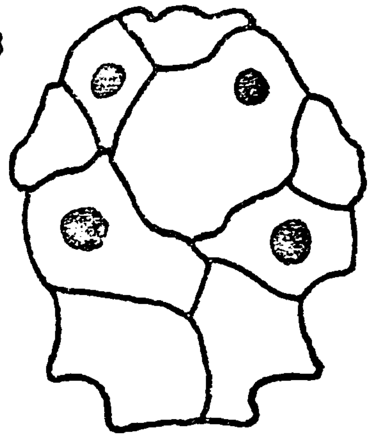
A *M. brongniarti* Hébert

Campanian

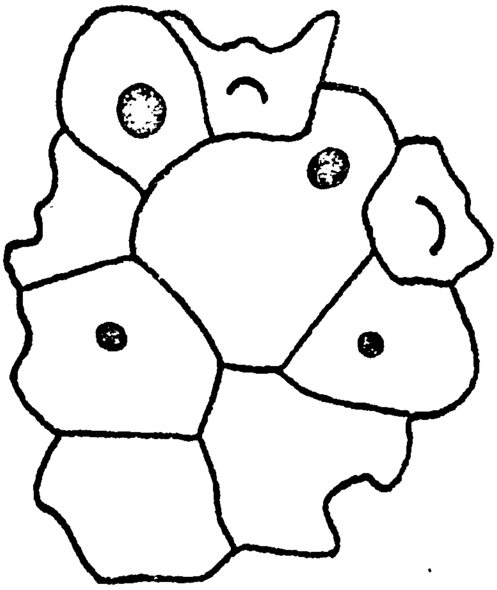
Meudon, Paris

Mus. Hist; Nat., Paris

B



C



B and C

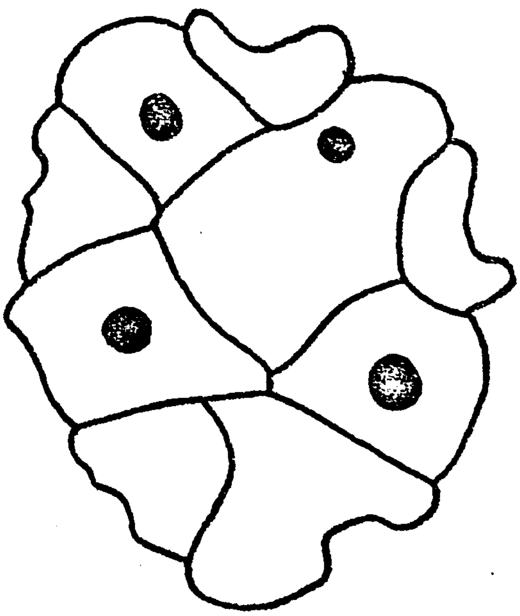
M. brongniarti Hébert

Senonian P

Meudon

Lambert Collection

D



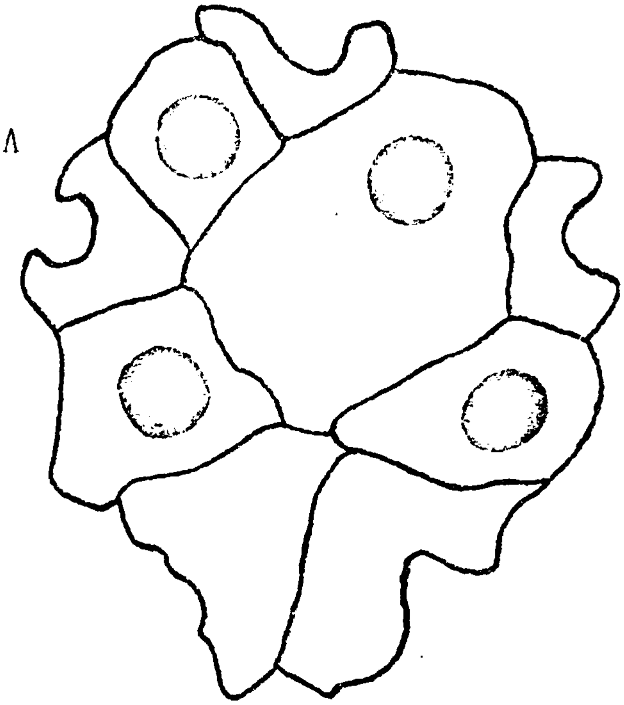
D *M. schroederi* Stolley

Senonian N

Reims

Lambert Collection no. 845

A



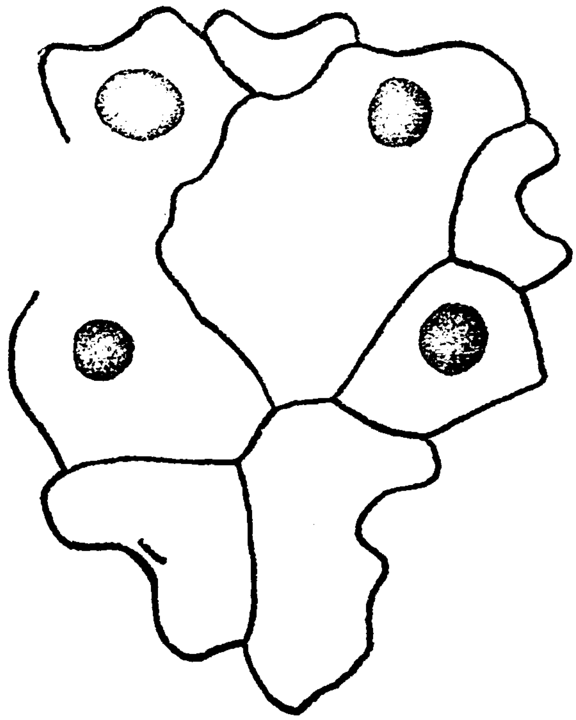
M. schlueteri (Coquand)

Upper Turonian (Deformis Zone)

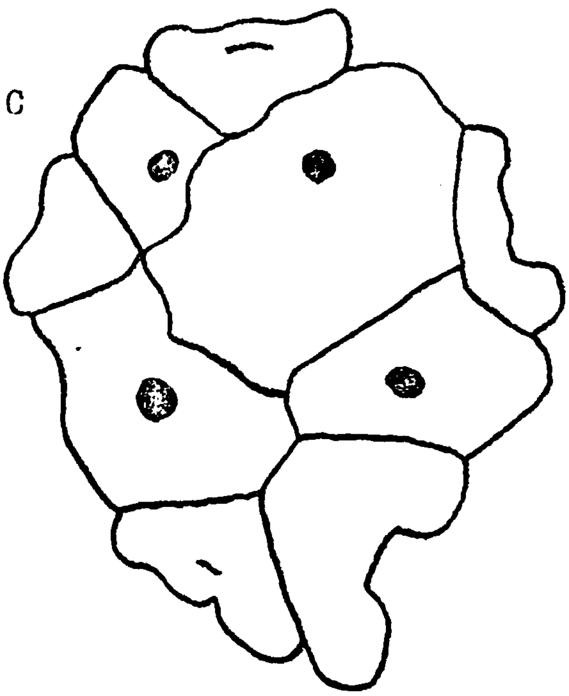
Erwitte, Germany

Author's Collection
A no. 542
B no. 545
C no. 533

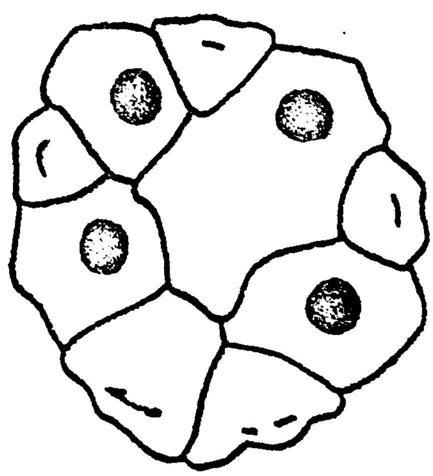
B



C



D



D M. grimmensis Nietsch

Upper Campanian

Wolsu, U.S.S.R.

Muzeum Ziemi Warsaw no. Ee 641

M. fastigatus Gauthier

All specimens from the upper Lower Campanian of Alemania Quarry, Hannover.

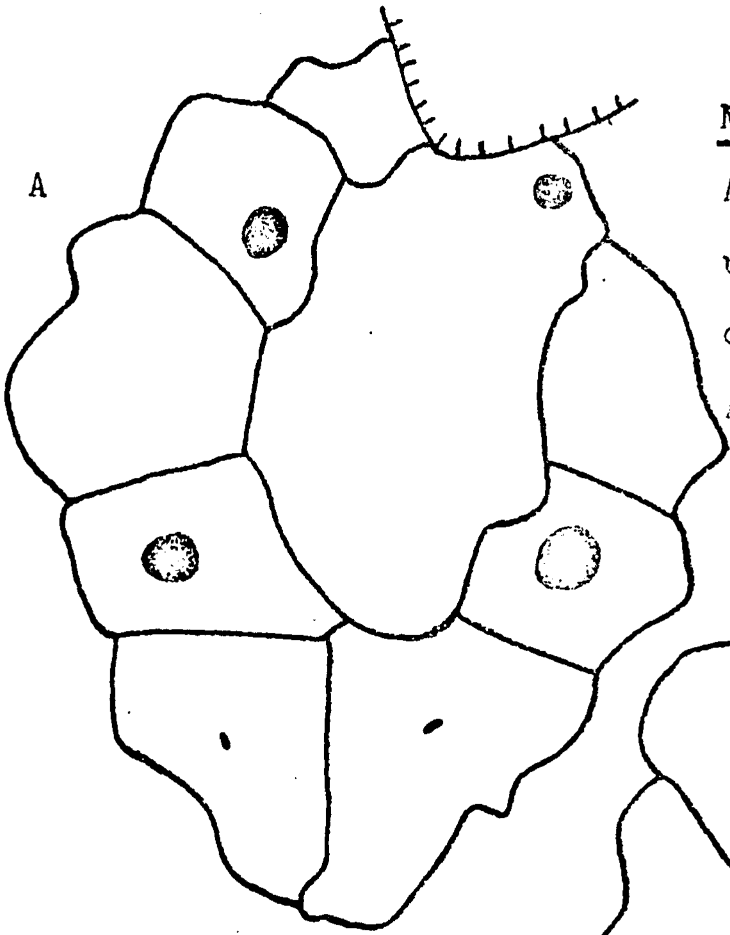
Author's Collection

A no. 1328

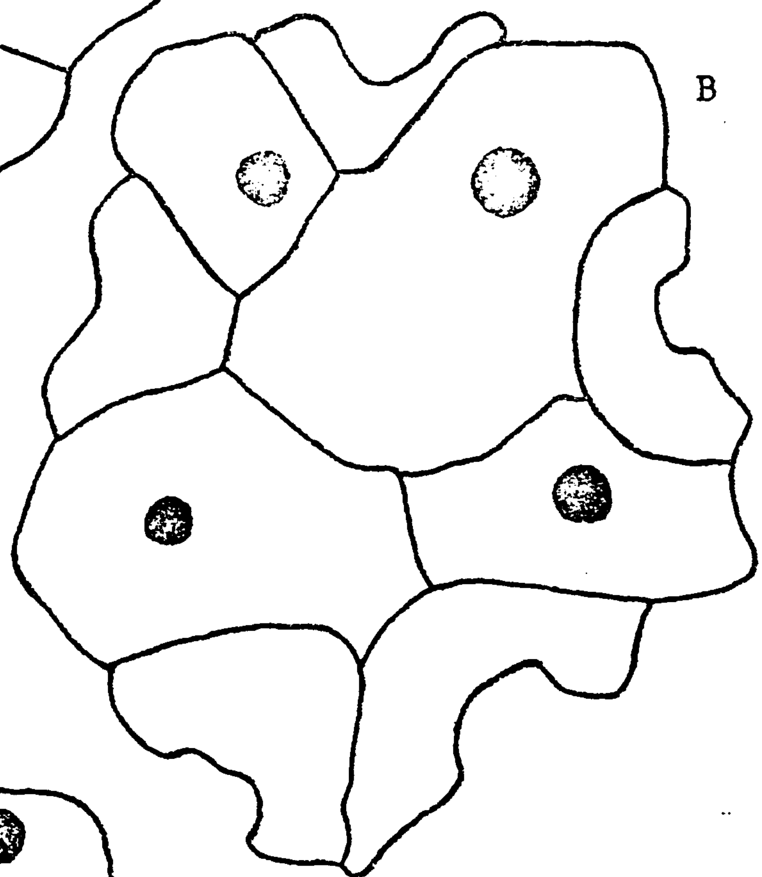
B no. 1083

C no. 1097

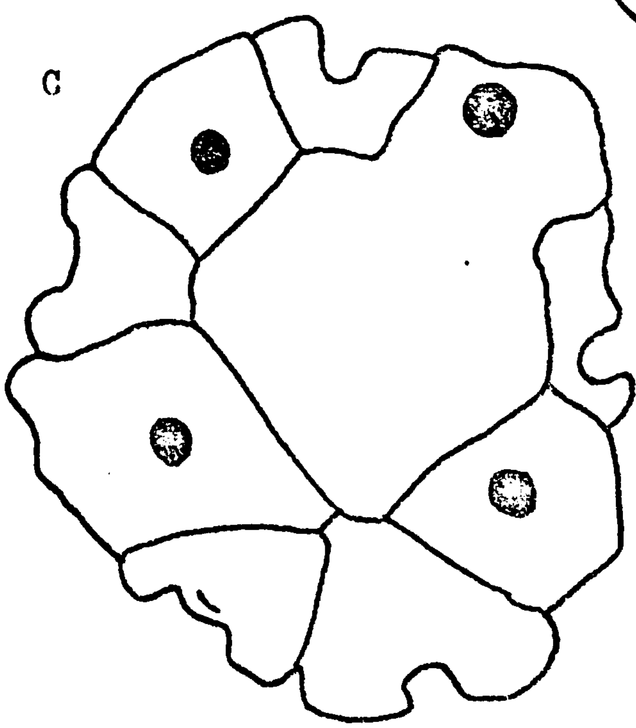
A



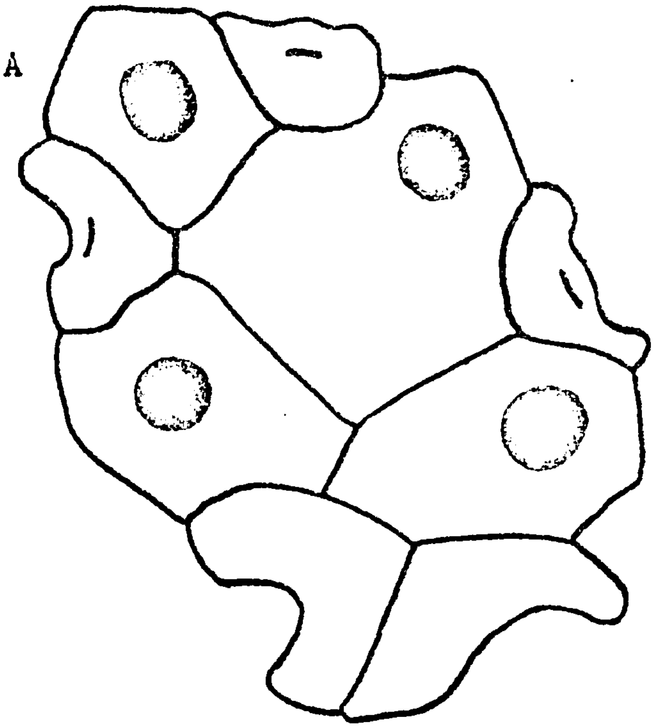
B



C



A

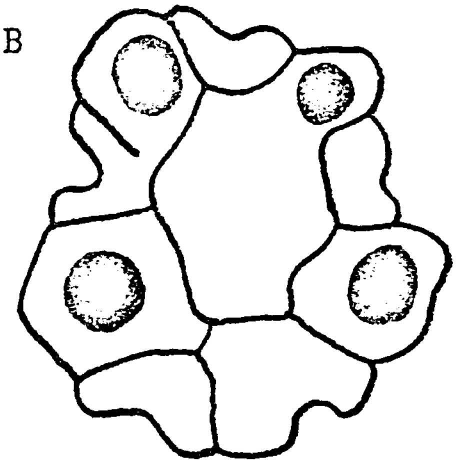


All specimens from the upper Lower Campanian of Alemania Quarry, Hannover. Author's Collection

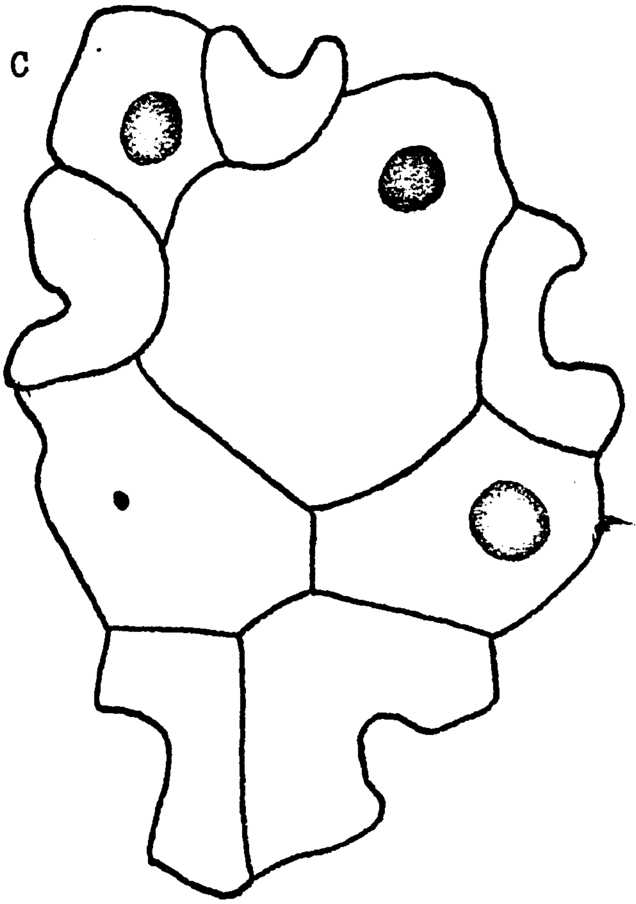
A M: schroederi Stolley
no. 1089

B M. glyphus Shlüter
no. 1102

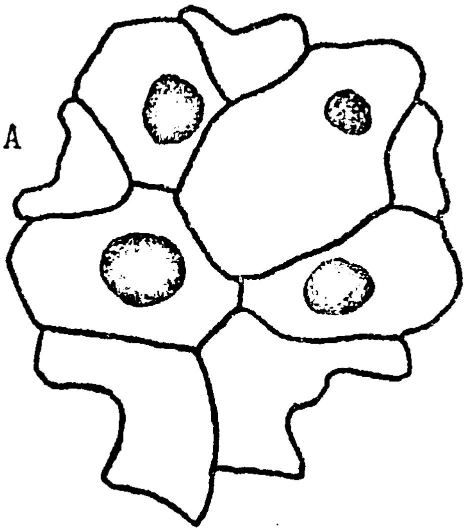
B



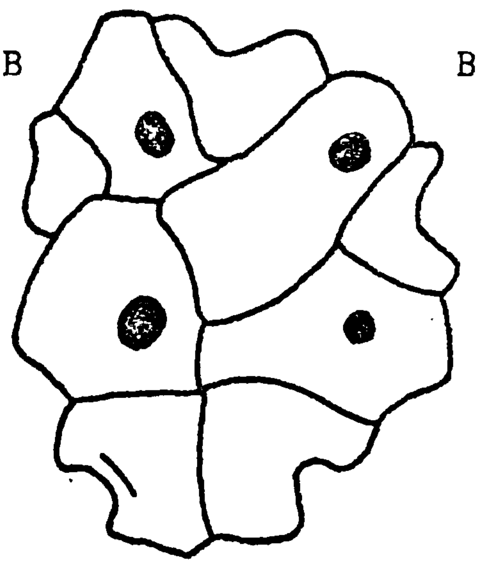
C



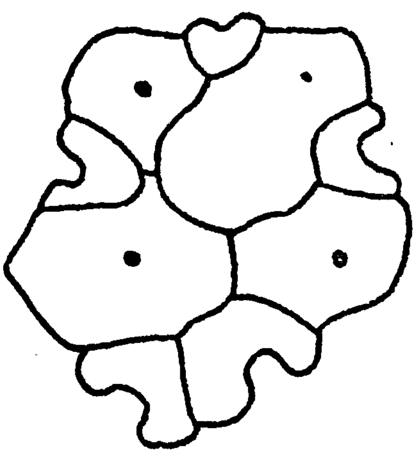
C M. glyphus Schlüter
no. 1329

A 

A M. schroederi planus Maczynska
Assise de Nouvelles (Campanian)
Heure - le - Romain, Belgium
Mus. Roy. Hist. Nat. Belg:
no. I.G. 5185

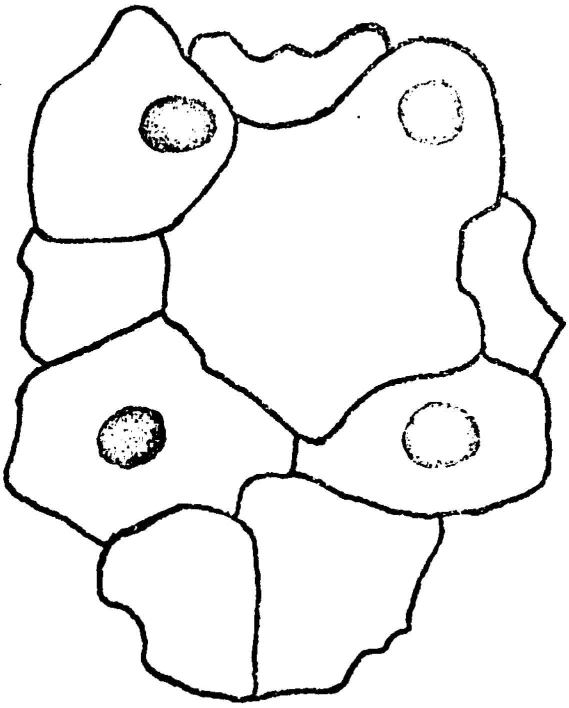
B 

B M. schroederi / glyphus
Upper Campanian (vulgaris/basiplana Subzone)
Teutonia Quarry, Hannover
Author's Collection no. 842

C 

C M. coravium Poslavskaja
Lower Campanian
U.S.S.R.
Muzeum Ziemi Warsaw no. Ee 640

A



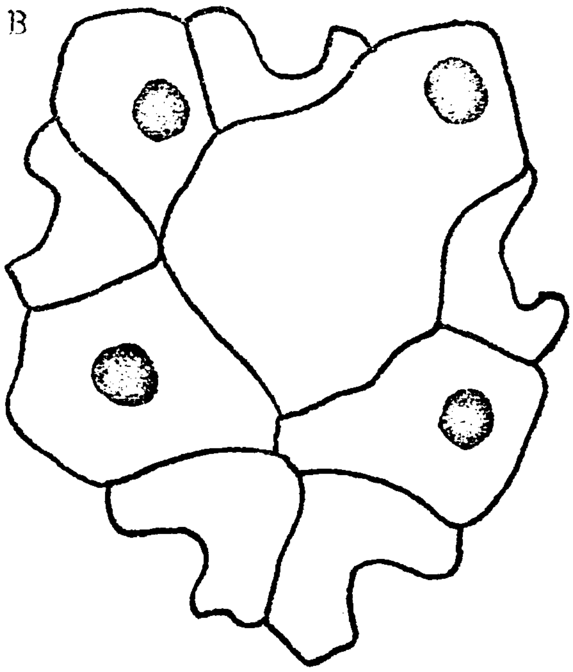
M. stolleyi (Lambert)

Upper Campanian (vulgaris/basiplana Subzone)

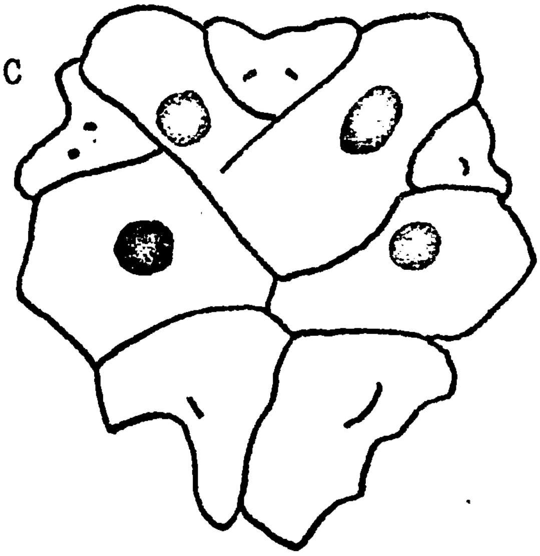
Teutonia Quarry, Hannover

Author's Collection
A no. 851
B no. 852
C no. 839

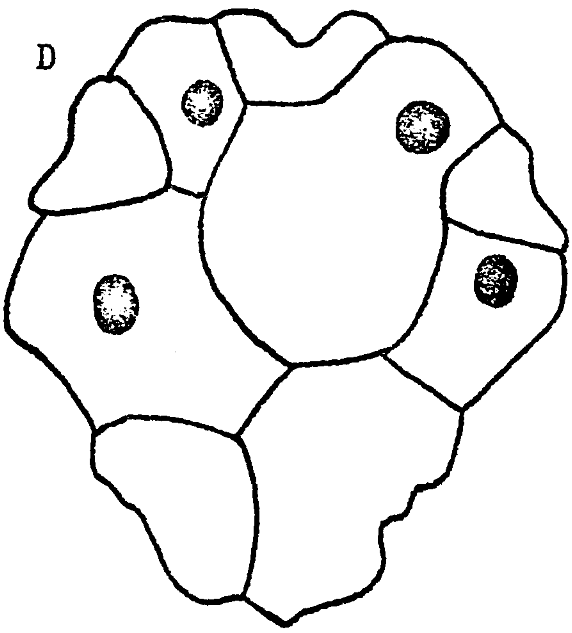
B



C



D

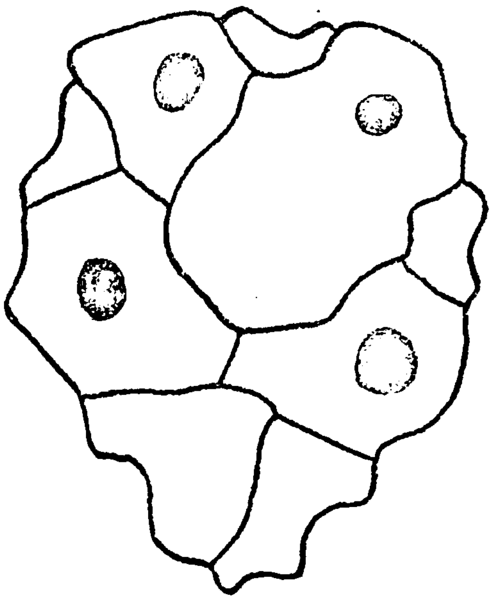


D M. coranguinum (Leske)

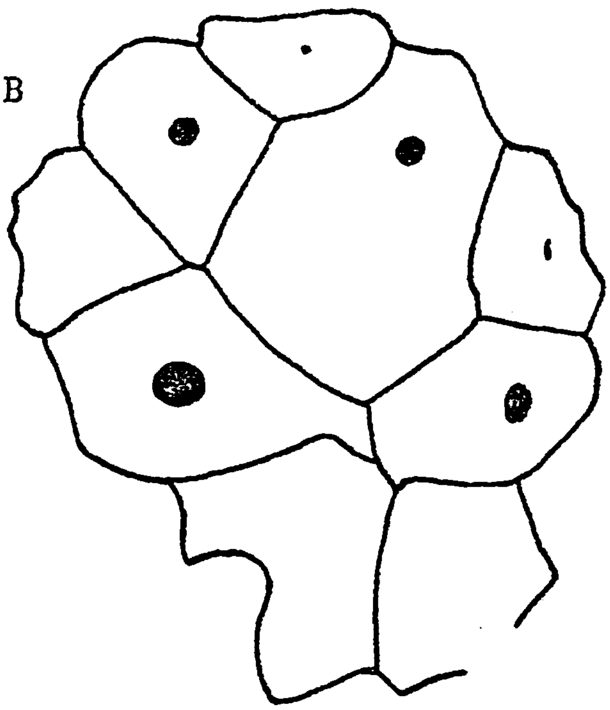
Lower Coniacian

Staffhorst Mine Shaft

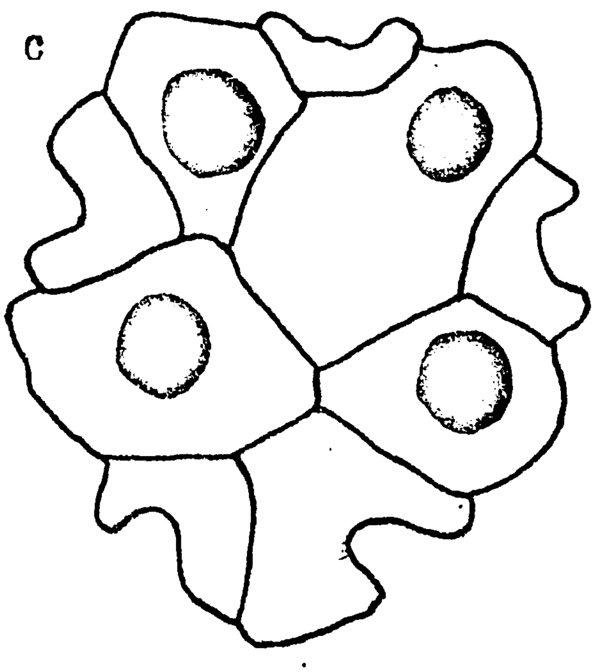
Spiegler Collection

A


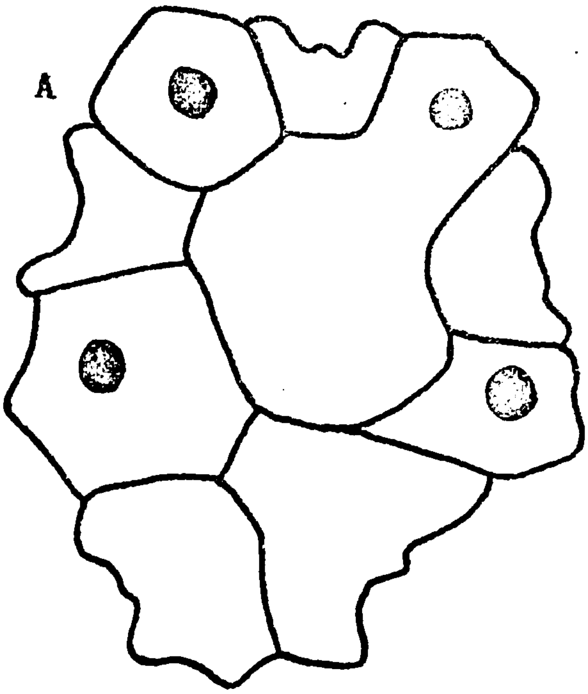
A M. gibbus (Lamarck)
Craie d'Obourg
Harmignies, Belgium
Mus. Roy. Hist. Nat. Belg.
no. I.G. 6435

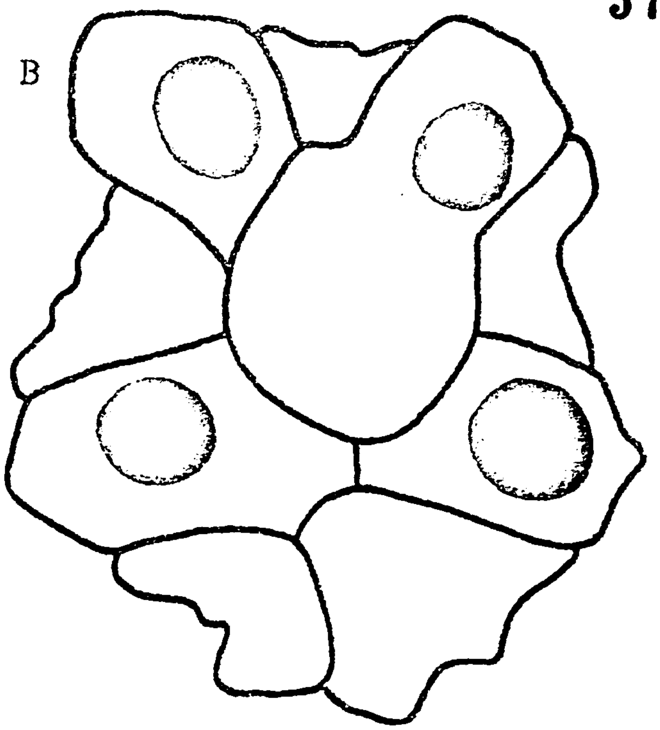
B


B as A

C


C M. belgicus Lambert
The paratype
Craie de Saint Vaast
Framèries, Belgium
Mus. Roy. Hist. Nat. Belg.
no. 9210 (I.G. 6372).

A


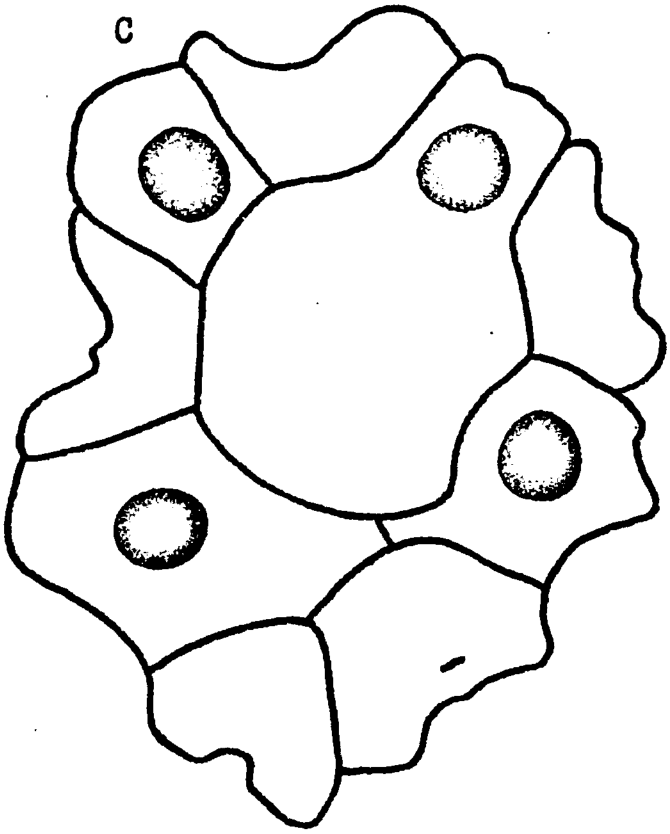
B


A and B M. brevis Desor

Santonian

Fabies (Rennes - les - Bains)

Lambert Coll.

C


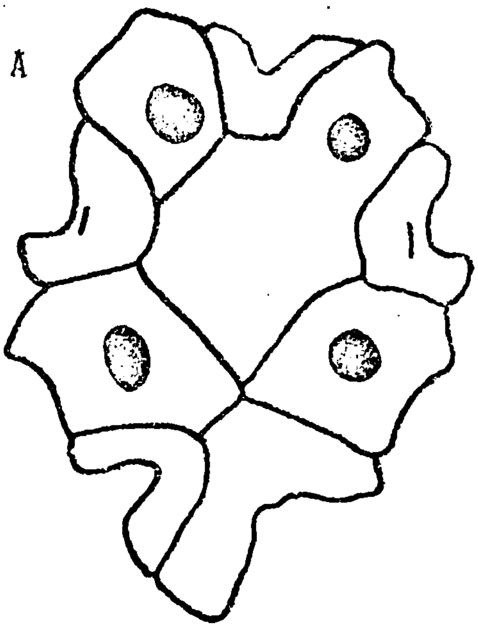
C M. heberti de Lacvivier

Santonian

Liencres (Santander)

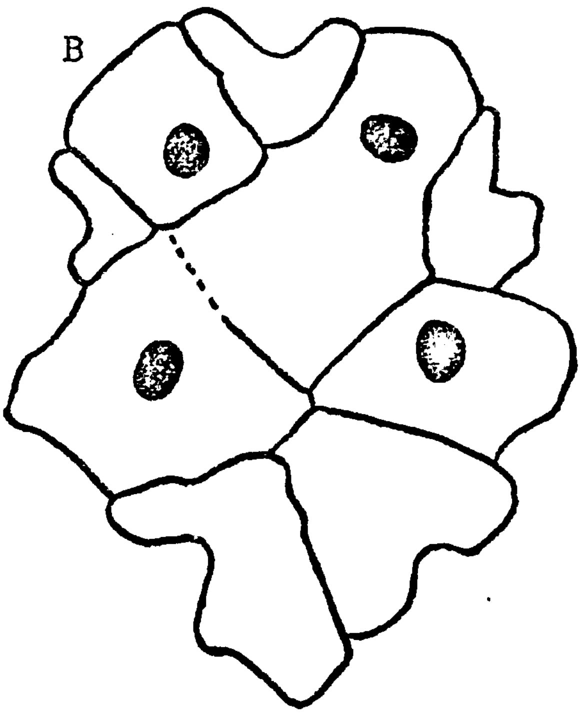
Lambert Collection

A



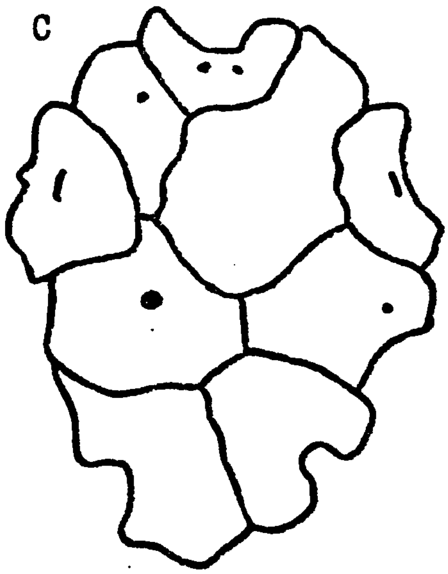
A M. douvillei Lambert
The holotype
Santonian
Santa Marina (Santander)
Lambert Collection

B



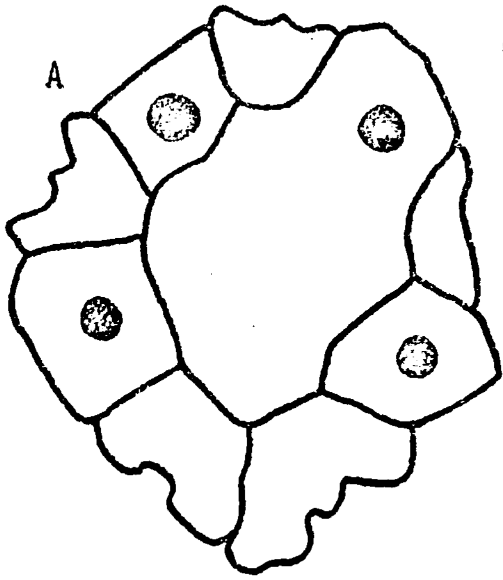
B M. douvillei Lambert
Locality and horizon as A
Lambert Collection

C



C M. coribericum Lambert
Santonian
Llencres (Santander)
Lambert Collection

A



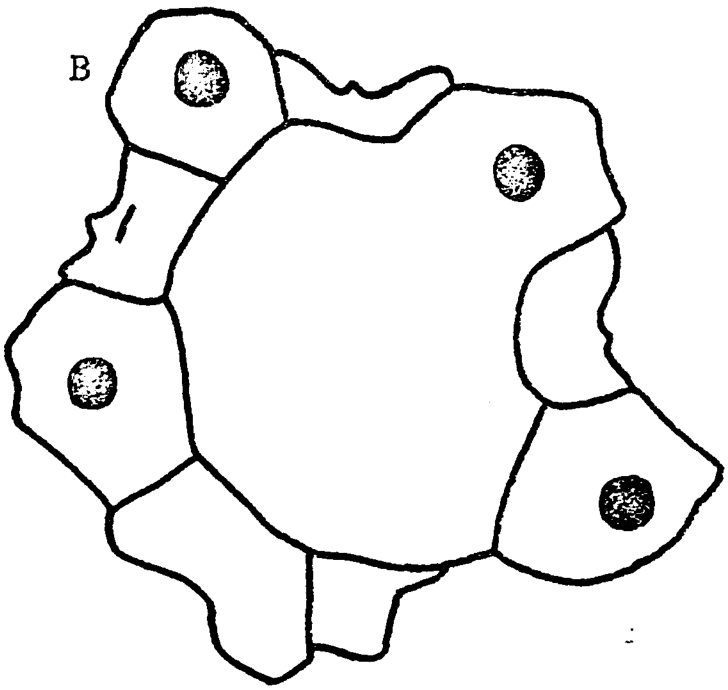
A M. mengaudi (Lambert)

The holotype

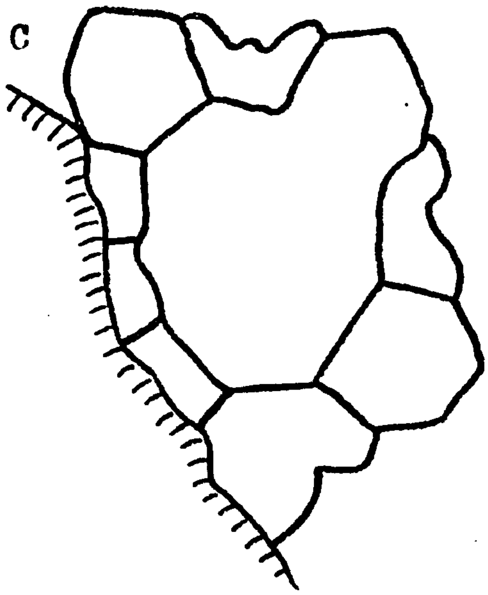
Cabo Menor (Santander)

Lambert Collection

B



C



B and C

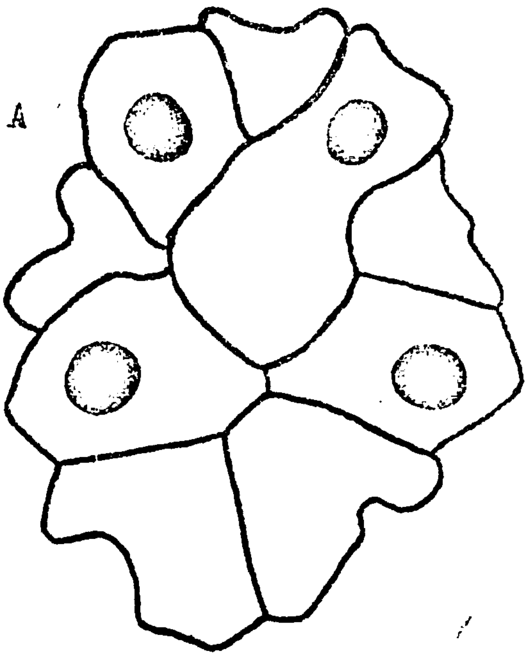
Two other specimens of

M. mengaudi

Cabo Menor

Lambert Collection

A



A <u>M.</u> <u>sismondai</u> Lambert

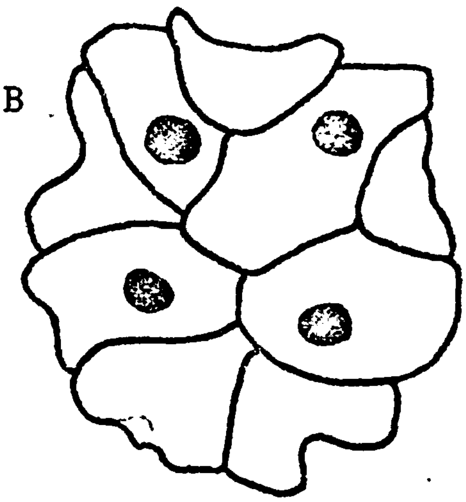
The holotype

Upper Senonian (Upper Camp.)

La Palarea (Nice)

Lambert Collection

B

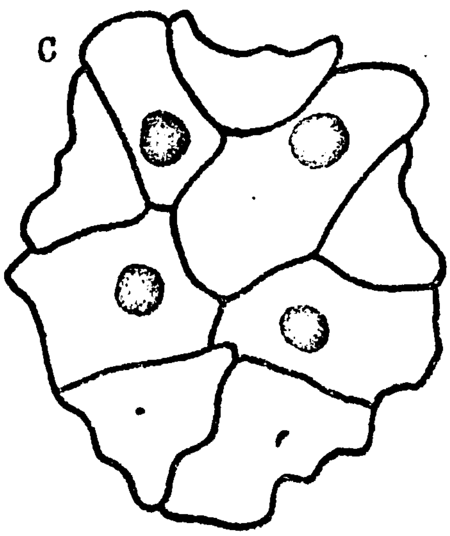


B <u>M.</u> <u>sismondai</u> Lambert

Djidde (Anatolie)

Lambert Collection

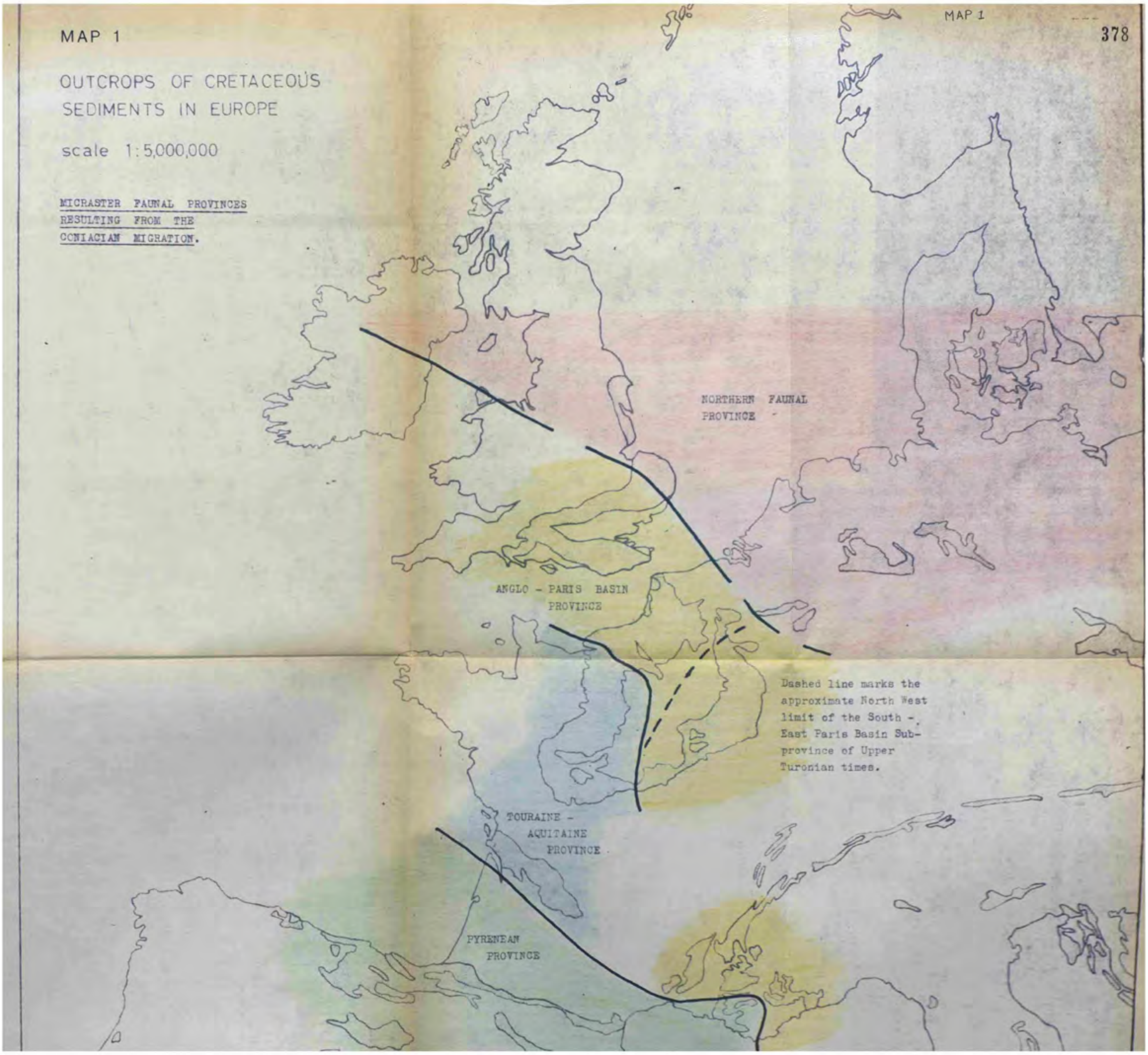
C

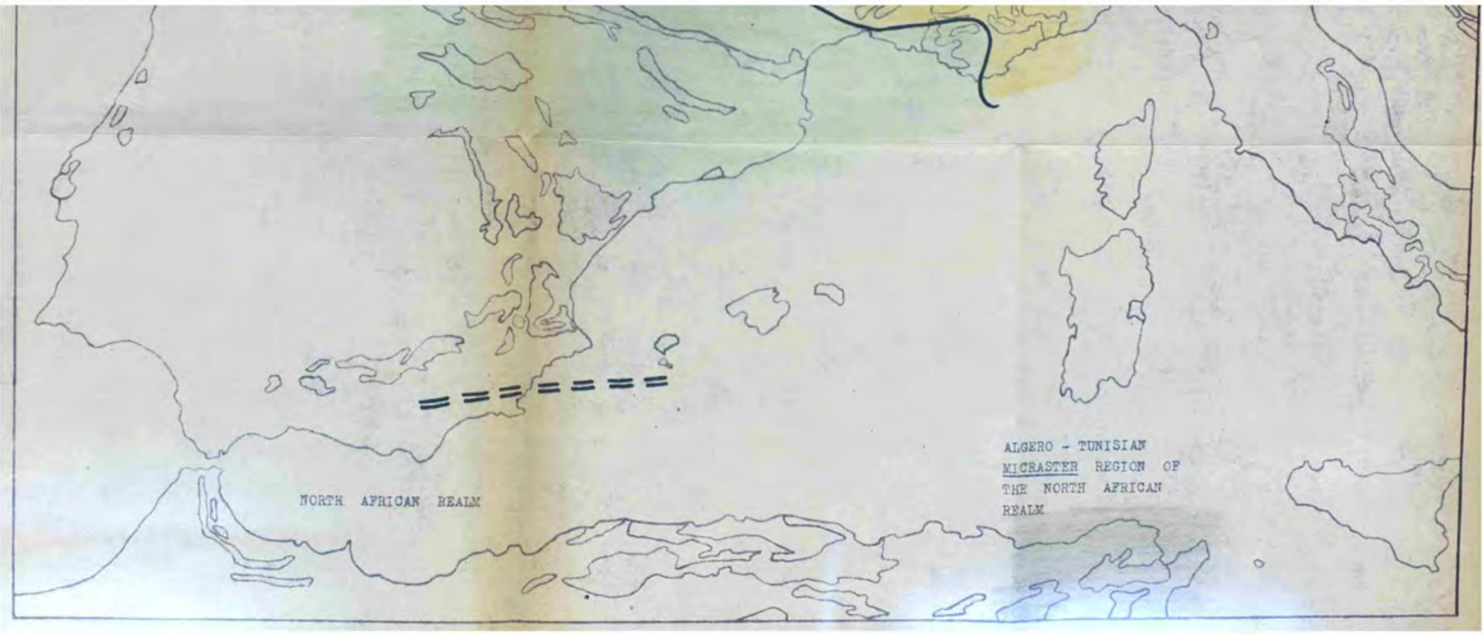


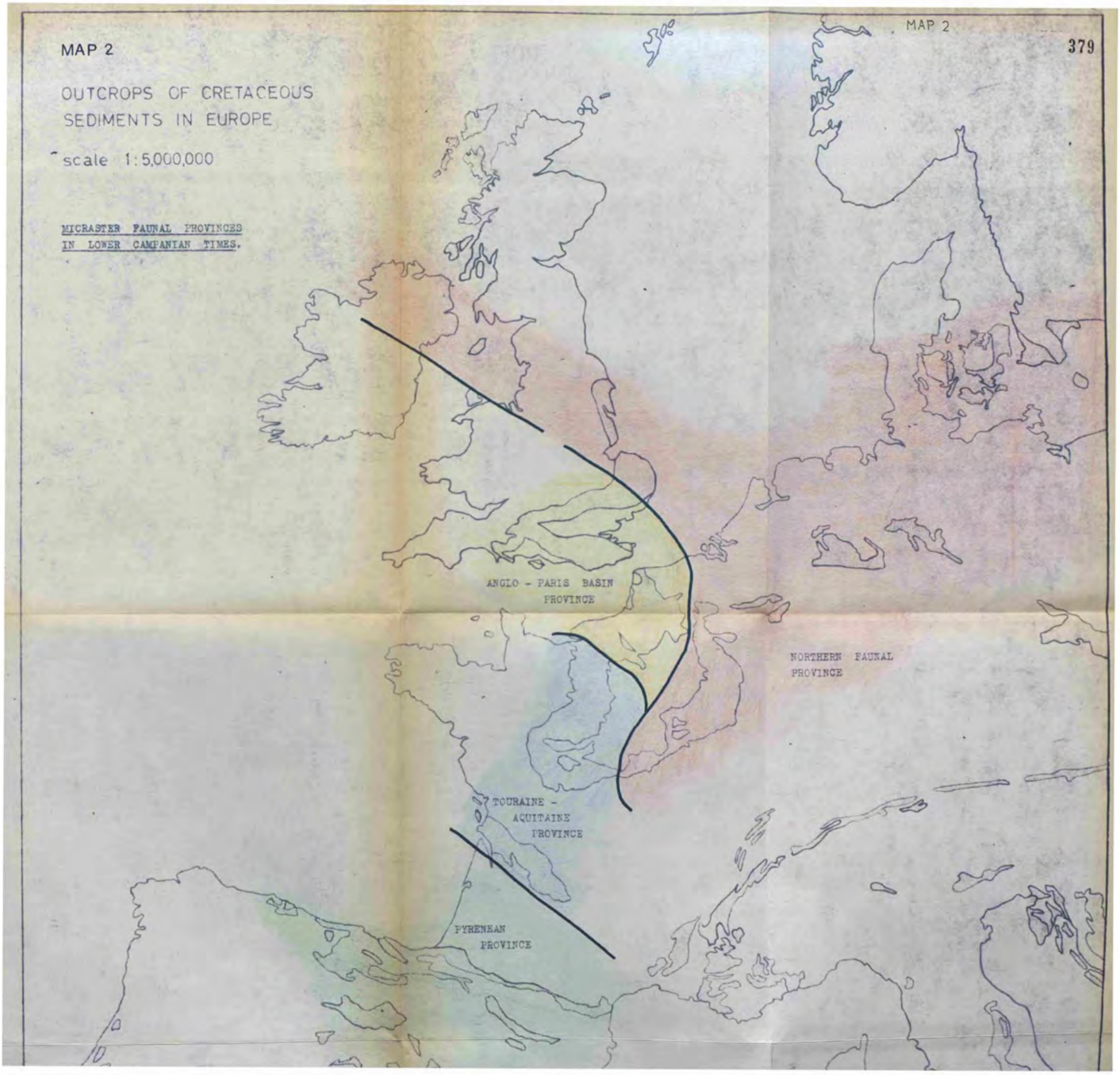
C <u>M.</u> <u>sismondai</u> Lambert

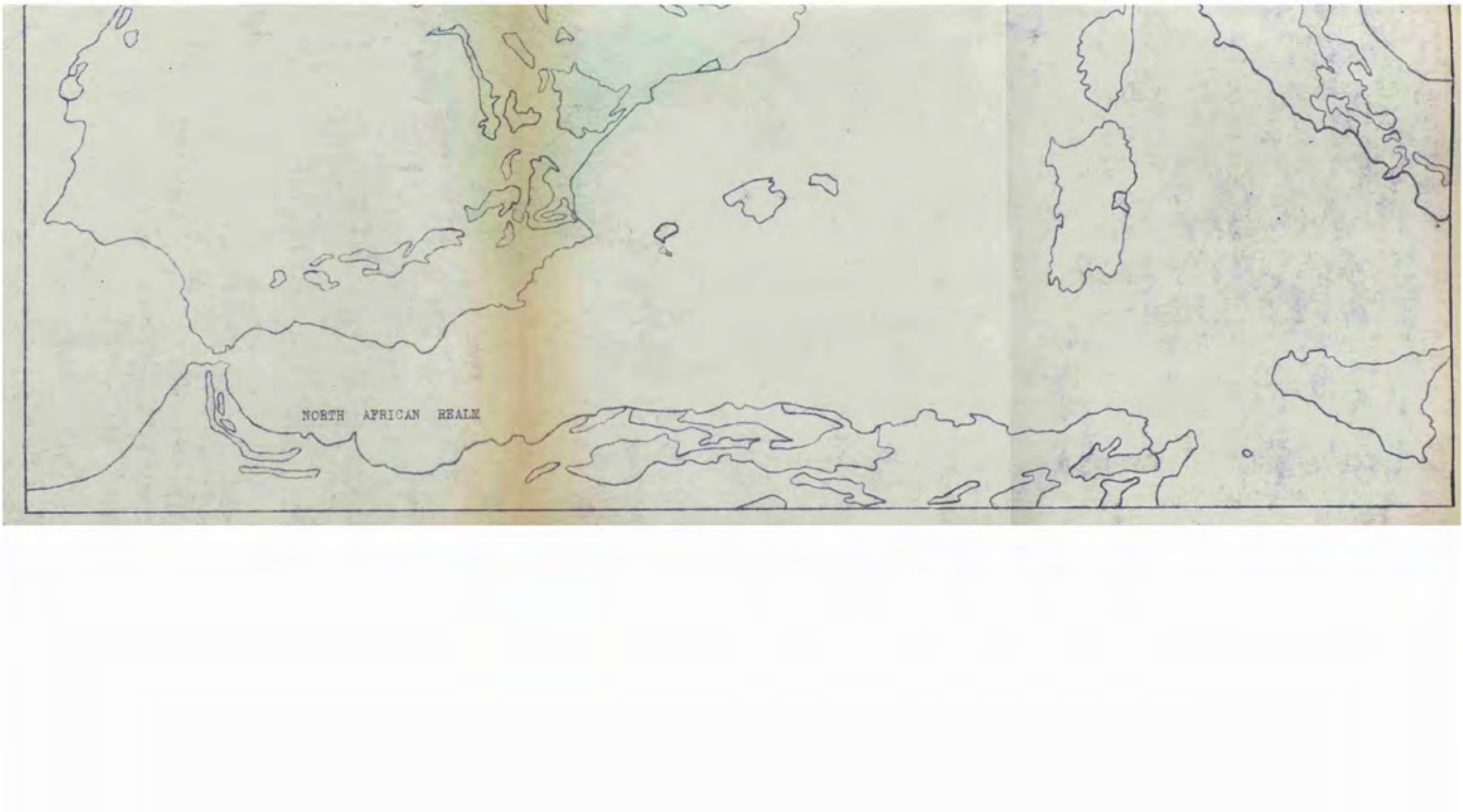
Djidde (Anatolie)

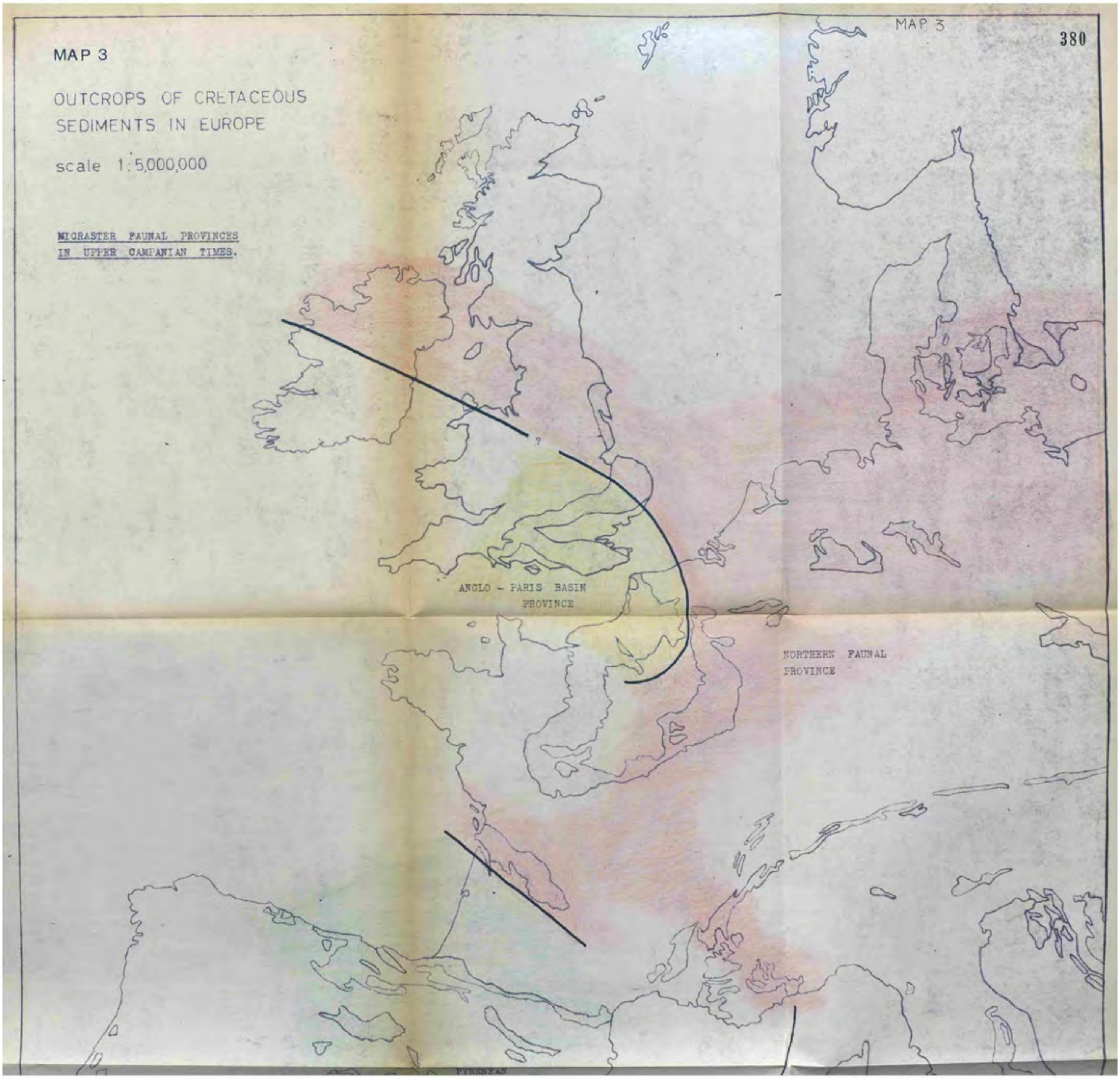
Lambert Coll. no. T.45


MAP 1
OUTCROPS OF CRETACEOUS SEDIMENTS IN EUROPE
scale 1:5,000,000
MICRASTER FAUNAL PROVINCES RESULTING FROM THE CONIACIAN MIGRATION.
MAP 1
NORTHERN FAUNAL PROVINCE
ANGLO - PARIS BASIN PROVINCE
Dashed line marks the approximate North West limit of the South - East Paris Basin Sub-province of Upper Turonian times.
TOURAINE - AQUITAINE PROVINCE
PYRENEAN PROVINCE


NORTH AFRICAN REALM
ALGERO - TUNISIAN
MICRASTER REGION OF
THE NORTH AFRICAN
REALM


MAP 2
OUTCROPS OF CRETACEOUS SEDIMENTS IN EUROPE
scale 1:5,000,000
MICRASTER FAUNAL PROVINCES IN LOWER CAMPANIAN TIMES.
MAP 2
ANGLO - PARIS BASIN PROVINCE
NORTHERN FAUNAL PROVINCE
TOURAINE - AQUITAINE PROVINCE
PYRENEAN PROVINCE


NORTH AFRICAN REALM


MAP 3
MAP 3
OUTCROPS OF CRETACEOUS SEDIMENTS IN EUROPE
scale 1:5,000,000
MICRASTER FAUNAL PROVINCES IN UPPER CAMPANIAN TIMES.
ANGLO - PARIS BASIN PROVINCE
NORTHERN FAUNAL PROVINCE

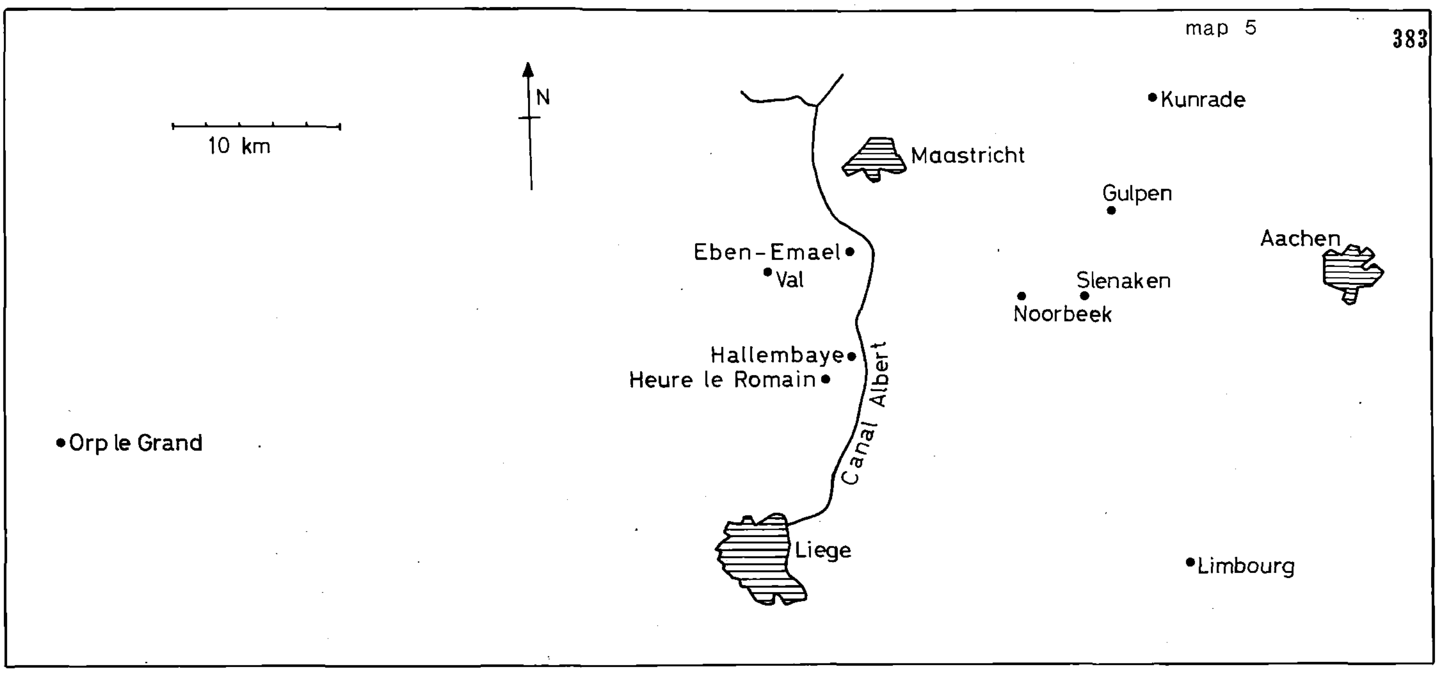

PROVINCE
NORTH AFRICAN REALM

MAP 4 LOCALITIES IN NORTHERN GERMANY (1 cm = 10 Km)

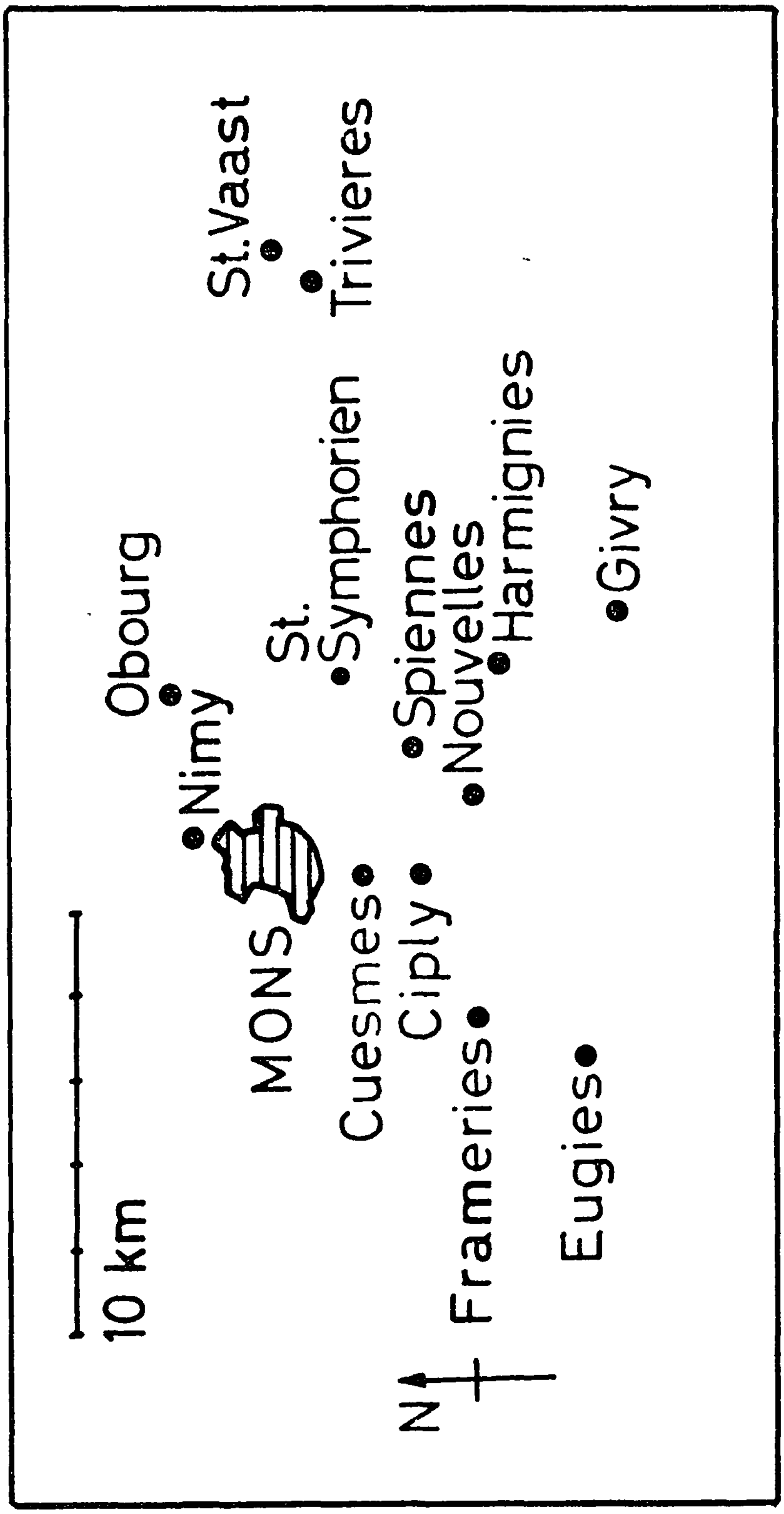
Bo	Bottrop	M	Munster
Br	Braunschweig	Mi	Misburg
C	Coesfeld	Mu	Mulheim
Da	Darup	N	Nettlingen
Db	Dolburg	O	Oelinghausen
Ds	Dorstadt	Pa	Paderborn
Do	Dorsten	Pe	Peine
Dü	Dülmen	Q	Quedlinburg
Dm	Dortmund	Rh	Rheine
Er	Erwitte	Rf	Rothenfelde
Es	Essen	Rs	Rostock
G	Grimmen	Sa	Salder bei Saltzgitter
Ha	Hamm	Sc	Schlangen
Han	Hannover	So	Söhlde
Hl	Halle	St	Staffhorst
Hö	Höver	W	Wüllen
I	Iburg		
K	Kölstadt		
KF	Kl. Flöthe	Re	Recklinghausen
L	Lehrte		
Lä	Lägerdorf		
Lg	Lengerich		
Lü	Lüneburg		

MAP 4

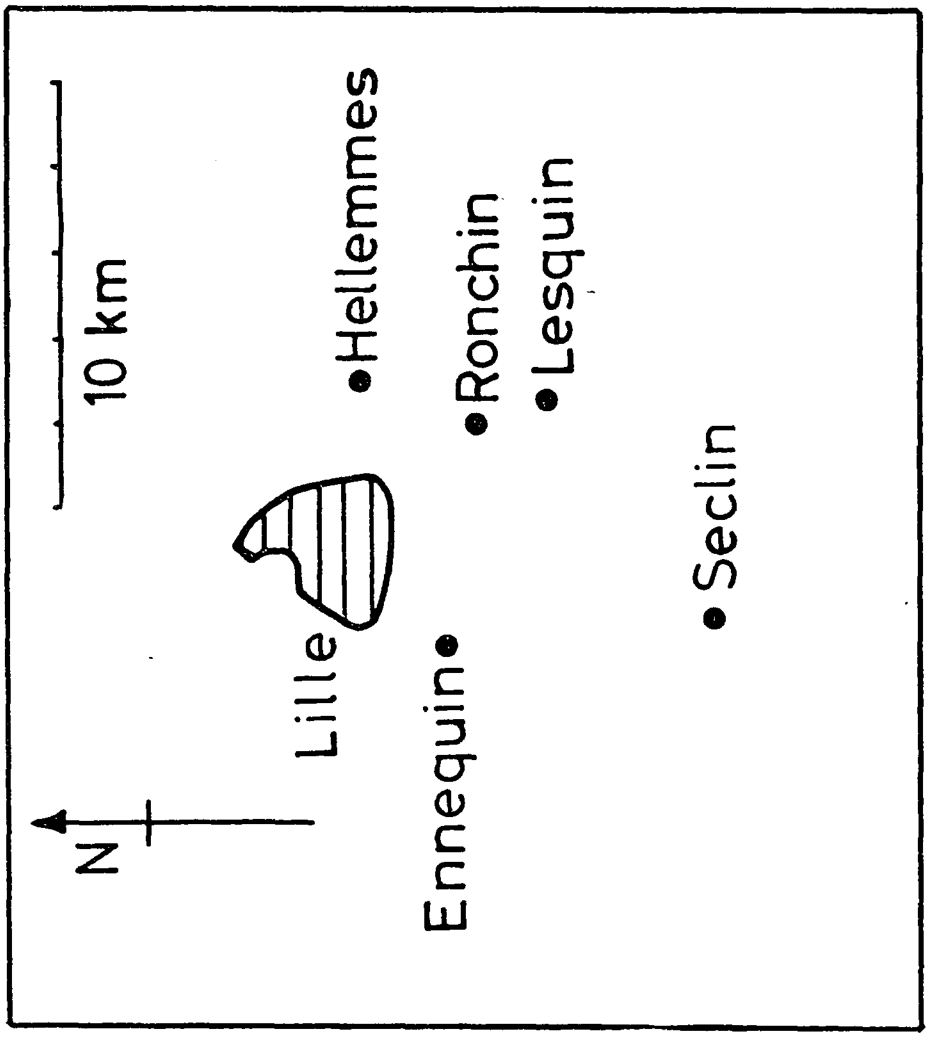

HOLLAND
Lä
Rs
G
Lü
St
Han
Mi
L
Ho
Pe
Br
Sö
N
Sa
KF
Ds
Rh
Lg
I
Rf
Hl
W
C
Da
M
O
Sc
K
Q
Dü
Ht
Pa
Do
Ha
Do
Er
Re
Bo
Dm
Es
Mü

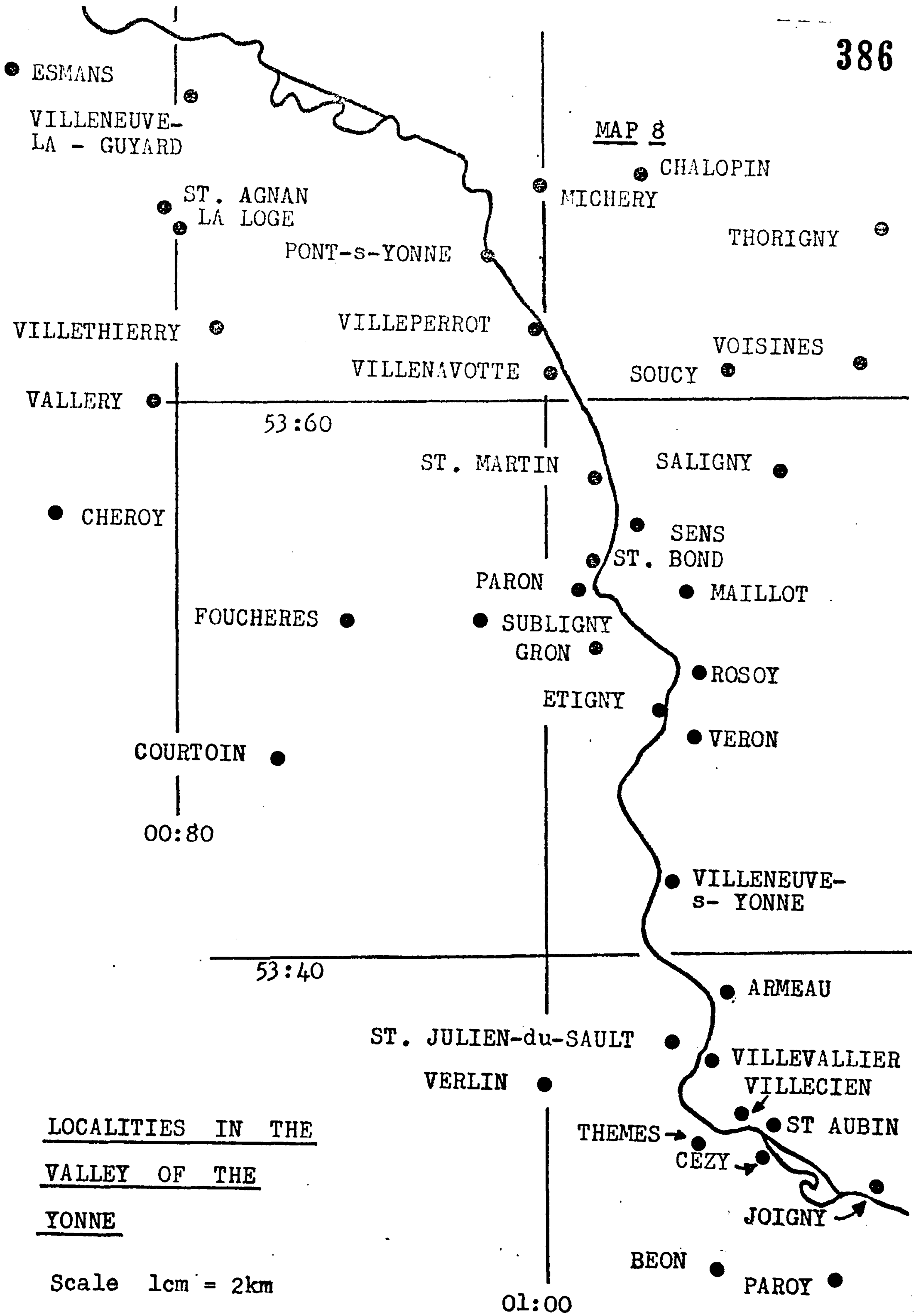

map 5
10 km
N
Kunrade
Maastricht
Gulpen
Aachen
Eben-Emael
Val
Slenaken
Noorbeek
Hallembaye
Heure le Romain
Canal Albert
Orp le Grand
Liege
Limbourg

MAP 6 LOCALITIES IN THE MONS BASIN



MAP 7   LOCALITIES IN THE LILLE REGION





LOCALITIES IN THE VALLEY OF THE YONNE

Scale 1cm = 2km

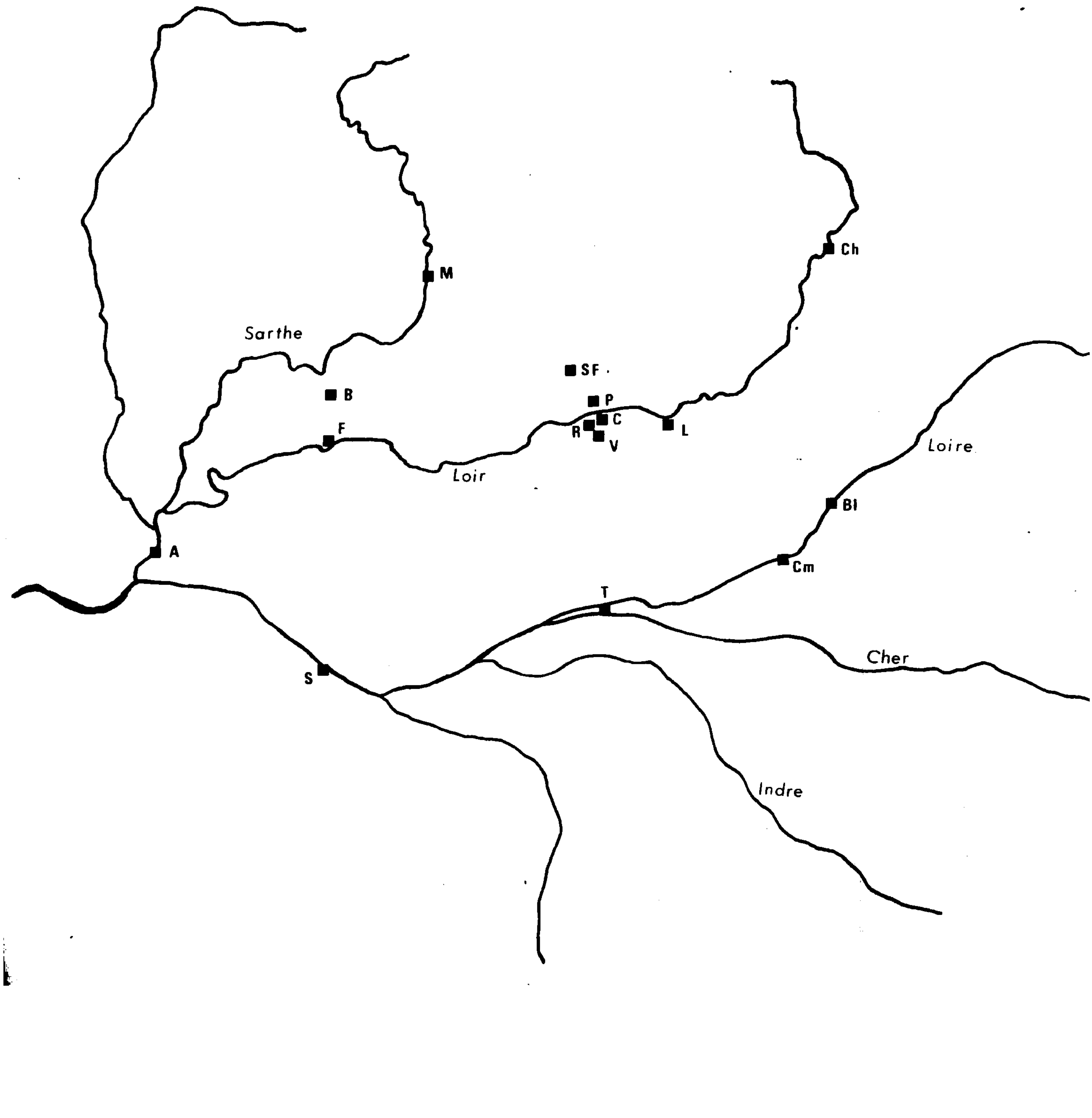
MAP 9 LOCALITIES IN THE TOURAINE

1 cm = 10 Km.

A	Angers
B	Bousse
C	couture
Ch	Châteaudun
Cm	Chaumont
F	la Flèche
L	Lavardin
M	le Mans
P	Poncé
R	la Ribochère
S	Samur
SF	St. Fraimbault
T	Tours
V	Villedieu

Bl	Blois

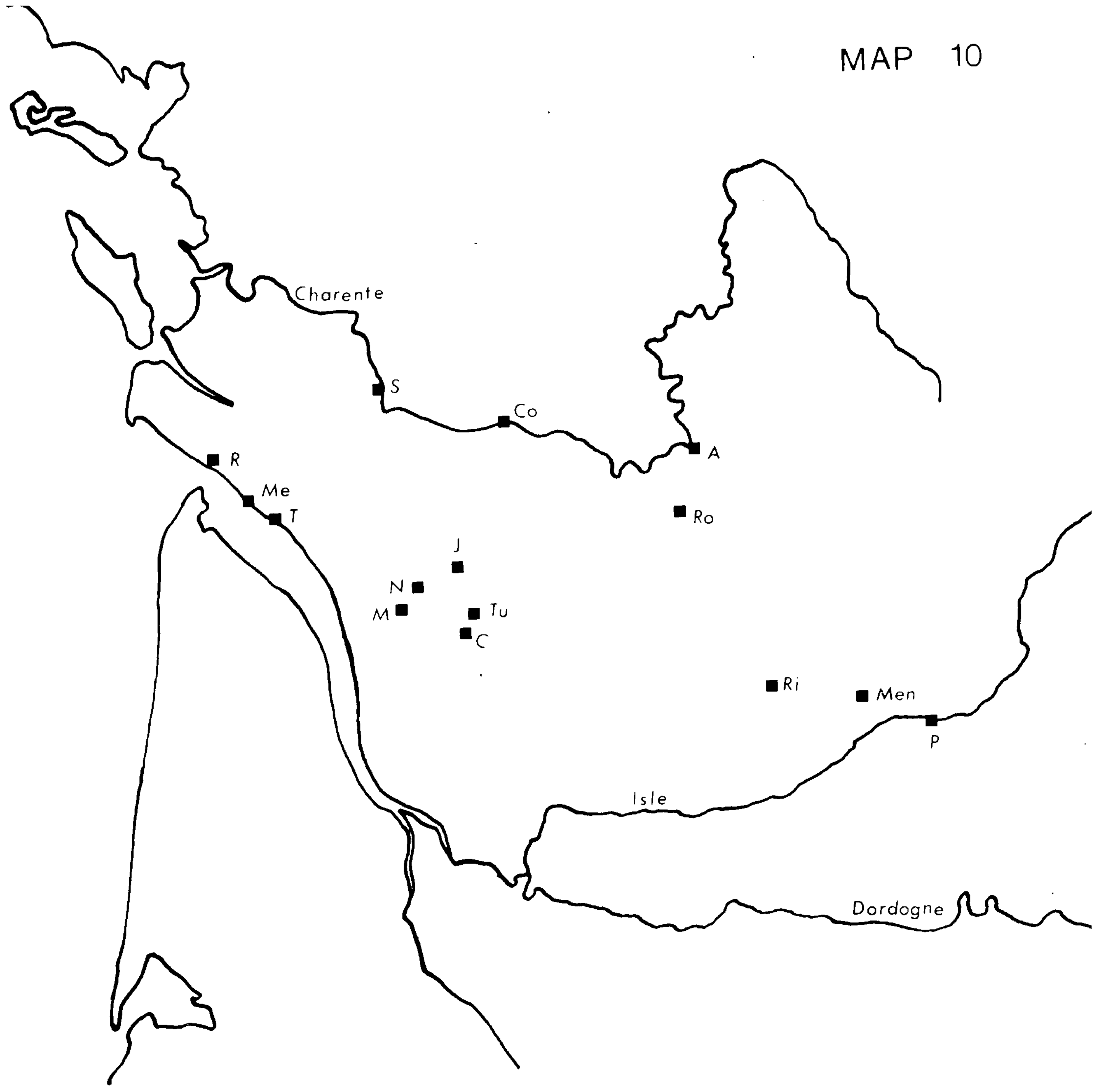
MAP 9



MAP 10 LOCALITIES IN AQUITAINE
1 cm = 10 Km

A	Angoulême
C	Chartuzac
Co	Cognac
J	Jonzac
M	Mirambeau
Me	Meschers
Men	Mensignac
N	Nieul-le-Virouil
P	Périgeux
R	Royan
Ro	Rousselières
Ri	Ribérac
S	Saintes
T	Talmont - Caillaud
Tu	Tugéras

MAP 10

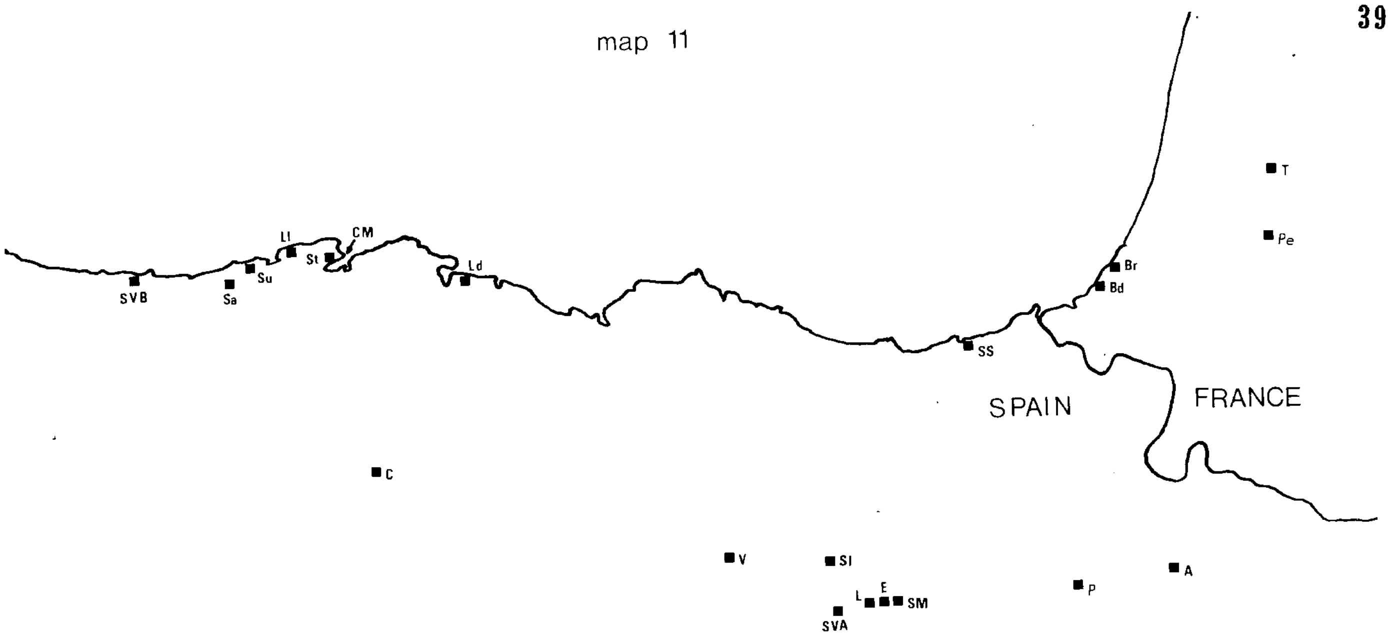


MAP 11 LOCALITIES IN THE SANTANDER REGION AND THE WESTERN PYRENEES.

1 cm = 10 Km

A	Arce
Bd	Bidart
Br	Biarritz
C	Cornejo
CM	Cabo Menor
E	Eulate
L	Larraona
Ld	Laredo
Ll	Llencres
Pa	Pamplona
Pe	Peyrehorade
Sa	Santillana
Sl	Salvatierra
SM	San Martin
SS	San Sebastian
St	Santander
Su	Suances
SVA	San Vicente de Arana
SVB	San Vicente de la Barquera
T	Tercis
V	Vitoria

map 11

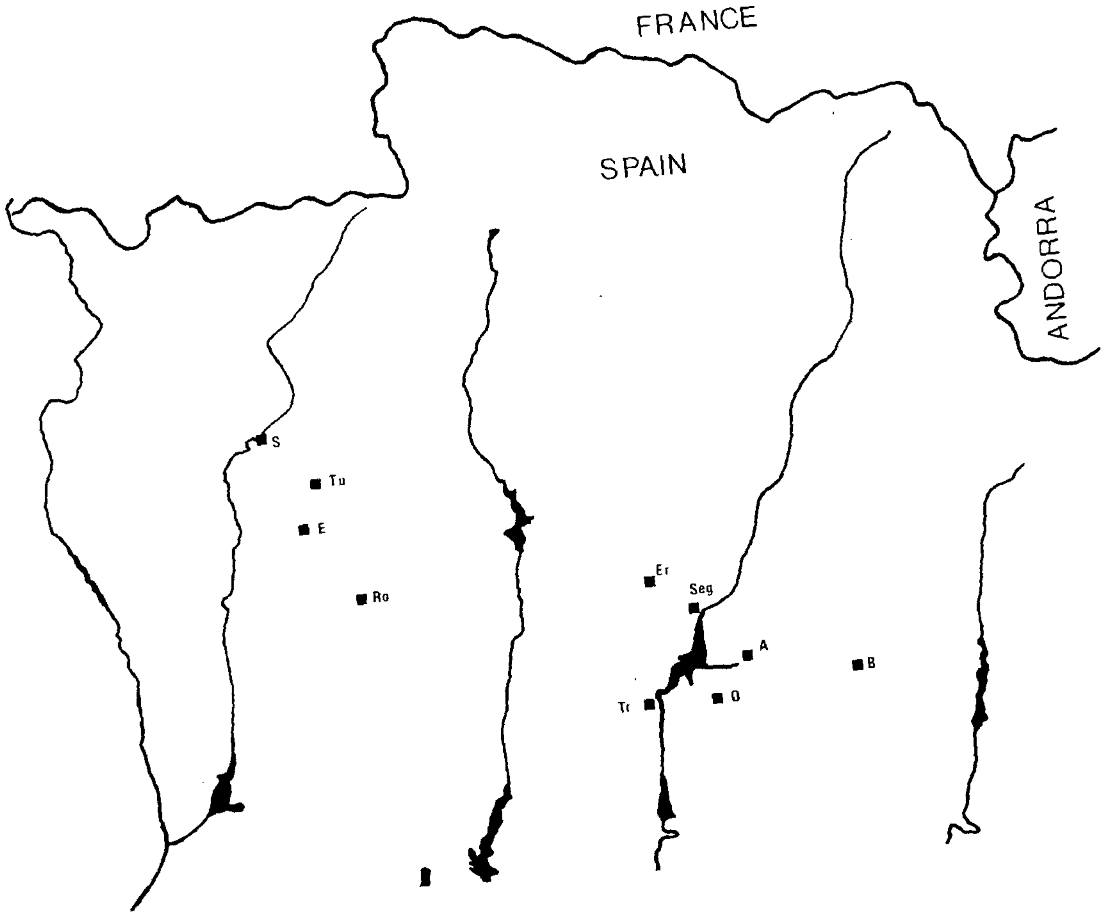


MAP 12 LOCALITIES IN THE MONTSECH AREA OF THE SPANISH PYRENEES

1 cm = 5 Km

A	Aramunt
B	Boixols
E	Egea
Er	Erina
O	Orcau
Ro	Puebla de Roda
S	Seira
Seg	Pobla de Segur
Tr	Tremp
Tu	Turbon

MAP 12

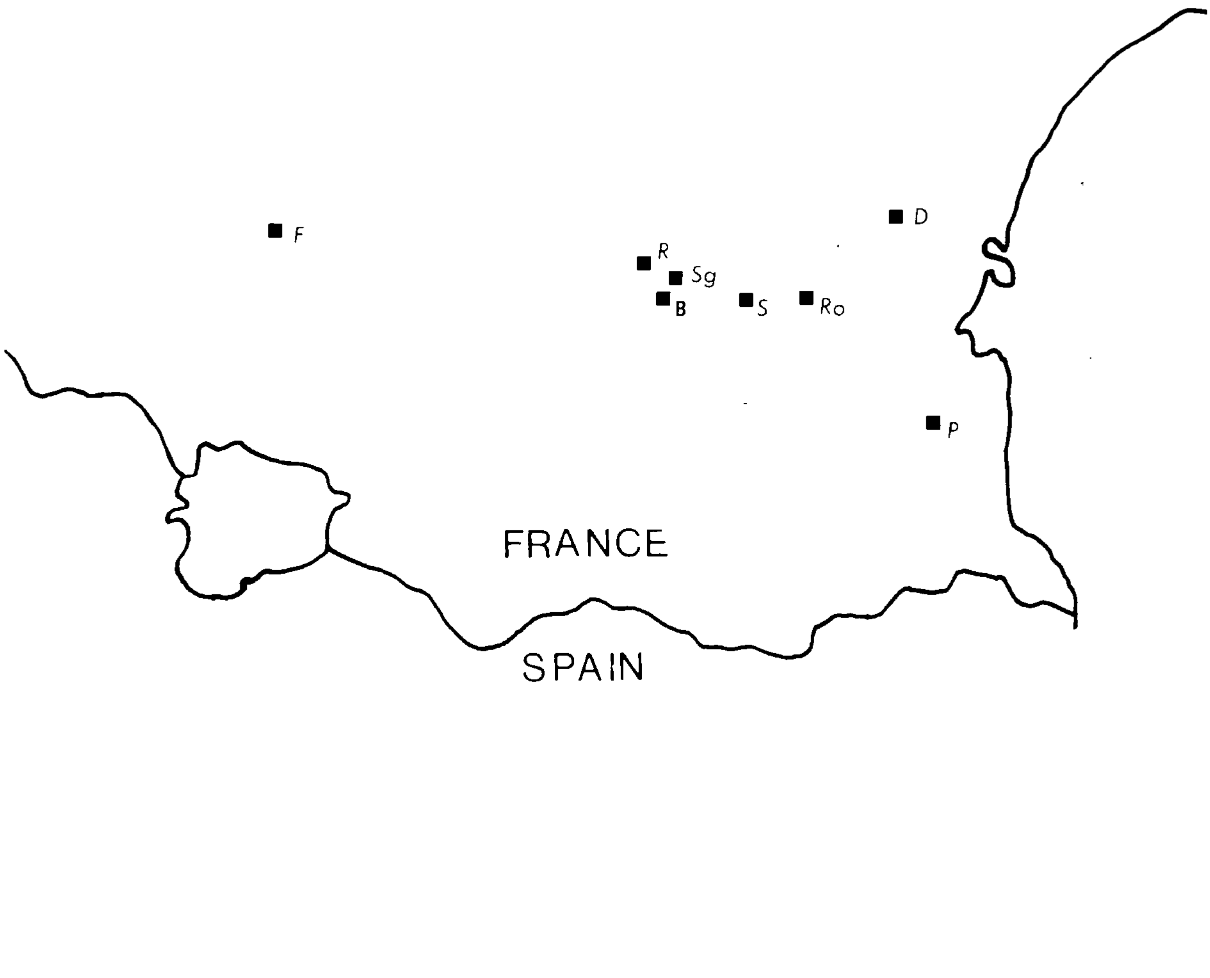


MAP 13 LOCALITIES IN THE PETITES PYRENEES AND CORBIERES

1 cm = 10 Km

B	Bugarach
D	Durban
F	Foix
P	Perpignan
R	Rennes-les-Bains
Ro	Rouffiac
S	Soulatge
Sg	Sougraigne

MAP 13



MAP 14 LOCALITIES IN THE RHONE VALLEY AND SOUTH EAST FRANCE

1 cm = 10 Km

A	Avignon
B	le Beausset
Bl	Blaussac
C	Contes
Ca	Cantaron
D	Dieulefit
M	Menton
Ma	Martigues
Mo	Montpellier
N	Nîmes
Ni	Nice
Ny	Nyons
PSE	Pont-St.-Esprit
Q	Quissac
R	Roquebrune
S	Sauve
U	Uchaux

MAP 14