FOSSIL FORAMINIFERA FROM THE CRETACEOUS ROCKS OF SOUTH INDIA

Part I. Ariyalur Area Orbitoids

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1. General Introduction

It was clear from the reports of the pioneer geologists,—Blanford (1865), King (1880), and Kossmat (1897) that we have along the east coast of South India several small but nevertheless very interesting exposures of marine fossiliferous Cretaceous rocks, due to a transgression of the southern sea in this region during the upper Cretaceous period. During the last thirty years, the present writer has been engaged in the study of the stratigraphy and palaeontology of these rocks, and a number of papers dealing with several aspects of these researches have been published from time to time. A connected account embodying the results of these contributions has been just published by him in the *Proceedings of the Academy*;[10] a reference to this paper would be helpful in furnishing the reader with the necessary full background for appreciating the geological setting of the several rock formations referred to in the present foraminiferal studies and their special importance.

Very early in the course of this work, it occurred to the present writer that one of the most valuable and interesting lines of investigation would be the study of the Foraminifers from these rock formations about which only a passing reference had been made now and then by the pioneer workers. In view of the present recognised importance of this group of fossils in the study of Cretaceous rocks all over the world, it was obvious that similar work in the rocks of South India was urgently called for. Starting on this line of enquiry nearly thirty years ago, the author recorded in the year 1924 the occurrence of numerous small Foraminifers in the phosphatic nodules of the Utatur group; and this was followed by the find of similar microforaminifers in various other beds of the South Indian Cretaceous by a number of workers,—the genera commonly noticed as a result of these studies being *Nodosaria*, *Textularia*, *Planorbulina*, *Anomalina*, *Rotalia*, *Robulus*, *Lenticulina*, *Nonion* and *Globotruncana*. Special attention was also drawn by the writer to the occurrence of abundant Miliolidae in some of the limestones

of the Niniyur group. Recent investigations have further revealed the presence of several other important groups of Foraminifers in these Cretaceous formations the study of which has now been undertaken by the author with reference to certain beds in the Trichinopoly and Pondicherry areas; the present paper deals with a general account of the Orbitoidal fauna recently noticed in some of the rocks belonging to the Ariyalur group.

I am much obliged to several of my erstwhile colleagues in the Central College for all the assistance they have given in the preparation of the material and taking the photomicrographs used in illustrating these papers. I would also like to thank Sri. Y. Nagappa, Palaeontologist, Assam Oil Co., Ltd., for helpful discussions.

2. STRATIGRAPHY OF THE AREA

Before proceeding to deal with the Foraminifers, it will be useful to recapitulate briefly the stratigraphical classification of the Cretaceous rocks of the Trichinopoly District (which is the type area for these coastal Cretaceous rocks) and indicate the position therein of the beds from which the Orbitoids are now being described. The Trichinopoly Cretaceous is divided into 4 groups; starting from the oldest these are: (i) the Utatur, (ii) the Garudamangalam (Trichinopoly), (iii) the Ariyalur, and (iv) the Niniyur. The entire succession ranges in age from the upper Albian to the Danian of the European stratigraphical scale.

The Foraminifera now under study all come from a collection of certain arenaceous limestones occurring as bands a few miles to the east of Ariyalur; stratigraphically their position is just below the Danian Niniyur group, and representing the topmost members of the Ariyalur division. Their age would thus be Maestrichtian. The exact stratigraphical position of these beds in the Ariyalur-Niniyur succession is shown in the diagrammatic section given below (*vide* Text-Fig. 1).

3. PREVIOUS WORK

The earliest reference to the occurrence of Foraminifers in this area was by Stoliczka in 1873[12] who found them in some of the limestones collected by H. F. Blanford from Niniyur and Chokanadapuram about 10 miles NNE of Ariyalur. In this collection, Stoliczka noticed the occurrence of some Orbitoids represented by " a single well defined species, *Orbitoides faujasi* Defr. and two doubtful ones". The *O. faujasi* of Stoliczka and its subsequent nomenclatural history has been recently reviewed by the author elsewhere,[9] and it is now clear that this form is the same as what is now called *Lepidorbitoides minor*. More recently, after nearly seventy years after Stoliczka's

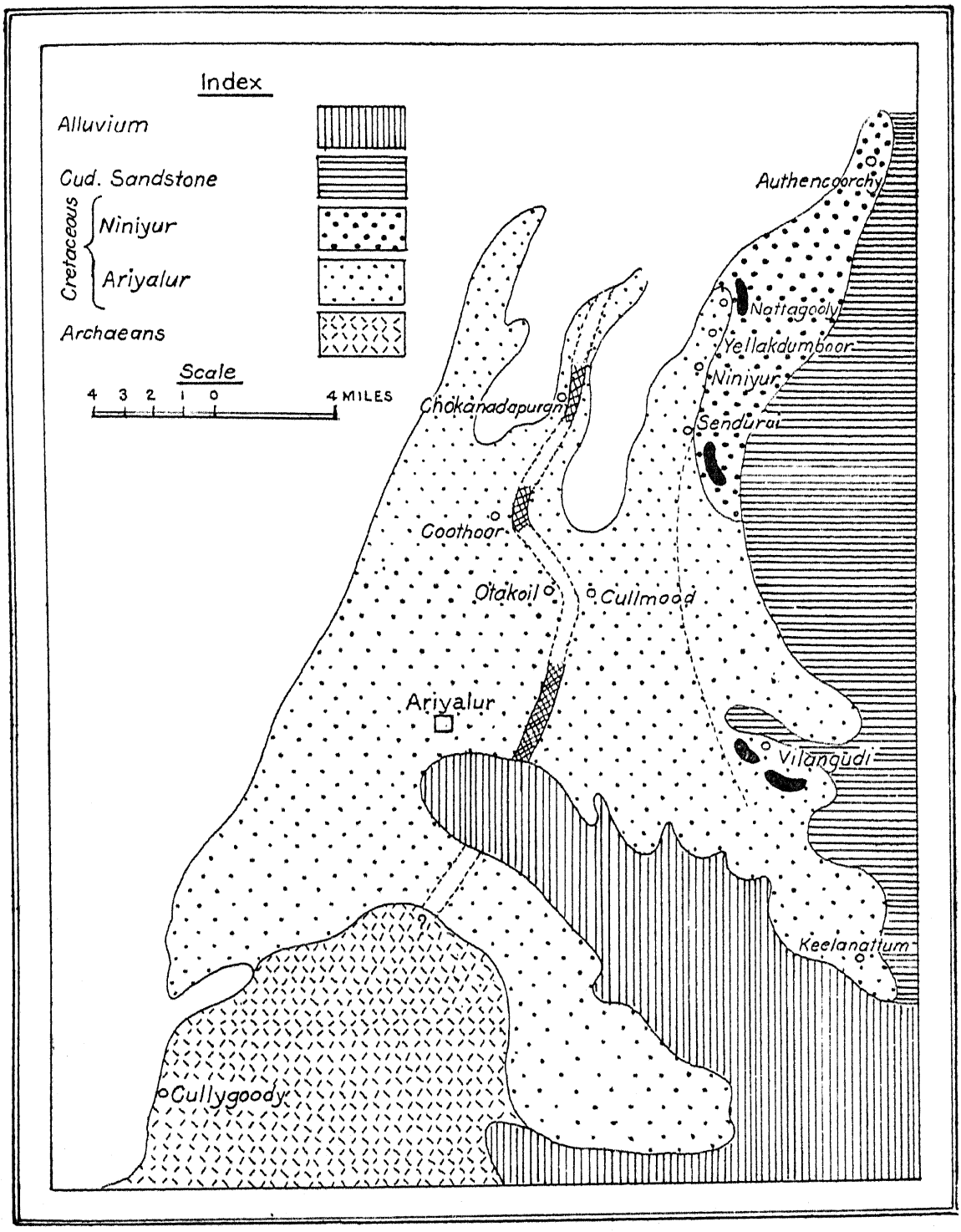
Orbitoids; this area evidently needs further exploration. It is also specially interesting to note that in one of the limestones occurring in a locality so far south as Cullygoody (Kallakudy), Thalmann is recently reported[4] to have found some *Lepidorbitoides*,—an occurrence altogether unexpected according to our current notions regarding the age of the rocks in that region (Cenomanian).

4. PRESENT WORK

The above is a brief review of our knowledge till recently of the Orbitoids from the Trichinopoly Cretaceous beds; and it will be readily admitted that this record is by no means satisfactory or impressive. Such a review however reveals to us the vast scope for foraminiferal research in this area, and points out the need for more extensive studies in this fascinating field.

About two years back, when examining sections of some of the rocks from the Ariyalur area (collected by a geological excursion party from the Central College) the present writer found that some of the rock sections revealed the presence of numerous Orbitoids;[6,7] in addition they also contained abundant and well preserved *Siderolites*.[8] Numerous small Foraminifers also occur quite commonly belonging to the genera *Rotalia*, *Lenticulina*, *Operculina*, *Anomalina*, *Amphistegina*, *Cibicides*, and *Camerina* (?). In view of the importance of this find and the very promising nature of the material, a larger and more representative collection of some of these selected rocks was later obtained for detailed study through the kindness of Sri. S. Subramanian, Geologist of the F.A.C.T. (Ltd.) in Ariyalur. From the general trend and disposition of these rocks in the field, it would appear that the Orbitoidal beds now noticed east of Ariyalur are the southern extension of the similar Orbitoidal beds already noticed near Coothoor and Chokanadapuram, and probably represent portions of one and the same band as indicated in the map given below of the Ariyalur area (Text-Fig. 2). It would be most fruitful to survey the area all along this line, and also to look for possible continuations of this band north of Chokanadapuram on one side and south-east of Ariyalur on the other. It seems likely that the limestone near Cullygoody (Kallakudy) in which Thalmann is reported to have found *Lepidorbitoides* (referred to above) is probably a representative of this band at its southern extremity (*vide* Text-Fig. 2).

The rock specimens from near Ariyalur now under study were collected from two adjacent bands of limestones, one of them crowded with Gryphea shells, and the other full of Inoceramus shell fragments. The latter (Inoceramus bed) occurs just east of the former (Gryphea bed), both of them with a general north-south strike. Although the two rocks look similar and are



TEXT-FIG. 2. Map of the Ariyalur area showing the Maestrichtian limestone band (containing Orbitoids and Siderolites) occurring to the east of Chokanadapuram, Coothoor, and Ariyalur, and its probable full extent.

found close together, there is a striking difference in their foraminiferal contents. While some of the smaller Foraminifers are no doubt common to both, a significant fact is that all the Orbitoids and Siderolites which are so abundant are exclusively confined to the Gryphea bed and totally absent from the adjacent Inoceramus bed. There appears to be thus a sharp micro-palaeontological boundary between the two, and the exact meaning of this is not clear. This is a point requiring further attention.

The present paper deals only with the Orbitoids noticed in these Ariyalur rocks, and is based on the study of about 25 rock specimens of which nearly 100 sections have been prepared and examined. It must, however, be pointed out that most of the observations recorded here are based on the study of rock slides wherein we get only sectional views of these Foraminifers often in random directions; at times, though rarely, these shell sections in some of the slides are recognisably 'oriented' and these are the ones that have been selected for description here. For fuller and more conclusive studies, it is necessary to separate the shells from the rocks in which they are found and base all our identifications on such prepared material. Luckily most of the Ariyalur rocks are well suited for such treatment, and work in this direction is under progress.

5. DESCRIPTION

By far the most common among the Foraminifers occurring in the present material (confined however to the Gryphea bed) are the Orbitoids,—some of the slides being crowded with their remains (Plate XXVIII, Fig. 5). Most of these are random sections and often fragmentary; but now and again we get some nice vertical or transverse sections quite useful for study. A few good equatorial sections, though often only partial, are also noticed.* All the sections show the usual Orbitoidal characters and the photomicrographs reproduced in the accompanying Plates give a good general idea of these forms.

One striking feature is that these shells as a whole are small in size, much smaller than the generically similar forms described from other Cretaceous

* In naming the orientation of these sections, the following is the terminology used by the author: sections in the median plane including the entire circumference and passing right through the centre are designated 'equatorial' sections; sections at right angles to the median plane and passing through the centre are called 'vertical' sections. Sections in a plane parallel to the equatorial but not cutting the centre are named 'horizontal' sections, while sections parallel to the vertical, but not passing through the centre will be referred to as 'transverse'. All other sections not conforming to any of the above recognisable orientations will be generally described as 'oblique'.

beds from India or outside.† Many of these are about 2 mm. or less in diameter; occasionally we get some whose diameter is about 3 to 4 mm. The thickness and its ratio to the diameter are also quite variable,—some being short and stout, and others thin and flat. The following measurements made on some vertical sections will give an idea of the variation in size and proportion:

Diameter	Thickness
(in mm.)	
3·0	0·75
2·3	0·53
2·0	0·8
1·13	0·33
0·86	0·23
1·4	0·3
1·16	0·46
1·93	0·53
1·33	0·43

Several of the sections belong to the megalospheric forms and show a bilocular nucleoconch (of which the first is almost spherical, and the second, slightly bigger in size, is more or less reniform in shape partly embracing the first) similar to that of *Lepidorbitoides*; the shape and arrangement of the equatorial chambers are also generally similar. The existence of stolon passages connecting the adjacent equatorial chambers is often clearly seen; so also the 'cribriform perforate' nature of the chamber walls. Pillars of varying prominence are also commonly noticed.‡ From all these characters, it is seen that many of these shells belong to the genus *Lepidorbitoides*. The question whether there is no true *Orbitoides* in this area had better be

† Quite recently, however, some Orbitoids of a similar small size have been described by H. H. Renz [*Micropalæontologist*, Jan. 1955, **1** (1)] from the upper Cretaceous (Maestrichtian) of North-Central Venezuela.

‡ In describing certain Lepidocyclinas from the Bikini Drill Holes, Storrs Cole (U.S.G.S. Professional Paper 260–O, 1954) has pointed out that in some of these, we get structures which look like 'pillars' but are really not so; *e.g.*, in his description of the form *L.* (*Eulepidina*) *gibbosa* he says: "The roofs and floors of the lateral chambers are thin at the centre, but thicken at each end. The thickened ends of the floors and roofs of one tier of chambers join those of the next adjacent tier on each side to produce a column-like structure between the tiers of chambers. However, pillars are not present." Then again, in *L.* (*Eulepidina*) *planata*: "The lateral chambers are arranged in definite tiers. The rectangular chamber cavity is open, and bounded by relatively heavy floors and roofs. The line of juncture between the tiers of lateral chambers is thickened giving the appearance of pillars. However, true pillars are not present."

Some of the Orbitoids in the present Ariyalur material also show a similar feature.

Plate XXVII, Fig. 2 (× 35) is the transverse section of an Orbitoid, where the shell appears to be flat, rather curved—slightly asymmetrical and gradually tapering towards the peripheral margin. The length of the form is 2·3 mm. and the width 0·5 mm. Since the section is not truly vertical these measurements do not represent the diameter and thickness of the entire shell though they would give us some idea of the proportion between the two. The equatorial zone of chambers is quite clear; these chambers are squarish in outline with curved outer walls and slightly equitant. The presence of a median stolon connecting the adjacent chambers is clearly indicated all along the equatorial zone. The number of tiers of lateral chambers on each side is small—7 in the centre and only 2 or 3 at either end. The lateral chambers are flat, their length being about 3 or 4 times the height. The most striking feature of this form is the presence of pillars arranged more or less at regular intervals on either side all along the median zone, and appearing as knobs on the surface. The pillars are bigger in the centre and get gradually reduced in size as we proceed towards either end. The surface diameter of the central pillar (seen clearly in the photograph) is about 66 μ.

The Orbitoid in Plate XXVII, Fig. 3 (× 40) is a very interesting form,—the pillars being its most striking feature. The section is almost certainly vertical; the region of the nucleoconch as also parts of the equatorial zone have however been badly damaged during fossilization. The form is stout in the centre and rapidly tapers towards either end in a characteristic manner. The diameter is about 2 mm., the thickness in the centre is 0·8 mm., while towards either end it gets reduced to 0·3 mm. The form is asymmetrical, and there is a corresponding variation in the number of tiers of lateral chambers on either side; for instance, in the central region we have 12 of these on one side, and only 7 on the other. The walls of the lateral chambers are thick. Under high power we see the fine stoloniferous passages connecting the lateral chambers as in the form in Fig. 1. The shell possesses well developed pillars on either side along the median zone, the 3 in the centre which seem to radiate on either side from the region of the nucleoconch being much more prominent and ending in distinct knobs on the surface, their surface diameter being about 100 μ. It is interesting to note that the central pillar on one side seems to get forked with the result that we see 4 surface knobs on that side as against 3 on the other. As we go away from the centre towards either end, the pillars get reduced in thickness; one of them about half-way down has a terminal thickness of about 66 μ.

In the general shape of the shell and the possession of particularly well developed pillars especially in the centre of the test, this form is similar to

the new species *Lepidorbitoides blanfordi* of S. R. N. Rao.[5] According to him, this species is quite distinct from the typical *L. minor* of Maestricht, and includes in its synonymy Vredenburg's *Orbitoides minor* (= *O. faujasi*, Stoliczka) from this very area.

Plate XXVII, Fig. 4 (× 70) shows the vertical section of an interesting form, very nicely preserved. Its diameter is 1·16 mm. and thickness 0·46 mm. The shell is much inflated in the centre and slopes fairly rapidly towards either end where the thickness is only about 0·12 mm. The median zone of equatorial chambers, as also the tiers of lateral chambers, are well seen. The equatorial chambers are clearly equitant and show the usual arched roofs. There are 7 tiers of lateral chambers in the centre and these get reduced to 3 towards the outer margin. In size, the lateral chambers are about 66 μ long and 16 μ high. The chamber walls are thick (12–14 μ), and almost equal to the height of the chambers. Under high magnification, the fine stoloniferous passages connecting the proximate lateral chambers in adjacent tiers are very clearly seen. The embryonic apparatus as seen in this section indicates a bilocular nucleoconch which is very distinctive; the smaller locule is triangular and the bigger one, spherical; the base of the former measuring 50 μ is just in tangential contact with the latter which has a diameter of 83 μ. The nucleoconch is enveloped by a well defined common wall measuring about 16 μ in thickness. The most striking feature of the shell is the prominent and very stout central pillar on one side, ending in a conspicuous knob on the surface. Its thickness at the inner end is 100 μ, and this rapidly increases to 166 μ at the outer end. Otherwise there are no pillars on either side, and the surface of the shell is quite unornamented.

This form has some general resemblance in its characters to a type of *L. blanfordi* figured by S. R. N. Rao[5] (Pl. VI, Fig. 8 of this paper) and may perhaps belong to the same species.

Plate XXVIII, Fig. 6 (×45). The shell in this case is clearly asymmetrical, with the nucleoconch also eccentrically placed, being shifted towards the more convex side of the shell. The diameter of the form is 1·93 mm. The unequal development of the lateral chambers on either side of the median zone is clearly seen, the thickness on one side being 0·2 mm. and on the other, 0·33 mm. thus making up a total thickness of 0·53 mm. There are numerous pillars arranged all along starting from the equatorial zone and terminating on the surface in knobs; they are of uniform size with a terminal thickness of about 50 μ. The details regarding the equatorial and lateral chambers are not clearly preserved.

The nucleoconch, however, is well seen. It is bilocular and enveloped by a distinct common wall. The first chamber is spherical with a diameter of 83 μ while the second one is bigger in size (Diam. 116 μ) and reniform in shape embracing nearly half of the earlier chamber.

Plate XXVIII, Fig. 7 ($\times$ 25). In this photograph we see a long and thin section of an Orbitoid, the length being 4·4 mm. and the width only 0·33 mm. The median zone of chambers, however, is quite prominent with a width of 83 μ. There are only 3 or 4 tiers of lateral chambers on either side and the total thickness of these on each side is only about 0·12 mm. Judged by these features what we see here may be a transverse section of a thin flat form like *L. rutteni* of Thiadens; or else it may represent a transverse section cut far away from the centre of a microspheric form with a diameter much more than 4·4 mm.

Plate XXVIII, Fig. 8 ($\times$ 75). We have here an Orbitoid of special interest. It is a transverse section of a shell obviously flat and discoidal, with practically no great variation in thickness from end to end. Its length is 0·95 mm. and width, 0·25 mm. The median zone of chambers is quite clear, but the lateral zones are very indistinct with little or no indication of the 'lateral chambers in tiers' seen in the usual Orbitoids. There are no pillars. The most interesting feature shown by the form is that the equatorial chambers in the median zone show in several places a wavy and 'alternating biserial' arrangement with clear indications of connecting stolon passages. The shell probably belongs to the genus *Monolepidorbis*, which according to Galloway is a true Orbitoid, but with lateral zones of the nature of laminae. According to Cushman the genus *Monolepidorbis* "needs further study to place it accurately". The present form, which is the only one of its kind noticed in the Ariyalur material, is evidently of special interest.

Plate XXIX, Fig. 9 ($\times$ 75). We have here a vertical section of a shell with several unusual features. The form is lenticular, inflated in the centre and rapidly tapering towards either end thus resulting in a distinct rim. The diameter of the shell is 1 mm. and its thickness in the centre is 0·42 mm. The form is distinctly asymmetrical with a smoothly curved outline on one side and a prominent triangular and pointed umbonal elevation on the other. The shell is therefore of unequal thickness on either side, being 0·16 mm. in one case and 0·26 in the other. Its most distinctive feature is the presence of a prominent spiral of fairly big sized chambers on one side along the median line. This starts with a bilocular embryonic apparatus of which the bigger spherical locule is about 100 μ in diameter, followed by a series of 5 to 6 fairly big sized and flattened chambers (diameter measuring about 116–132 μ)

arranged in a spiral and possessing distinct chamber walls. The later chambers of this spiral appear to be split up along the median line, accompanied by an 'alternating' arrangement of the divisions on either side. The presence of stoloniferous passages is also indicated especially in the region of the earlier chambers. A careful consideration of the above features makes it doubtful whether the form is really an Orbitoid; on the other hand, one sees here a striking resemblance to certain transverse sections of *Helicostegina* (*e.g.*, *H. dimorpha*) described by Barker and Grimsdale.[2] This is obviously an interesting form, but its exact identity must be considered as still uncertain.

Plate XXIX, Fig. 10 (× 65). Here we have a nice equatorial section (but not complete) of an Orbitoid showing a bilocular nucleoconch surrounded by a spiral of periembryonic chambers, generally similar to what has already been noticed by S. R. N. Rao in his *Orbitocyclina* (*O. ariyalurensis*) from this very area.[5] The two chambers of the nucleoconch are almost equal in size, one being spherical with a diameter of 83 μ, and the other slightly abutting against the first with a diameter of 66–70 μ. The nucleoconch is followed by a distinct spiral of periembryonic chambers of which 11 could be counted (probably there are more); of these, the first 5 gradually increase in size (diameter of chamber 5 = 66 μ) and form a girdle in contact with the outer wall of the nucleoconch, and the following 6 mark the extension of the spiral but quite away from the centre. Both the chambers of the nucleoconch as well as the succeeding periembryonic chambers (especially the first 5) show thin but distinct chamber walls enclosing each of them. These walls which are of clear transparent material are sharply defined since the chamber cavities themselves are infilled by dark ferruginous matter. Some of the later chambers of the spiral become helmet-shaped and show what look like median stolons passing from one to the other.

Outside the spiral, the section shows very clearly, in places, the nature and arrangement of the equatorial chambers. These show the typical arcuate shape with curved outer margins and pointed inwards with slightly incurved sides. The walls of the chambers are thick and juxtaposed. The chambers are alternating in adjacent rows and are so arranged that " the outer walls of the chambers in one circle form the inner walls of the chambers in the following circle".

The nature of the nucleoconch and the shape and arrangement of the equatorial chambers would *prima facie* suggest the reference of this form to the genus *Lepidorbitoides*; but the occurrence of a spiral of periembryonic chambers (also noticed in 3 or 4 other sections in the present material) makes the position rather interesting and raises certain questions regarding their

generic assignment. As already mentioned above, this will be referred to and discussed in a later part of this paper.

Plate XXIX, Fig. 11 (× 45). One of the slides contains an almost complete equatorial section, only a part of which (in the central region) is seen reproduced in this picture. The full diameter is about 5 mm. There is no prominent bilocular embryonic apparatus in the centre; on the other hand, we see even there whorls of small chambers. This suggests that the section is probably of a 'microspheric form'. As we proceed away from the centre, the equatorial chambers gradually increase in size (from 33 μ to 66 μ) and become quite distinct. The chamber walls are quite thick (33 μ in the outer regions) and the outline of the chambers as determined by the chamber walls becomes ogival, though the chamber cavities themselves are rounded in shape. The chambers are alternating in adjacent circles. Under high power, the 'stolon system' is clearly seen, there being as many as 5 or 6 stolon passages radiating from each chamber and connecting it with the adjacent ones.

The general form and arrangement of the equatorial chambers noticed here are similar to what has been described by Thiadens[13] in two of his new species of *Lepidorbitoides* (both from the upper Cretaceous of Cuba)—*L. rutteni* and *L. palmeri*. It may however be noted that in both these species, Thiadens has recorded the presence of a 'spiral' of periembryonic chambers surrounding a typical *Lepidorbitoides*-type of bilocular nucleoconch.

Plate XXIX, Fig. 12 (× 100). This figure again shows part of an equatorial section; but the chambers here are distinctly rhombic or diamond-shaped in outline, the longer diagonal measuring 83 μ and the shorter 50 μ. Towards the peripheral margin the chambers become flattened and their size also gets reduced to 58 $\mu \times 33$ μ. The chambers are arranged in intersecting arcs and are alternating in position in adjacent circles. The chamber walls are thick and prominent (16–20 μ), but there are distinct stolon passages connecting them with one another.

While it is true that a rhombic outline is one of the several possible shapes of the equatorial chambers in Orbitoids, it has been recognised as a significant feature of certain species. Vredenburg[14] noticed 'rhombic' equatorial chambers in 3 of the species of *Orbitoides* described by him, *viz.*, *O. media*, *O. apiculata*, and *O. minor*,—the last one being the same as *O. faujasi* described by Stoliczka from the present area. The disposition of the equatorial chambers in the present case shows a striking similarity with that in *O. cf. minor* figured by Vredenburg. More recently, in his description of a new species of *Lepidorbitoides—L. macgillavryi*, Thiadens

says that in this form the embryonic apparatus is of the *Lepidorbitoides*-type, and the equatorial chambers are " ogival to diamond-shaped on intersecting curves, the diagonal measuring 74 μ near the periphery". He considers the possession of ' diamond-shaped ' equatorial chambers as a very distinctive feature of this species.

6. REVIEW AND DISCUSSION

The above is a brief account of some of the Orbitoids noticed in the rocks from near Ariyalur. In addition to these many of the slides contain numerous other Orbitoidal remains; several of them are incomplete or fragmentary sections, but are nevertheless useful in showing one or more of the characters noticed in the forms described above and therefore useful in confirming our observations. Generally speaking, it may be mentioned that the Orbitoids in the present material are much more varied and abundant than in any of the previous collections from this area; the author, however, would like to make it clear that in describing the forms individually and separately as is done above, no suggestion is intended to be conveyed that each of them is a new type,—generically or specifically,—and distinct from the others. It is quite possible that some of these shells are referable to forms previously described from this area or outside, while others are new; but the writer has hesitated to definitely designate them as such since he is of opinion that it is desirable to await the results of further investigations before finalising such conclusions. It is well to exercise a certain amount of restraint in all palaeontological work, especially in creating new genera and/or species; this is particularly necessary in dealing with a group like the present one (Orbitoididae) where it is well known that " even individuals within a single species vary tremendously ". The present studies, however, are enough to bring out certain important points which we may now proceed to indicate and discuss.

The first question which we may consider at the outset is regarding the occurrence of *Lepidorbitoides minor* in these Ariyalur rocks. Our starting point in this discussion is the first Orbitoid,—*O. faujasi*,—described by Stoliczka from this area so far back as 1873. This was later re-examined by Vredenburg; he noticed that in its characters this form agreed so well with that of *O. minor* Schl. of Maestricht that he accordingly renamed Stoliczka's orbitoid and identified it with *O. minor*. In 1907, Silvestri created the genus *Lepidorbitoides*; and in 1916, Douville showed that Vredenburg's *O. minor* really belonged to the genus *Lepidorbitoides* with the result that the old *O. minor* of Vredenburg would now be called *L. minor*. In his recent paper on the Ariyalur Orbitoids, S. R. N. Rao says that the forms here differ

in several respects from the typical *L. minor* of Maestricht, and should therefore be considered as belonging to a new species which he called *L. blanfordi*; in the synonymy of his new species he includes *O. faujasi* of Stoliczka and *O. minor* of Vredenburg. Thus according to S. R. N. Rao, it would appear that there is no true *L. minor* in the Ariyalur beds.

It is hardly possible at this stage to go into the details and discuss all the arguments in favour of or against the above view. The characters fixing the identity of the typical *L. minor* of Maestricht have been recently given by Thiadens,[13] and it appears to the present writer that there are several Orbitoidal sections in the Ariyalur rocks which show features (in the shape of the equatorial chambers, nature of the pillars, etc.) considered as diagnostically characteristic of the type *L. minor* as defined by Thiadens. Even granting that we have here a new species of *Lepidorbitoides*—*L. blanfordi*—as made out by S. R. N. Rao, the fact remains that shells answering to the description of true *L. minor* also occur in these rocks side by side. On the evidence of the present material, we may reasonably conclude that *L. minor* does occur in the Ariyalur rocks.

The next question which we may proceed to briefly consider is regarding the significance of the occurrence of a whorl (or spiral) of periembryonic chambers noticed in some of these Orbitoids as mentioned in the descriptive notes given above. Vaughan considered that this feature was of generic value and therefore created in 1929 the new genus *Orbitocyclina* to cover this type; and it is following this view that S. R. N. Rao recorded the occurrence of *Orbitocyclina* (*O. ariyalurensis*) from the Ariyalur beds. The genus *Orbitocyclina* resembles *Lepidorbitoides* in all respects, its only distinctive character being the possession of a cycle of periembryonic chambers. Within recent years more or less similar periembryonic chambers have been noticed in many species of *Lepidorbitoides*, and the question has been raised whether this character is of such great significance as to warrant the removal of these forms from the genus *Lepidorbitoides*, and creating a new genus *Orbitocyclina* to accommodate them, especially after M. G. Rutten[11] has shown that the stoloniferous apertures also in both the genera are similar; in fact, Rutten questioned the validity of the new genus *Orbitocyclina* of Vaughan and actually stated that it was only a synonym of *Lepidorbitoides*. A couple of years later Thiadens[13] noticed the occurrence of a periembryonic spiral of chambers in his 3 new species of *Lepidorbitoides* from the upper Cretaceous of Cuba, *L. rutteni*, *L. palmeri*, and *L. magillavryi*,—and affirmed that the synonymy of the two genera—*Lepidorbitoides* and *Orbitocyclina*—is "definitely proved". It is not clear, however, whether the exact arrange-

ment of the periembryonic chambers noticed by Thiadens in his 3 species of *Lepidorbitoides* is similar to that seen in the Ariyalur Orbitoids referred to above; judged by the figures given by him, it would appear that there is a distinct difference.

Apart from the synonymy of these two genera, the more interesting and important question to consider is the evolutionary significance of the occurrence of such a periembryonic spiral of chambers. In this connection reference has to be made to 3 other genera,—*Helicolepidina* (Tobler, 1922), *Polylepidina* (Vaughan, 1929) and *Actinosiphon* (Vaughan, 1929)—which show a comparable feature. In the words of Galloway, we have in *Helicolepidina*: " megalospheric nucleoconch bilocular, composed of a spherical chamber followed by a smaller hemispherical chamber, and these followed by smaller arcuate chambers arranged in a spiral." In *Polylepidina*, as Cushman puts it, we have 4–10 embryonic chambers " of which one or two may be somewhat larger than the others..... The chambers may be arranged also in a distinct spiral". In *Actinosiphon*, the position is a little different. Here " the embryonic apparatus of the megalospheric form consists of a rather large subspherical initial chamber, followed by a smaller chamber whose longer diameter is parallel to the circumference of the first chamber. The latter chamber is followed by about 11 other chambers which entirely encircle the first two chambers, and outside this circle, there are several other chambers opposite chamber No. 3 " (Cushman).

It will thus be seen that there are 4 genera in the Orbitoididae possessing distinct periembryonic chambers round the nucleoconch: (i) *Lepidorbitoides* (certain species), (ii) *Helicolepidina*, (iii) *Polylepidina*, and (iv) *Actinosiphon*; and the problem is to discuss the significance of this feature and its evolutionary importance. A perusal of the recent literature on this subject shows that there is considerable difference of opinion, and it is hardly possible to go into the details of this discussion here.

A brief reference may however be made to the problem regarding the genus *Orbitocyclina*—whether it should be accepted as a distinct genus as proposed by Vaughan in 1929, or whether it should be treated merely as a synonym of *Lepidorbitoides* (or alternatively as its sub-genus) as argued by later workers. While it is true that *Orbitocyclina* resembles *Lepidorbitoides* in several respects, such as the form of the nucleoconch, shape of the equatorial chambers, and the nature of the stoloniferous passages, there seems to be a clear difference in the arrangement of the periembryonic chambers between the two genera. The kind of spiral arrangement, its nature and disposition noticed in the *Orbitocyclina* described by S. R. N. Rao, and also

seen in the form described above (Pl. XXIX, Fig. 10) is something distinctive and has no resemblance to what is seen in some *Lepidorbitoides*; on the other hand, it is essentially similar in the present case to the 'spiral' found in *Helicolepidina*. Paying due regard to this important fact, and remembering its possible implication in evolutionary studies, it would appear that it is desirable to retain Vaughan's *Orbitocyclina* as a distinct genus and accept its validity. If there are any *Lepidorbitoides* which show this particular type of spiral of periembryonic chambers, they may accordingly be transferred to *Orbitocyclina*. If this is done, *Orbitocyclina* would have a definite position in the evolutionary series; and Barker's suggestion[1] in connection with *Helicolepidina* "that a possible lineage may be found through *Polylepidina* to some form such as *Orbitocyclina*, the spirality observed in these genera reaching a maximum in *Helicolepidina*" would become more meaningful. In a later paper, Barker and Grimsdale[2] have made out a case to show that *Polylepidina* and *Helicolepidina* are "descended from *Amphistegina* through the new genera *Helicostegina* and *Eulinderina* by a complete series of transitional forms". According to these authors, an Amphistegina-like ancestor gave rise ultimately to *Helicolepidina*, the intermediate links in the chain being *Helicostegina*, *Eulinderina*, and *Polylepidina*—this entire evolutionary transition having taken place in the lower to upper Eocene period. In this connection, it may be noted that in the present Ariyalur material, we have several remains of the Amphisteginidae, together also with a form which is probably *Helicostegina*; and the occurrence of these along with the kinds of Orbitoids described above makes the entire assemblage specially worthy of further attention.

Another interesting observation which may be briefly referred to here is that some of these Ariyalur Orbitoids on careful examination seem to show certain 'lepidocycline' features both in regard to the nucleoconch and the shape of the equatorial chambers. In his study of the Cretaceous Orbitoids of India nearly 50 years ago, Vredenburg[14] had already noticed a similar feature in the case of his *Orbitoides socialis* (from undoubted Cretaceous beds) about which he said: "One is bound to admit that the characters of this species appear undistinguishable from those of oligocene lepidocyclines; whether it represents their forerunner or only indicate a deceptive case of 'convergence' must be left to future research"; and he actually designated his form as *Orbitoides* (*Lepidocyclina*?) *socialis*.

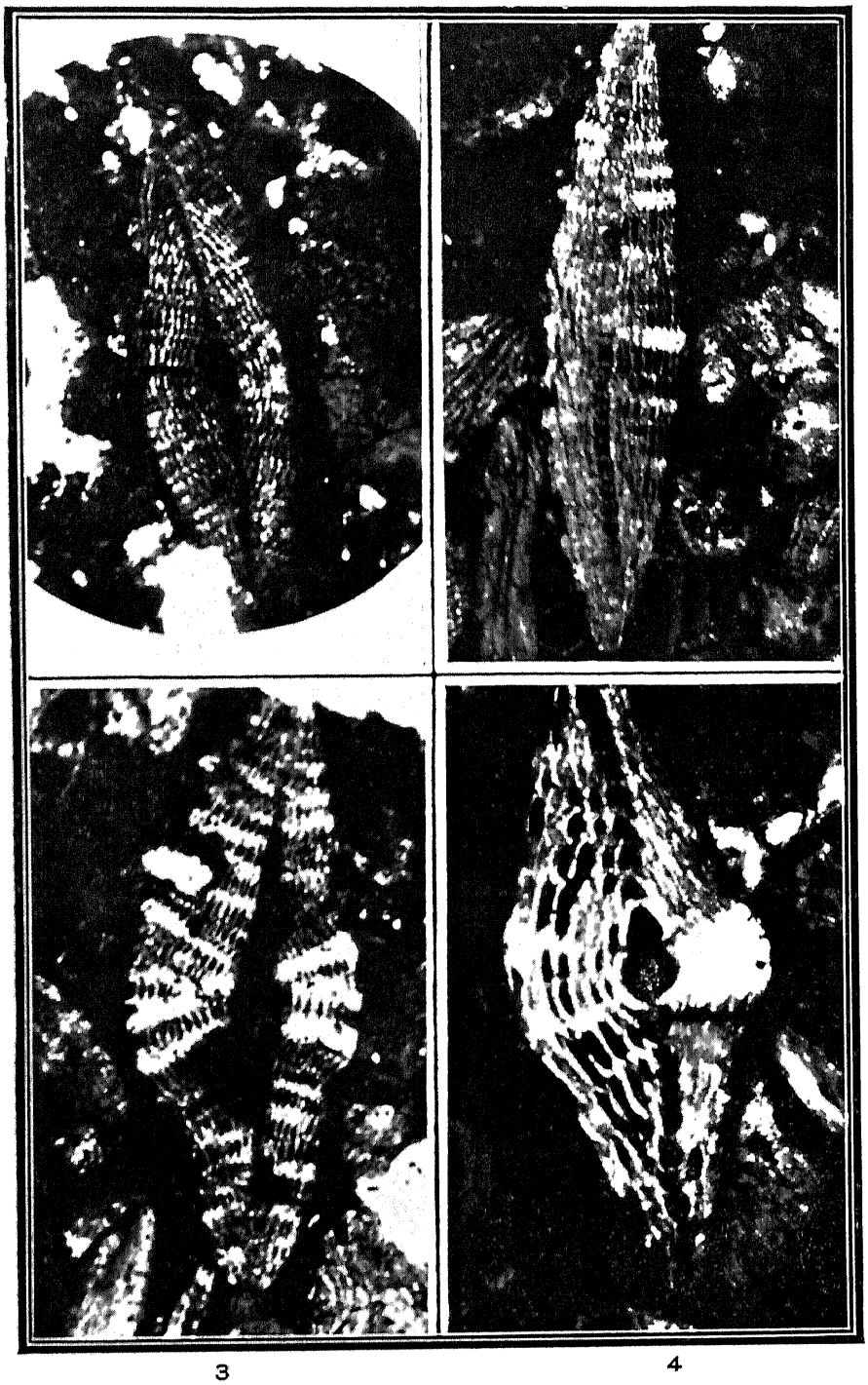
Quite recently Caudri[3] has drawn our attention to several occurrences being frequently noticed now-a-days of "small lepidocyclinoid Orbitoids in beds intermediate in age between upper Cretaceous and those in which true

lepidocyclines first appear (*viz.*, mid-Eocene), and also discussed their possible significance with special reference to the stratigraphic distribution of *Lepidorbitoides*. Some of the Orbitoids in the present Ariyalur material appear to be of the 'small lepidocyclinoid' type mentioned by Caudri, and their occurrence here in undoubted upper Cretaceous beds taken together with similar forms found in the lower part of the Tertiary elsewhere would obviously be of special interest in discussing the current ideas regarding the stratigraphic and evolutionary interrelationship between the two important genera *Lepidorbitoides* and *Lepidocyclina*.

It is hardly possible to go into the details of this very interesting problem in the course of the present paper; a few observations may however be made to indicate the importance of this line of investigation. As Caudri puts it, the genus *Lepidorbitoides* was created in 1907 by Silvestri to include "all the lepidocyclinoid forms from upper Cretaceous that were formerly included in *Orbitoides*". According to Cushman, both the genera *Lepidorbitoides* and *Lepidocyclina* belong to the same sub-family Lepidocyclinæ Tan. in the family Orbitoididae. In between these two genera we have in the Palaeocene and lower Eocene beds forms like *Orbitocyclina*, *Orbitosiphon*, *Actinosiphon* and *Polylepidina* all of which in one way or the other seem to represent transitional stages connecting *Lepidorbitoides* and *Lepidocyclina*. While most of the Orbitoids in the Ariyalur rocks answer to the description of *Lepidorbitoides*, there are some which seem to depart from the normal *Lepidorbitoides* characters and show a resemblance to one or the other Palaeocene and/or lower Eocene genera mentioned above as connecting *Lepidorbitoides* with *Lepidocyclina*. While Caudri deals with the significance of the occurrences of "Lepidocyclina-like *Lepidorbitoides*" up in the lower Tertiary, we seem to have in the Ariyalur material an example of the occurrence of small 'lepidocyclinoid' Orbitoids down in the upper Cretaceous. The detailed study of the Orbitoids included in the assemblages mentioned above will evidently be of the greatest interest and may enable us ultimately to work out the links in the evolutionary chain connecting the typical upper Cretaceous *Lepidorbitoides* at one end with the true middle Eocene *Lepidocyclina* at the other. In fact, as Storrs Cole recently says: "It is apparent to those familiar with the subject that careful revision is necessary of the various genera and subgenera at present included under the family Orbitoididae."

7. SUMMARY

The author is now engaged in a detailed study of the fossil Foraminifera from the Cretaceous rocks of South India; the present paper deals with the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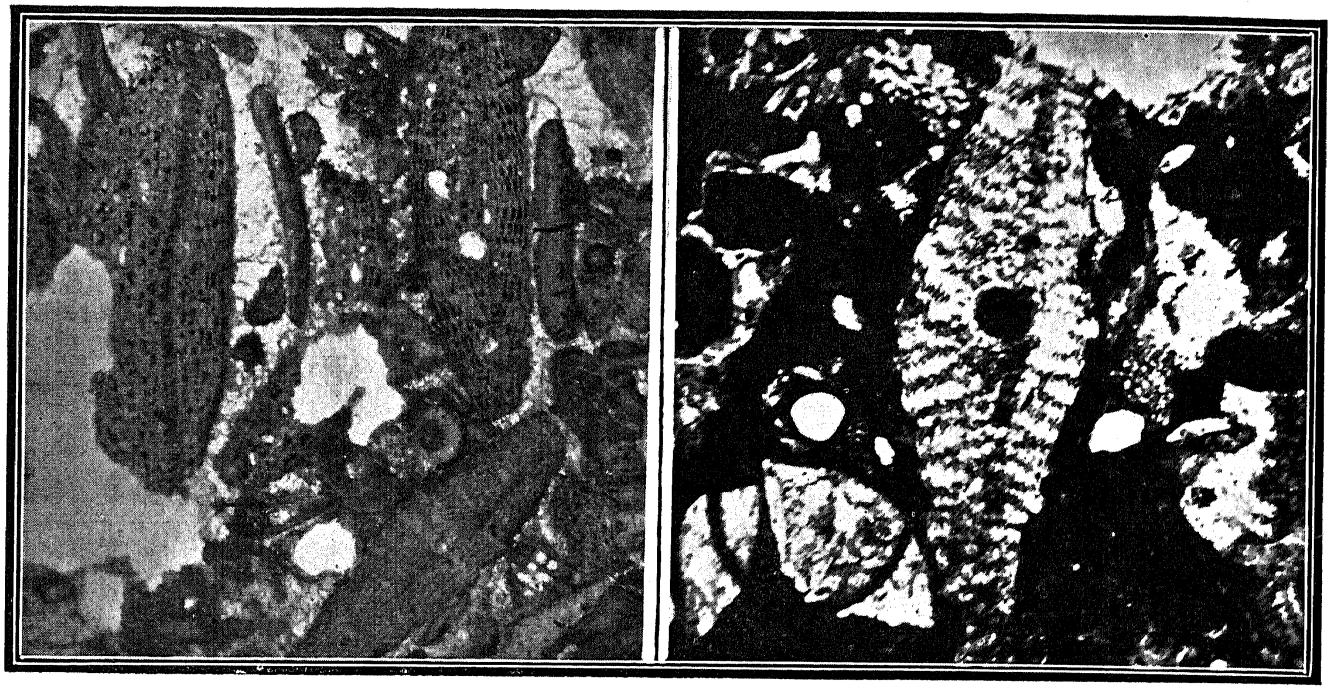

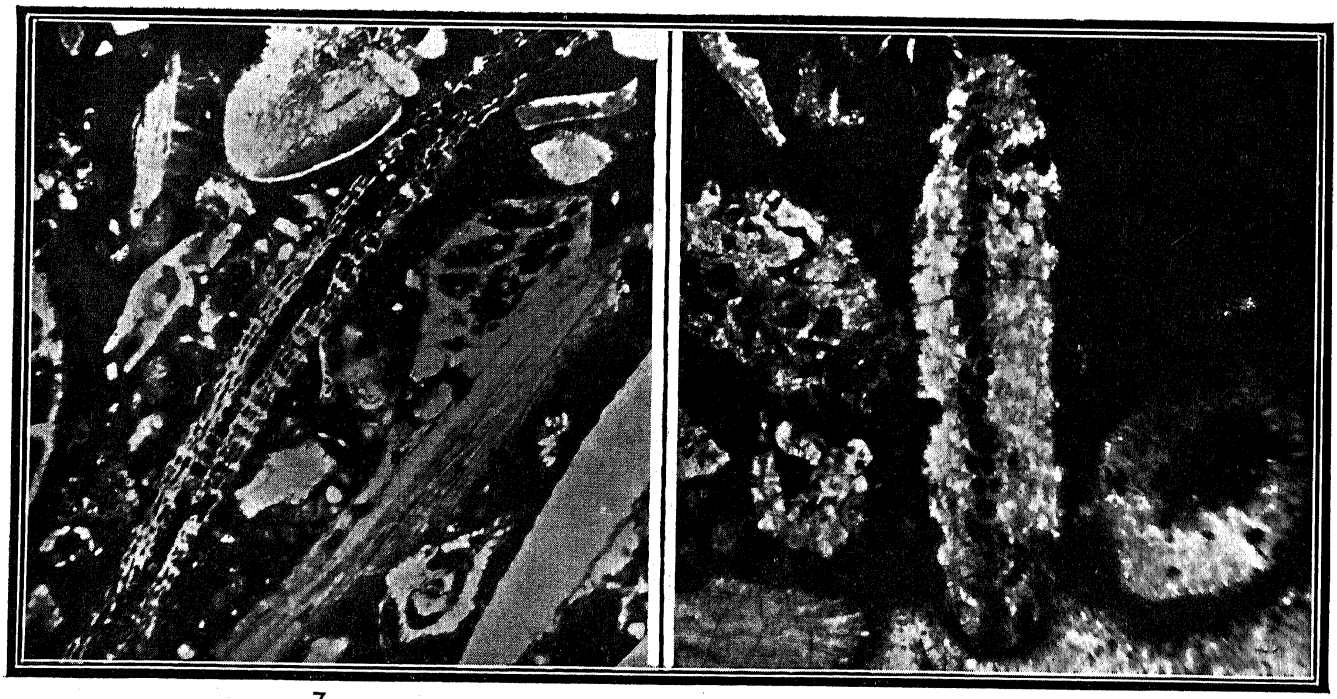

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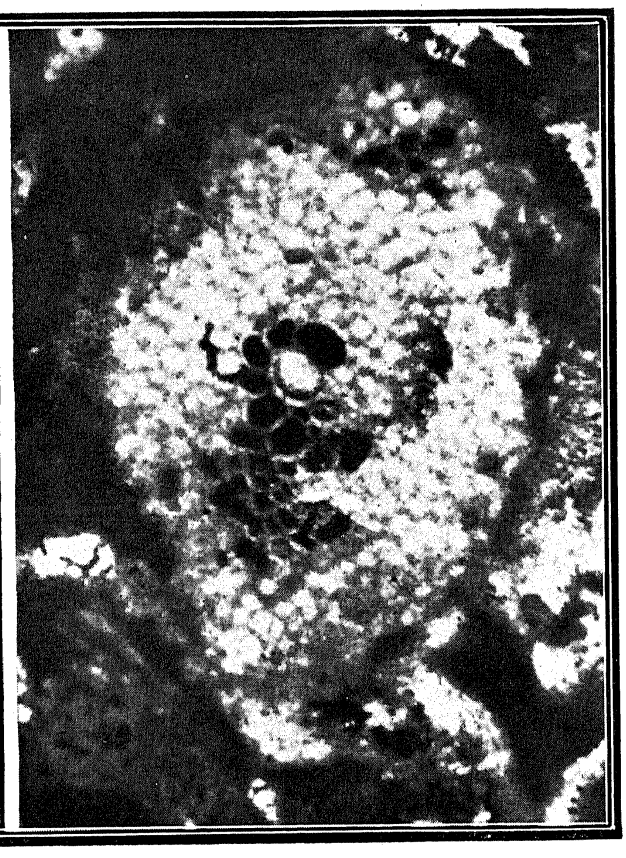

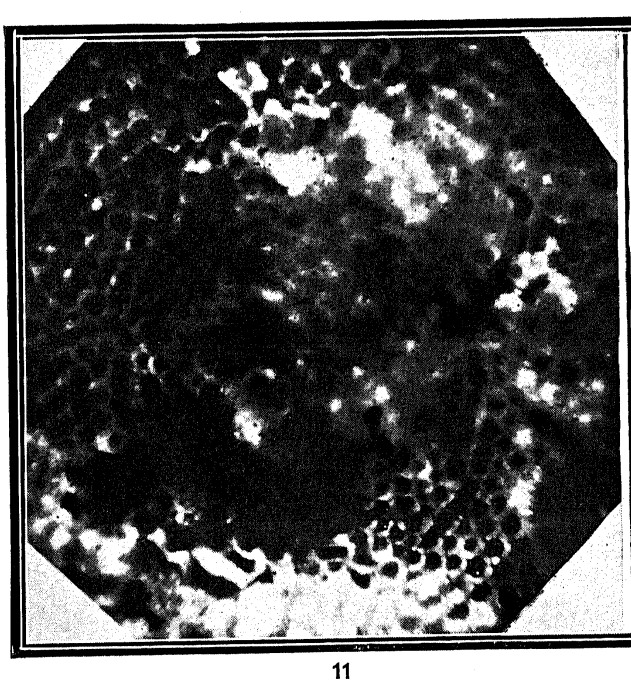

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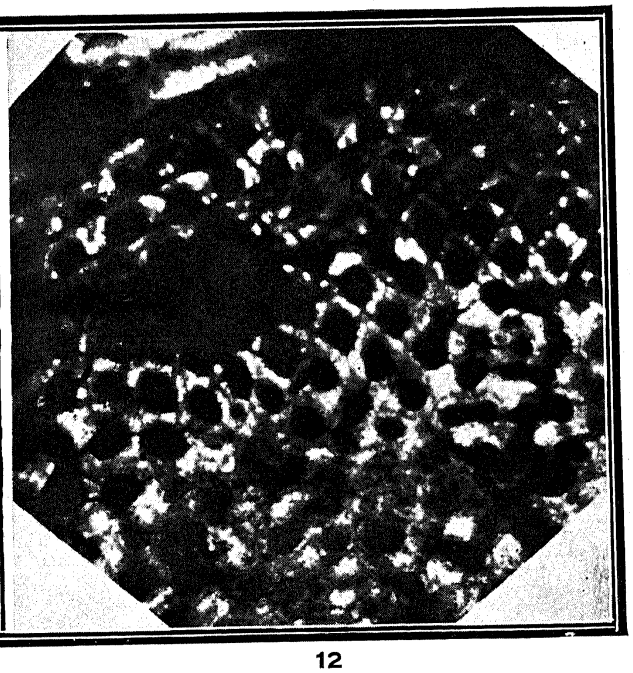

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Orbitoids found in a limestone band recently noticed near Ariyalur, in the Trichinopoly area. The abundance of these Orbitoids, together with plenty of associated *Siderolites*, indicates that the containing rock is of Maestrichtian age and occupies a stratigraphical position in the Ariyalur group just below the overlying Niniyur Group (Danian). While some of the Orbitoids occurring here resemble certain species of *Lepidorbitoides* and *Orbitocyclina* already described, there are others which appear to be new. The paper gives a general account of these Orbitoids, drawing special attention to some of their interesting features. The probable significance of these in the study of the family Orbitoididae is briefly discussed.

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