CALCAREOUS ADHERENT FORAMINIFERA FROM THE BRITISH JURASSIC AND CRETACEOUS AND THE FRENCH EOCENE

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ABSTRACT. Previous records of calcareous adherent Foraminifera from the British Jurassic are reviewed and the presence of four genera, *Bullopora* Quenstedt, *Carixia* Macfadyen, *Nubecularia* Defrance, and *Nubeculinella* Cushman, is established. Emended diagnoses for three of these genera are given and the type species of one, *Nubecularia lucifuga* Defrance, is redescribed from topotype (Eocene) material. All the species and varieties of the Jurassic genera, including certain free-living forms, are redescribed, and their morphological variation, diagnostic characters, and stratigraphical ranges are given. Three Cretaceous taxa, *Bullopora laevis* (Sollas), *B. sollasi* (Chapman), and *B. tuberculata* (Sollas), are also discussed. Lectotypes are designated for *Nubecularia triloculina* Ten Dam, *Nubeculinella tibia* (Jones and Parker), and *Bullopora laevis* (Sollas).

THROUGHOUT the last hundred years confusion has reigned over the systematic position of most of the genera and species of Jurassic calcareous adherent Foraminifera. The unwitting failure of the early workers (Defrance 1825, d'Orbigny 1839, Quenstedt 1856) to provide adequate descriptions of their genera was largely the cause of this, since it was not appreciated until much later that the key to the relationships between these genera lay in the structure of the test wall. The difficulties thus created were subsequently increased by the loss of some of the type specimens, and by the erection of new genera and species by later authors who were themselves unable to define satisfactorily the existing species. The prevailing confusion is today exemplified by the diagnoses given in the four or five most widely used textbooks of recent years (Galloway 1933, Glaessner 1945, Cushman 1948, Pokorny 1958, Rauzer-Chernousova and Fursenko 1959); these authors seldom agree on the definition of a single genus of calcareous adherent Foraminifera. During the past twenty years several attempts have been made to bring order into this group. Macfadyen (1941) attempted a lengthy synonymy for *Bullopora rostrata* Quenstedt, at that time one of the most difficult species to define accurately. Avinmelech and Reiss (1954) erected a new classification for the imperforate adherent forms (in which they mistakenly included *Bullopora*) by elevating the subfamily Nubeculariinae to the rank of family (Nubeculariidae) and dividing this into two subfamilies, this whole group being then, of course, excluded from the family Ophthalmidiidae. Barnard (1958) reviewed the more important Mesozoic genera and discussed the probable evolutionary history of some species.

The purpose of this paper is to redescribe the genera so far reported from the British Jurassic and to review all the known species. In attempting this, the writer has had at his disposal his own material and also the collections of Jurassic Foraminifera deposited in the British Museum (Natural History) by previous authors. These included hitherto undescribed, but very valuable, Jurassic collections of J. F. Blake, H. B. Brady, and F. Mockler.

The author is indebted to Mr. J. M. Edmonds (University Museum, Oxford) for the loan of the types of *Webbina laevis* Sollas, and to Dr. I. Seibold (University of Tübingen) for the loan of a topotype specimen of *Bullopora rostrata* Quenstedt. He is very grateful

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THE GENERA OF CALCAREOUS ADHERENT FORAMINIFERA

The literature on the Jurassic microfaunas of Britain contains references to the following seven genera of calcareous adherent Foraminifera: *Bullopora* Quenstedt, *Calcitornella* Cushman and Waters, *Carixia* Macfadyen, *Nubecularia* Defrance, *Nubeculinella* Cushman, *Vitriwebbina* Chapman, and *Webbina* d'Orbigny. Many well-known species, for example, *Nubecularia triloculina* Ten Dam and *Nubeculinella bigoti* Cushman, have been recorded under several generic names owing to the general lack of agreement about generic characters. Much of this confusion exists because the diagnostic characters of *Bullopora*, *Nubecularia*, and *Nubeculinella* have never been clearly stated. A comparison of the diagnoses of these genera as given by the original authors and by subsequent compilers of textbooks (Galloway 1933, Glaessner 1945, Cushman 1948, Sigal 1952, and Pokorny 1957) has shown that the following questions have to be answered before their true systematic position can be established:

1. Are the test walls of *Bullopora* and *Nubecularia* perforate or imperforate?
2. Does the test of *Bullopora* possess an initial coil, and, if so, what type of coil occurs?
3. Is the presence or absence of a ventral wall of any classificatory significance, and, if so, at what taxonomic level?

Further questions concerning the shape of individual chambers and the arrangement of the later chambers also arise, but are of importance at specific rather than generic level.

The genera are discussed here in the chronological order of their erection, the questions posed above being answered as they arise.

Genus WEBBINA d'Orbigny 1839

Type species. Webbina rugosa d'Orbigny.

Discussion. The wall structure is not mentioned by d'Orbigny except for a statement that the exterior is rugose. Loeblich and Tappan (1955) state that they examined the holotype and found it to have a fimbriate keel and phialine lip, to be milky white in appearance and apparently imperforate. Their figures (1955, pl. 4, figs. 6, and 6*a*) show that it has no initial coil.

As Barnard (1958, p. 116) has already said, extensive use of thin sections is usually necessary before the type of wall structure in calcareous adherent Foraminifera can be ascertained. The external appearance of a test is sometimes misleading since vitreous tests may appear milky white (and thus porcellaneous) when poorly preserved or when

infilled with sediment. Loeblich and Tappan were not, of course, able to section the holotype so that its external appearance remains undiagnostic. Most of the records of *Webbina* from the Jurassic are of specimens with vitreous perforate tests and no initial coil, or of porcellaneous imperforate tests with an initial coil. The remainder are misdeterminations of arenaceous adherent Foraminifera and can therefore be disregarded. No specimens with phialine lips have ever been reported. The only species recorded is *Webbina irregularis* d'Orbigny and, as shown below, all previous records of this (except for those of misdetermined arenaceous forms) can be distributed between *Bullopora* and *Nubeculinella*.

A search for topotype specimens of *W. rugosa* in dredged material from off the Canary Isles has been unsuccessful. Should future work establish that the test of this species is in fact perforate, it might then be regarded as a senior synonym of *Bullopora*. However, until such specimens are found it would seem desirable to use this name with caution for Recent specimens, and not at all for Jurassic forms.

Genus NUBECULARIA Defrance 1825

Type species. Nubecularia lucifuga Defrance 1825.

Discussion. Little has hitherto been known about the true nature of this genus. The original description is poor and the figures of the type specimens are obscure. Unfortunately, the types were lost when the University of Caen was destroyed in 1944 and topotype specimens have not been described. *Nubecularia lucifuga* has been reported many times since 1825, from Mesozoic, Tertiary, and Recent sediments. The best description was that of Carpenter (1862), but this, like most of the others, was based on Recent forms.

Material. Through the good offices of Dr. J. Roger the writer has been able to obtain a sample from the type locality of Hauteville, Dept. de la Manche; material has also been available from the neighbouring locality of Frésville. These samples yielded specimens which corresponded well with Defrance's original description and figures, inadequate though these were.

Emended diagnosis. Test calcareous, imperforate, porcellaneous; attached during life; consisting of a proloculus followed by a second tubular chamber, then a series of chambers usually initially arranged in a tight coil but later becoming irregular; chambers separated by necks and not by true septa. Aperture simple, single, or multiple.

Remarks. Nubecularia differs from *Nubeculinella* Cushman in that it is fundamentally a closely, if irregularly, coiled form. *Nubeculinella* possesses only a small planispiral initial coil and thereafter is completely uncoiled.

Nubecularia lucifuga Defrance

Plate 21, figs. 1–6

Material. Twenty specimens (seventeen thin sections); preservation good.

Locality. Hauteville and Frésville; Middle Eocene.

Description. The test is calcareous, opaque, porcellaneous, imperforate, and whitish in colour. In thin section, the wall appears structureless and brown. Initially, there is a

tendency for the coiling to be planispiral, but this does not persist and in the adult it is extremely irregular. No uncoiled specimens have been observed by the writer, but Defrance (1825, figs. 3*c*, *d*) illustrated two individuals having four or five rectilinear chambers. It has not been possible to determine the total number of chambers present in this author's specimens owing to the complicated growth pattern commonly developed in the later stages, but there are usually more than ten. Nearly all the sectioned specimens were found to be coiled round small foreign objects, for example, echinoid spines and fragments of polyzoans; the remainder were probably attached to seaweeds. The presence of one flattened surface on specimens found loose in washed residues is taken as presumptive evidence for attachment during life. It is these somewhat flattened forms that show most clearly an initial planispiral coil of from one to three whorls. A basal wall is present in all the attached forms and its absence in some of the free forms is most probably due to abrasion after death. The chambers are generally inflated proximally and taper distally: they may be separated by distinct necks or by minor constrictions of the wall. Septa have not been observed. The principal aperture is terminal and simple but supplementary apertures may sometimes be present (Plate 21, fig. 2).

Dimensions. The author's specimens range from 0·6–2·0 mm. in diameter but it is possible that some individuals are larger than this. (Externally, many individuals are so shapeless that they are not definitely recognizable as foraminifera until they have been sectioned.)

Remarks. This species differs from the Jurassic species *N. triloculina* Ten Dam in its larger size and much greater irregularity of growth, especially in the adult stage. The initial coil of the Jurassic species is much more regular, almost planispiral, and is usually visible on the under surface. The range of *N. lucifuga sensu stricto* is unknown but it can now be stated that all records of it from the Jurassic of Britain are incorrect (see synonymies below). The author has refrained from selecting a neotype for this species as he feels that it should be done by someone with more knowledge of the morphological variation exhibited by the species in the type locality.

Nubecularia lucifuga is certainly one of the most abused names in the whole of the foraminiferal literature. A cursory examination of the specimens referred to this species, and deposited in this museum by workers over the last fifty years, has sufficed to show that they include many quite unrelated forms. Perforate and imperforate, septate and non-septate specimens have all been embraced by this name. It is quite clear that a detailed

EXPLANATION OF PLATE 21

Figs. 1–4. *Nubecularia lucifuga*; ×30. Topotypes from the Middle Eocene of Hauteville. 2, Several apertures seem to be visible. 3, The spicule to which the specimen is adherent can be clearly seen. 4, Shows the flattened under-surface. 1*a*–4*a*, Thin sections of the above specimens; ×30. 2*a*, 4*a*, The 'spicules' to which the specimens are attached are clearly seen; a basal wall is present wherever the chambers are in contact with the 'spicule'. 3*a*, Shows the wall structure very clearly; P44642–5.

Figs. 5, 6. *Nubecularia lucifuga* Defrance; ×30. Thin sections of topotypes from the Middle Eocene of Hauteville. 5, The proloculus and tubular second chamber are visible; P44646. 6, The wall structure is exceptionally clear; P44647.

Figs. 7–11. *Nubecularia triloculina* Ten Dam. 7, Upper surface, P44648. 8, Lower surface, P44649. Both from the Upper Lias Risby Warren, north Lincolnshire; ×100. 9, Upper surface of lectotype, ×95; P44635 (see also Plate 23, figs. 2, 3). 10, 11, Thin sections showing porcellaneous wall structure and mode of growth; ×205. Specimens from the Upper Lias, Risby Warren, north Lincolnshire; P44652–3.

study of this genus together with all allied and isomorphic foraminifera of Tertiary and Recent age, will eventually be necessary. Such a study is beyond the scope of the present work.

Genus BULLOPORA Quenstedt 1856

Type species. Bullopora rostrata Quenstedt 1857 (by subsequent monotypy).

Date of erection of the genus and type species. Many authors have accepted 1856 as the year of publication of the genus *Bullopora* Quenstedt, but a few, including Sherborn (1888*b* and 1893) and Ellis and Messina (*Catalogue of Foraminifera* 1940 et seq.), have quoted it as 1858. The authors favouring 1858 have assumed that the date given on the title-page of the bound volume of *Der Jura* was that of the entire work, whereas it was, in fact, published in five parts between the years 1856 and 1858; the dates of publication of the parts are given as footnotes on the appropriate pages. The correct dates of publication are quoted fully in the *Catalogue of the Books, Manuscripts, Maps and Drawings* in the British Museum, Natural History (1913), and are as follows:

Quenstedt, A. F. 1856–58. *Der Jura*, Tübingen.
Part 1, pp. 1–208, pls. 1–24, April 1856.
Part 2, pp. 209–368, pls. 25–49, September 1856.
Part 3, pp. 369–576, pls. 50–72, December 1856.
Part 4, pp. 577–824, pls. 73–100, May 1857.
Titles, indexes, &c., pp. 825–842, 1858.

It follows that as the first description of *Bullopora* appears on p. 292 (mentioned again p. 554) the genus dates from 1856. The species *B. rostrata* Quenstedt is not mentioned until p. 580 (figured on pl. 73); it therefore dates from 1857.

Discussion. Quenstedt's original description was responsible for much of the subsequent confusion, later authors being divided on two fundamental points: (*a*) the structure of the wall, (*b*) the presence or absence of an initial coil. Barnard (1958) did a great deal to clarify the systematic position of this genus but unfortunately he examined neither type nor topotype specimens. His statement (1950, p. 378) that the wall is constructed of fibrous calcite was not supported by figures, but he has kindly made material available so that illustrations can be given here. There is an inconsistency in his descriptions of the morphology of the juvenile stages of *Bullopora rostrata.* In describing (1948) *B. rostrata* Quenstedt and *B. globulata* Barnard from the Lower Lias, he gave the impression that both species have tests formed of a linear series of chambers; no mention was made of a coil and none was figured. However, in his description of *B. rostrata* from the Oxford Clay (1952, p. 349) he states that 'The initial end consists of a hemispherical proloculum followed by a rather thick tube of about one turn'. This presumably indicates a coil. However, the two figured specimens (1952, B8) show no such tube; in one the proloculus is subspherical but has a short neck, and in the other it abuts directly against the second chamber. Macfadyen (1941) has also stated that *B. rostrata* has an initial coil, and this was accepted by Glaessner (1945), on Macfadyen's authority, as a diagnostic feature of the genus. However, a re-examination of Macfadyen's material has shown that all his determinable specimens are referable to *Nubeculinella bigoti.* As Barnard (1958) has already pointed out, most of the specimens Macfadyen described were from the Oxford Clay.

In his original description of *B. rostrata*, Quenstedt does not mention an initial coil nor does his figure show one. But the accuracy of his figure (1857, pl. 73, fig. 28) is suspect since chambers 4–7 appear to be reversed; they begin with a narrow neck and expand distally, a most unusual mode of growth if correctly depicted. Nothing is said regarding the nature of the test wall except for statements earlier (pp. 292, 554) that it is light or white in colour. This is suggestive, but nothing more, of a porcellaneous form. Later authors did not examine Quenstedt's material and his specimens were eventually lost. Over 100 years elapsed before topotype material was examined and a neotype selected (Seibold and Seibold 1960). Through the kindness of Dr. I. Seibold the writer was able to examine a topotype specimen and to compare it directly with Upper Jurassic specimens from Britain. The agreement was excellent. Externally, the test could be seen to be vitreous, and although it was not possible to section the German specimen, sections of the British specimens showed that the wall had a radiate fibrous structure. It has not yet been possible to decide whether the fibrous structure, seen under low and medium magnifications of the microscope, is produced by fibres of calcite with their axes normal to the surface of the test or by the presence of large numbers of minute canals likewise aligned perpendicularly to the surface. The topotype specimen began with a subspherical proloculus followed by nine aludel-shaped chambers, each of which terminated in a distinct neck: the tapering of the chambers was much more rapid in the juvenile stage than in the adult. The neotype (1960, pl. 7, fig. 14) is similar but apparently lacks the proloculus. Neither the German specimens nor the British ones show any sign of an initial coil, and it may therefore be asserted that no such coil exists. In the light of this information, the following diagnosis of the genus *Bullopora* is proposed.

Emended diagnosis. Test adherent, consisting of a linear or curvilinear series of chambers which are variable in shape but commonly subglobular or pyriform. Proloculus separate from, or partially embraced by, the second chamber. There is no initial coil. Wall calcareous, vitreous in appearance when well preserved, probably perforate; in thin section showing its radiate fibrous structure.

Affinities of the genus. Bullopora has previously been assigned to at least three different families, the most recent suggestion being that of Barnard (1958) who advanced cogent arguments for placing it in the Lagenidae. It may, however, still be argued that *Bullopora* should be placed in the family Polymorphinidae as Cushman (1948) did when he assumed it to be an aberrant polymorphinid that had lost the typical spiral arrangement of its chambers and adopted an adherent mode of life. But against this must be set the fact that *Bullopora* and the earliest-known member of the Polymorphinidae, *Eoguttulina*, occur together in the Lower Lias; however, Oberhauser (1960) has recently shown that *Eoguttulina* cf. *liassica* ranges down into the Trias of Switzerland. Wall structure apart, *Bullopora* and *Eoguttulina* bear little resemblance to one another and it is hard to believe that the first off-shoot of the latter was such an unusual form. On the other hand, in Lower Lias times the lagenids were already well established and were showing considerable morphological variation. An 'aberrant' attached form thus occasions no surprise. Moreover, as Barnard (1949, 1958) has shown, certain undoubted lagenids (referred in 1957 to the new genus and species *Tentifrons barnardi* by Loeblich and Tappan) adopted an adherent mode of life in the late Cretaceous.

Avinmelech and Reiss (1954) having relied in good faith on earlier, but erroneous,

accounts for the diagnostic characters of *Bullopora*, wrongly attributed their new species (*B. negevensis*) to this genus. Their proposed classification of the imperforate calcareous adherent Foraminifera is undermined by such statements as (p. 838) 'the homoeomorphic perforated *Webbina* and *Vitriwebbina* &c. are entirely different from *Bullopora* and taxonomically distinct'.

Genus VITRIWEBBINA Chapman 1892

Type species. Vitriwebbina sollasi Chapman 1892.

Vitriwebbina was erected to include species from the Lower Cretaceous (Cambridge Greensand and Gault) described by Sollas 1877 and Chapman 1892 respectively. Both authors state that the shell wall is finely tubulated and the former gives figures of *W. tuberculata* Sollas showing vertical canals; his figures of *W. laevis* Sollas were unfortunately rather poor, the tests only being shown in outline. This led Chapman to misinterpret Sollas's description when he discovered, as he thought, two groups of smooth calcareous adherent Foraminifera in the Gault. He referred the specimens in one of these groups to *V. laevis* (Sollas) and the others to a new species, *V. sollasi*. The latter was described as having a pitted surface and an external flange. The two specimens assigned to *V. laevis* possessed neither of these characters. Later authors accepted Chapman's description of *V. laevis* (Sollas) as this seemed better than the original. However, Sollas's material has recently been located in the University Geological Museum, Oxford, and on comparing this with the original figures of *W. laevis* and with Chapman's Gault specimens, it is immediately obvious that the first description was inadequate. (This is not really surprising since Sollas's intention was only to differentiate between *W. laevis* and *W. tuberculata*.) It so happens that some of the specimens described as *W. laevis* by Sollas are in no way different from those Chapman described as *V. sollasi*. Most specimens have an external basal flange round each chamber and all have a thin basal wall. According to Chapman, a primary feature for distinguishing between these two species is the pitting of the surface which occurs in *V. sollasi* (the surface of *V. laevis* is said to be smooth). A re-examination of the types has revealed that Chapman mistook a mosaic recrystallization pattern in the sediment infilling the chambers, for pitting of the wall. Empty chambers appear vitreous, and infilled chambers opaque when viewed by reflected light. Pseudo-pitting shows up quite well in Barnard's illustration of one of Chapman's specimens (Barnard 1958, pl. 24, fig. 2). It is therefore concluded that *V. sollasi* Chapman is a junior subjective synonym of *V. laevis* (Sollas).

Cushman (1940) placed *Vitriwebbina* in synonymy with *Bullopora* Quenstedt but did not give his reasons. Barnard (1958) followed Cushman in regarding *Vitriwebbina* as a junior synonym of *Bullopora*, but then removed *Bullopora* from the family Polymorphinidae and placed it in the family Lagenidae. However, Chapman (1896) stated explicitly that *Vitriwebbina* had a polymorphine initial end, a feature which, if present, would certainly exclude it from the Lagenidae. It follows, therefore, either that *Vitriwebbina* and *Bullopora* are not synonymous, or, if they are, that *Vitriwebbina* does not have an initial polymorphine stage. The present author, after examining all the available material, has concluded that Chapman was incorrect in postulating a polymorphine juvenile stage for *Vitriwebbina*. Most specimens consist of a simple linear or curvilinear series of chambers, but a few show the proloculus completely embraced by the second

chamber, a condition that produces a superficial polymorphine appearance. Typical specimens of this type in the B.M. (N.H.) collections are P5247 (Chapman 1896, pl. 12, fig. 12) and P4922 (Vine collection). It may be noted that the syntypes of *V. sollasi* do not show this feature. As Barnard (1958, p. 121) has already pointed out, complete or partial embracement of the proloculus by the second chamber is a common feature amongst Jurassic lagenids. The view that *Vitriwebbina* is a junior synonym of *Bullopora* may therefore be accepted.

Genus CALCITORNELLA Cushman and Waters 1928

Type species. Calcitornella elongata Cushman and Waters 1928.

Discussion. Barnard (1950) has described some Upper Lias Foraminifera under the name *Calcitornella woodi* Barnard.

According to the original description of this genus the test consists of a proloculus followed by a second tubular chamber. This second chamber is clearly depicted in the figure of the type specimen (Cushman and Waters, pl. 6, fig. 5). Barnard's specimens are all multi-chambered, the proloculus being followed by a large number of aludel-shaped chambers (Barnard 1950, pl. 1, figs. 3 and 4 and text-fig. 1). This is a fundamental difference and precludes their assignment to *Calcitornella*. Their true systematic position is discussed below. It may be noted that all other records of *Calcitornella* are from rocks of Palaeozoic age.

Genus NUBECULINELLA Cushman 1930

Type species. Nubeculinella bigoti Cushman, 1930.

Cushman's description requires only slight emendation in the light of more recent observations. The initial coil, instead of consisting of a single chamber wound round the proloculus, consists of at least two tubular chambers and may also include a small number of aludel-shaped chambers. The whole coil may thus comprise up to $2\frac{1}{2}$ whorls (text-fig. 1, F and G; Plate 22, figs. 6, 7). In addition, it seems that while most species consist of individuals that are invariably attached throughout life, a few may include some free-living forms. Cushman recognized that the wall of the test is imperforate but since he provided no figures to support this, a thin section is reproduced here (Plate 22, fig. 5).

Sigal (1952) regarded *Nubeculinella* as a junior synonym of *Bullopora*, but as *Nubeculinella* has an imperforate porcellaneous wall and *Bullopora* a vitreous radiate wall, these genera are clearly distinct.

Genus CARIXIA Macfadyen 1941

Type species. Carixia langi Macfadyen, 1941.

This genus is easily recognized by its unusual form. In his diagnosis Macfadyen states, 'An adherent reticulation of unsegmented, imperforate, calcareous tubes set in a calcareous cement'. It resembles no other known Jurassic genus and is unlikely to be confused with any of those described above. For further information the reader is referred to Macfadyen's original description to which nothing can be added here. There are no other published records of the genus in Britain.

REVIEW OF BRITISH SPECIES

Family LAGENIDAE

Genus BULLOPORA Quenstedt

Bullopora rostrata Quenstedt 1857

Plate 24, fig. 4

1857 *Bullopora rostrata* Quenstedt, p. 580, pl. 73, fig. 28.
1867 *Webbina irregularis* d'Orbigny; Brady, p. 105, pl. 1, figs. 2, 3.
non 1891 *Webbina irregularis* d'Orbigny; Crick and Sherborn, p. 11, pl. 2, figs. 1, 2.
non 1941 *Bullopora rostrata* Quenstedt; Macfadyen, p. 25, pl. 1, figs. 13–17.
1948 *Bullopora* cf. *rostrata* Quenstedt; Barnard, p. 377, fig. 1d.
1950 *Bullopora rostrata* Quenstedt; Barnard, p. 31.
1952 *Bullopora rostrata* Quenstedt; Barnard, p. 348, fig. B8.
1958 *Bullopora* cf. *rostrata* Quenstedt; Barnard, pl. 24, fig. 4.
1960 *Bullopora rostrata* Quenstedt; Seibold, E. and Seibold, I., p. 372, pl. 7, fig. 14.

Description. The test is adherent, calcareous, vitreous, perforate, and consists of up to ten chambers arranged in a linear series. In thin section the wall is seen to have a radiate fibrous structure. All chambers except the first are aludel shaped, and each tapers to form a thin neck which connects with the proximal bulbous portion of the subsequent chamber. The aperture is terminal and simple. The proloculus may be subspherical or elongate, and may or may not possess a neck.

Remarks. Barnard (1948) recorded *B.* cf. *rostrata* Quenstedt from the Lower Lias of Dorset, and subsequently (1950) from the Upper Lias of Northamptonshire. The present author has examined Barnard's Lower Lias specimens and considers that although they are not so highly developed as the Upper Jurassic forms they are nevertheless more like typical *B. rostrata* than they are like *B. globulata* Barnard, the only other known Lower Jurassic representative of the genus. Both specimens (P39936, P39963) have well-developed necks on each chamber; the former is very large, over 5 mm. long.

Occurrence. Lower Lias to Kimmeridgian (also recorded from the Cretaceous); apparently uncommon until Upper Lias times.

Bullopora rostrata Quenstedt var. *irregularis* var. nov.

Plate 24, figs. 7, 8, 10, 13

Description. The test is adherent, calcareous, vitreous, perforate, and consists of up to seven chambers. The early chambers are like those of *B. rostrata* but the later ones become larger, more irregular in shape and resemble those of *Ramulina.* The later chambers are sometimes tuberculate; necks may be present or absent. No branching, such as occurs in *Ramulina*, has been observed. An irregular basal flange formed by finger-like calcareous processes from the wall is often present.

Occurrence. Oxford Clay and Kimmeridge Clay.

Material. Sixteen specimens; none complete.

Remarks. This variety is probably the precursor of *Ramulina* Jones, a genus so far not recorded from rocks older than the Cretaceous in Britain.

Bullopora globulata Barnard

1948 *Bullopora globulata* Barnard, p. 378, fig. 1*e*.
1950 *Bullopora globulata* Barnard, p. 32.

Occurrence. Lower to Upper Lias; the only British records are those quoted above.

Bullopora globulata Barnard var. *minima* var. nov.

Plate 24, figs. 1–3, 5, 6

1958 *Bullopora globulata* Barnard; Barnard pl. 24, fig. 5.

Description. The test usually consists of from three to eight—occasionally up to twelve—inflated chambers arranged in a linear or curvilinear series. The chambers range up to 0·30 mm. in maximum diameter but are usually much narrower: they abut closely against one another and are almost invariably adherent to lamellibranch shells. In some cases there is a suggestion of a neck separating the chambers, but this is rare. The proloculus is subcircular in outline and is inflated. In other respects this variant resembles *B. globulata s.s.*

Remarks. This variant is much smaller than typical members of the species. Barnard's (1949, 1950) figured specimens of *B. globulata* are all fairly large, being 3 mm. or more long at the seventh chamber, individual chambers being up to 0·6 mm. in diameter and up to 0·8 mm. long. A typical specimen of this new variety is 1·48 mm. long at the eighth chamber and has chambers not exceeding 0·17 mm. in maximum diameter. No gradation in size to typical *B. globulata* has been observed.

Material. Forty specimens from Ashley Down, Gloucester, and Barnstone, Notts.

Occurrence. Lower Lias (Ashley Down, Gloucester: H. B. Brady collection; Barnstone, Notts.: author's collection; Lyme Regis, Dorset: Barnard's personal collection).

Bullopora laevis (Sollas)

Plate 23, figs. 6–8; plate 24, figs. 9, 11

1877 *Webbina laevis Sollas*, p. 103, pl. 6, figs. 1–3.
1892 *Vitriwebbina sollasi* Chapman, p. 53, pl. 2, figs. 1–3.
1896 *Vitriwebbina laevis* (Sollas); Chapman, p. 332, fig. 3.
1896 *Vitriwebbina sollasi* Chapman, p. 586, pl. 13, fig. 1.
?1896 *Vitriwebbina laevis* (Sollas); Chapman, p. 585, pl. 12, fig. 12.
1958 *Bullopora sollasi* (Chapman); Barnard, pl. 24, fig. 2.

Description. The test is adherent, calcareous, perforate, and consists of numerous inflated, subglobular chambers the last few of which may be rather irregular in outline. The wall is radiate in structure. The proloculus is globular or elongate and is usually followed by three to five, occasionally up to eleven, chambers which normally increase gradually in size and meander irregularly over the surface of attachment. There is no

initial coil. Each chamber has a thin basal wall and usually a narrow external flange. The chambers generally abut closely one against the other, distinct necks being rare.

Lectotype. The specimen deposited in the Oxford University Geological Museum (register no. K750) and illustrated by Sollas (1877, pl. 6, fig. 1) is hereby designated lectotype of *Webbina laevis*. It consists of a subglobular proloculus and four inflated, rather elongate, chambers: these are empty and, therefore, vitreous in appearance. The test is bordered by a narrow flange. No aperture is visible.

Dimensions of the lectotype. Diameter of the proloculus: 0·17 mm.; diameter of the third chamber: 0·3 × 0·45 mm.; diameter of the fifth chamber: 0·33 × 0·60 mm.

Remarks. This species is not fundamentally different from the Jurassic *B. globulata* Barnard, but it tends to have fewer and larger chambers and in some cases to adopt a more irregular mode of growth. The early Jurassic representatives of *B. globulata* and the early Cretaceous forms of *B. laevis* are clearly distinct, the former having five or more chambers, the latter usually five or less. The largest specimen known to the author is in the Vine collection (P. 4921): it has twelve chambers most of which have short necks.

As explained earlier *Vitriwebbina sollasi* Chapman is a junior synonym of *B. laevis* (Sollas).

The other British Cretaceous species, *B. tuberculata* (Sollas) (Plate 24, figs. 12, 14, 15), has not been reported from the Jurassic but tubercles do occur on *B. rostrata* var. *irregularis*. It may be noted that the basal wall of *B. tuberculata* is fairly thick (Plate 24, fig. 12) whilst that of *B. laevis* is invariably thin (Plate 23, fig. 7; plate 24, fig. 11).

Occurrence. Cretaceous; common in the Gault and Cambridge Greensand.

General remarks on the species of Bullopora

It is impossible to give definitions of the various species of *Bullopora* that are at the same time concise, unambiguous, and all-embracing. Barnard (1958) recognized this and used letters to distinguish some of the forms which he illustrated. His figure D (1958, text-fig. 2), for example, is intermediate between *B. globulata* and *B. rostrata*. This text-figure is slightly misleading in that it suggests straight evolution from *B. globulata* to *B. rostrata* during the Lias, the latter species not appearing until Upper Lias times. But, as stated earlier, Barnard (1948, fig. 1*d*) has himself recorded *B.* cf. *rostrata* from the Lower Lias of Dorset where it occurs alongside *B. globulata*. In addition, a specimen referable to *B. globulata* var. *minima* (P44679 Lr. Lias, Tolcis, Devon) is known in which the four distal chambers (there are nine in all) are identical in shape with those of typical *B. rostrata*. It is nevertheless true to say that the common species in the Lower Lias is *B. globulata*, and that in strata of Upper Lias to Kimmeridge age it is *B. rostrata* that appears most frequently.

Barnard (1958, p. 123) has hinted that *B. laevis* (Sollas) is synonymous with *B. globulata* Barnard; if this is so, then on taxonomic grounds it is the latter name that should be allowed to lapse. However, although the writer agrees with Barnard that the Cretaceous *B. laevis* is an evolved form of *B. globulata*, the fact remains that there are distinct differences between the early Cretaceous and early Jurassic forms. It is, therefore, useful to retain the two names, at least for the time being, and to regard the base of the Cretaceous as a convenient, if arbitrary, dividing line between the two.

Family OPHTHALMIDIIDAE

Genus CARIXIA Macfadyen

Carixia langi Macfadyen

1941 *Carixia langi* Macfadyen, p. 28, pl. 1, figs. 18–20.
?1958 *Carixia langi* Macfadyen; Drexler, p. 491.

Remarks. Since Macfadyen's discovery of this species no further records of it have been published in this country. Drexler (1958) has recorded it from the Lias α of Siebeldingen/Pfalz. However, she did not figure her specimens and reported merely that the tubes were imperforate, calcareous, and unsegmented. She quoted the tube diameter as ranging from 0·08 to 0·10 mm., her smallest specimens thus having almost three times the tube diameter of Macfadyen's largest (0·03 mm.). Macfadyen tentatively assigned this species to the family Ophthalmidiidae. Drexler assigned hers to the Silicinidae but without giving any reason.

The present author has re-examined Macfadyen's material but can add little to the original description. Macfadyen stated that the tubes were imperforate but relied on their external appearance as evidence for this. He also said (p. 29) that 'the tubes appear glassy'. Since a glassy or vitreous appearance usually characterizes perforate rather than imperforate tests a few specimens have recently been sectioned. Viewed by transmitted light the wall of the sectioned specimens appears pale brown and seems to be structureless. This supports Macfadyen's belief that it is imperforate. It should, however, be noted that good sections of such minute specimens are very difficult to obtain. Further sections will therefore be desirable when new material becomes available. For the time being, *Carixia* should be retained in the Ophthalmidiidae.

Genus NUBECULARIA Defrance

Nubecularia triloculina Ten Dam

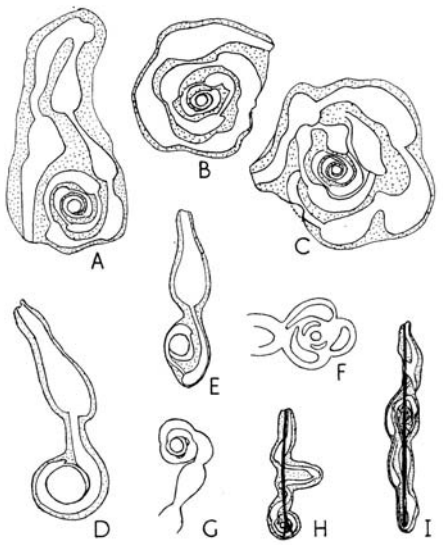
Plate 21, figs. 7–11; text-figs. 1 A–C

1860 *Nubecularia lucifuga* Defrance; Jones and Parker, p. 455, pl. 20, figs. 52–56.
1950 *Nubecularia triloculina* Ten Dam, p. 19 (not pl. 1, fig. 22).
1950 *Calcitornella woodi* Barnard, p. 6, figs. 1*a*, *b*, pl. 1, figs. 3, 4.

Description. Test calcareous, imperforate, porcellaneous; usually found free but during life adherent to foreign objects: composed of a spherical or subspherical proloculus and a second chamber of about one turn, followed by a series of aludel-shaped chambers initially coiled in a fairly tight planispire. Later chambers often adopt a more irregular, meandrine mode of growth and may cross the earlier whorls. Complete uncoiling in the adult stage is rare. There may be up to sixteen chambers in all, irregular growth beginning at any time after the seventh. The number of chambers per whorl in the juvenile stage ranges from two to four, there normally being an increase as growth proceeds. The chamber pattern is not normally visible on the upper surface but can usually be distinguished on the under side which is only covered by a very thin basal wall. In many specimens this wall is lost owing to post-depositional abrasion. There are no septa. The tests range up to about 0·4 mm. in diameter. Chamber shape varies considerably but the proximal

end is usually bulbous, the walls then tapering to form a narrow tube distally. Aperture terminal, simple.

Remarks. Jones and Parker (1860) first recorded this species under the name *Nubecularia lucifuga* Defrance. Later, Ten Dam (1950) proposed a new name, *N. triloculina*, for Jones and Parker's specimens when describing rather similar Foraminifera from the Albian



TEXT-FIG. 1. Line drawings showing internal structure of specimens immersed in a clarifying medium (clove oil). Chamber walls dotted. A–C, *Nubecularia triloculina* Ten Dam, ×89. Lower surfaces showing the shape of the chambers and the variation in coiling. In C the eleventh chamber is obscured as it lies on the upper surface of the test. All specimens from the Upper Lias, Risby Warren, north Lincolnshire; P44661–3. D, *Nubeculinella bigoti* Cushman, ×85. Juvenile stage of a detached specimen; note the short narrow second chamber and the long third chamber (see also Plate 23, fig. 1). Middle Oxford Clay, Woodham Brick Pit, nr. Aylesbury, Buckinghamshire; P44655. E, *Nubeculinella tibia* (Jones and Parker), ×85. Lectotype, P41672 (see also Plate 23, figs. 4 and 5). F, G, *Nubeculinella bigoti* Cushman, ×88. Initial ends of the specimens illustrated on Plate 22, figs. 7 and 6; F is infilled with pyrite which obscures the finer detail of the coil. H, I, *Nubeculinella tibia* (Jones and Parker) var. *bacularis* (Issler), ×50 (see also Plate 23, figs. 17, 19). Upper Lias, Risby Warren, north Lincolnshire.

of the Pays-Bas. Unfortunately, instead of examining the original specimens, he relied on Jones and Parker's figures and on their inadequate description. He was thus misled into believing that the British specimens were the same as those he had obtained from the Lower Cretaceous of the Netherlands. Barnard (1950) erected a new name, *Calcitornella woodi*, for specimens from the Upper Lias of Byfield, and placed Jones and Parker's specimens in synonymy with this new species. (For the reasons given above, the Lias specimens are here assigned to *Nubecularia* instead of to *Calcitornella*.) It is unfortunate that Ten Dam's taxon should have priority over Barnard's since the latter had the better description. However, Barnard's paper was not published until 28 December whilst

Ten Dam's appeared prior to 22 December, the day it was received in the library of the British Museum (Natural History). The name '*triloculina*' is misleading since the presence of three chambers per whorl in the adult stage is not a constant character of this species.

Ten Dam based his species on the five figured specimens of Jones and Parker which, therefore, became syntypes. The present author hereby selects one of these specimens (Jones and Parker 1860, pl. 20, fig. 54; now registered as P44635) as the lectotype of *Nubecularia triloculina* Ten Dam (Plate 21, fig. 9).

It may be noted that Ten Dam sought to show on the evidence of this one species that Jones and Parker's material (originally believed to have come from the Trias of Chellaston, Derbyshire) was in fact Lower Cretaceous in age. In this he was mistaken. Not only did Jones (1895, p. 161) admit that the sample must have come from the Lias, but all British workers who have made special studies of Liassic Foraminifera (Crick and Sherborn 1891, Macfadyen 1941, Barnard 1948 et seq., Adams 1957) are agreed that the 'Chellaston' sample is of Lias age. It contains a typical Upper Lias foraminiferal assemblage for eastern England and could not possibly have come from any other system. The slides containing Jones and Parker's foraminifera are preserved in the British Museum (Natural History) and are labelled by Jones, from the 'Lias of Leicestershire'. For further details concerning the origin of this material see Macfadyen (1941, p. 8).

Nubecularia triloculina Ten Dam differs from *N. mazoriensis* Bielecka and Pozoryski (1954), from the Upper Malm of Poland, in having fewer chambers, only one aperture, and in being less regularly coiled.

Occurrence. Upper Lias.

Genus NUBECULINELLA Cushman

Nubeculinella bigoti Cushman

Plate 22, figs. 1–7; text-fig. 1D, G, F

1888 *Webbina irregularis* d'Orbigny; Sherborn, p. 332.
1930 *Nubeculinella bigoti* Cushman, p. 134, pl. 4, figs. 3–4.
1941 *Bullopora rostrata* Quenstedt; Macfadyen, p. 25, pl. 1, figs. 14–16, ?fig. 13, not fig. 17.
1953 *Nubeculinella bigoti* Cushman; Barnard, p. 193, fig. B1.
1958 *Nubeculinella bigoti* Cushman; Barnard, pl. 23, fig. 1.

EXPLANATION OF PLATE 22

Figs. 1–7. *Nubeculinella bigoti* Cushman. 1, Felted mass of specimens on a *Gryphaea* shell, ×2. Oxford Clay, Weymouth, Dorset; P4100, Jesson collection (see also fig. 3). These specimens were described and figured as *Webbina irregularis* by C. D. Sherborn in 1888. 2, Scattered specimens on a *Gryphaea* shell, ×3. Oxford Clay, St. Ives, Huntingdonshire; P4864. 3, Part of fig. 1; ×27. The drum-like chambers and the initial coil comprising several chambers are clearly visible; P4100. 4, Part of fig. 2; ×25. Note the more pyriform chambers and simpler initial coil than in fig. 3; P4864. 5, Oblique thin section through two chambers of a specimen from the Middle Oxford Clay, Woodham Brick Company's Pit, nr. Aylesbury, Buckinghamshire; ×170. The thin basal wall is just visible and the porcellaneous nature of the entire wall is quite clear; P44654. 6, 7, Specimens attached to the same *Gryphaea* shell (P43360); Both ×26. Initial coils comprising more than four chambers are visible. The chambers are relatively poorly defined in fig. 6; in shape they are intermediate between those seen in figs. 3 and 4. For details of the juvenile stages see text-figs. 1, F and G. Middle Oxford Clay, Woodham Brick Company's Pit, nr. Aylesbury, Buckinghamshire.

Description. The test is calcareous, imperforate, and porcellaneous. It comprises an initial coil of from two to seven chambers and an uncoiled linear portion of seven to nineteen chambers. The subspherical proloculus is followed by a narrow tube-like chamber $\frac{1}{3}$–$\frac{1}{2}$ a turn in length which is only visible when the test is freed from its surface of attachment and examined in a clarifying medium. The third chamber is larger, being 1–$1\frac{1}{4}$ turns in length. The terminal portion of this chamber may bend away from the proloculus (text-fig. 1D) or may continue the coil. In the latter case it is succeeded by at least three aludel-shaped chambers which complete the second whorl. The uncoiled portion may be fairly straight or highly irregular. A basal wall is present but is always fairly thin.

Variation. In his original description of this species Cushman (1930) described the chambers as 'elliptiques en contour mais devenant irrégulières'. He figured one specimen (1930, fig. 2) with chambers of indefinite shape and another (1930, fig. 3) with more regular chambers separated by constrictions of the wall.

A study of numerous specimens from the Oxford Clay has revealed that the chamber shape is highly variable. Sometimes the chambers are drum-like (Plate 22, fig. 3), abutting closely against one another and therefore without necks, at others they are aludel-shaped (Plate 22, fig. 4), each chamber then terminating in a distinct neck. There is gradation between these two types (Plate 22, figs. 6, 7). In extreme cases the chambers become so elongate or irregular that they appear almost shapeless. In general, specimens attached to the same shell fragment tend to be more or less of the same shape. Specimens sometimes occur in such profusion on *Gryphaea* shells that they form felted masses on the surface (Plate 22, fig. 1).

Remarks. Sherborn (1888*a*) recorded *Webbina irregularis* (d'Orbigny) from the Oxford Clay of Weymouth. His specimens (Plate 22, figs. 1, 3) were attached to the larger valve of a *Gryphaea* and are now preserved in the British Museum (Natural History) (P4100). Sherborn states (p. 333) that 'the specimens of this finely arenaceous foraminifera do not call for any special notice'. He figured about a dozen specimens which, although irregular in their mode of growth, are shown as linear series of chambers without initial coils. Examination of the original material has shown that the specimens are not arenaceous, and that when complete they do possess initial coils. The chambers tend mainly to be drum-like rather than aludel-shaped (Plate 22, fig. 3) but a certain amount of gradation occurs.

Occurrence. ?Lower Lias, Upper Lias to Kimmeridgian. Very common in the Middle Jurassic and Oxford Clay. Specimens from the Kimmeridge Clay are in the Mockler collection, British Museum (Natural History). A few specimens possibly referable to this species are known from the Lower Lias (Barnard collection P39965 and Macfadyen collection P34893).

Nubeculinella bigoti var. *filiformis* Paalzow

1931 *Nubeculinella filiformis* Paalzow, pp. 5, 7, pl. 1, fig. 5.
1932 *Nubeculinella filiformis* Paalzow; Paalzow, p. 97, pl. 5, fig. 3.
1958 *Nubeculinella filiformis* Paalzow; Barnard, pl. 23, fig. 3.

Remarks. N. filiformis Paalzow has never been described from Britain although Barnard (1958) has figured one specimen from the Upper Lias. There appears to be no important

difference between *N. bigoti* and *N. filiformis*, the distinction being purely one of chamber shape and length, the former having more conspicuous constrictions between the chambers than the latter; *N. filiformis* is here, therefore, accorded only varietal rank.

Occurrence. Upper Lias.

Nubeculinella tibia (Jones and Parker)

Plate 23, figs. 4, 5, 10–13; text-fig. 1E

1860 *Nubecularia lucifuga* Defrance var. *tibia* Jones and Parker, p. 455, pl. 20, figs. 49–51 only.

Description. The test is usually found free. It is composed of a relatively small number of chambers (about six) which are initially closely but irregularly coiled, and which later become uncoiled and rectilinear or irregular. The proloculus is subglobular and is followed by a second chamber which may make up to one complete turn. All subsequent chambers are widest proximally and taper distally to form narrow elongate tubes. The surface of the test appears smooth, only the outline of the last two or three chambers being visible externally. The initial coil can only be seen clearly after immersion in a clarifying medium. Wall opaque, porcellaneous, imperforate. Aperture terminal, simple, round or oval.

Remarks. Relatively few specimens have the coil preserved, the majority comprising only the last few chambers.

Of the four specimens figured by Jones and Parker, one (fig. 48) is pustulose and should be referred to *N. tibia* var. *bulbifera* (Paalzow). A few years ago Dr. A. R. Loeblich selected one of the syntypes (P41672) for designation as lectotype of *N. tibia*, but his work was never published. The present writer therefore chooses the same specimen (P41672),

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EXPLANATION OF PLATE 23

Fig. 1. *Nubeculinella bigoti* Cushman, ×100. Photograph of specimen immersed in clove oil. Middle Oxford Clay, Woodham Brick Company's Pit, nr. Aylesbury, Buckinghamshire; P44655 (see also text-fig. 1 D).

Figs. 2, 3. *Nubecularia triloculina* Ten Dam. 2, Under surface of lectotype (retouched); ×95. 3, Pencil drawing of the specimen as seen in a clarifying medium. P44635; for upper surface see plate 21, fig. 9.

Figs. 4, 5. *Nubeculinella tibia* (Jones and Parker). Lectotype; ×100. 4, External view. 5, The same specimen in a clarifying medium. P41672; for further details of the initial coil see text-fig. 1, E. Lias, 'Chellaston, Derby'.

Figs. 6–8. *Bullopora laevis* (Sollas). 6, Lectotype; ×26 [= *Webbina laevis* Sollas 1877, pl. vi, fig. 1]. Oxford University Museum, K750; Cambridge Greensand. 7, Paratype, showing the fibrous wall structure and the thin basal wall, ×100. 8, Part of the wall, ×200. Oxford University Museum, K749; Cambridge Greensand.

Fig. 9. *Nubeculinella tibia* (Jones and Parker) var. *bulbifera* (Paalzow); ×100. Upper Lias, Risby Warren, north Lincolnshire.

Figs. 10–13. *Nubeculinella tibia* (Jones and Parker); ×100. Upper Lias, Risby Warren, north Lincolnshire; P44657–60.

Figs. 14, 17–19. *Nubeculinella tibia* (Jones and Parker) var. *bacularis* (Issler); ×100. Upper Lias, Risby Warren, north Lincolnshire. 14, Free-growing end chambers broken off a larger specimen; P44664. 17–19, P44666–8. The spicule to which the specimen is attached is visible in fig. 19. For details of inner structure see text-fig. 1, H, I.

Figs. 15, 16. *Incertae sedis*, ×100. Upper Lias, Risby Warren, north Lincolnshire; P44665.

and hereby designates it lectotype of *Nubeculinella tibia* (Jones and Parker). It is a smooth form which shows the initial coil (Plate 23, figs. 7, 8; text-fig. 1E).

In some recent German literature there are references to this species under the name *Nodobacularia tibia*, Cushman (1917) having designated *N. tibia* as the type species of *Nodobacularia* Rhumbler. He later (1940) placed *Nodobacularia* in synonymy with *Bullopora*, but this was an error, since *N. tibia* (Jones and Parker) has a wall structure which is entirely different from that of *Bullopora*. Macfadyen (1939) had previously erected a new genus, *Nodophthalmidium*, to include recent free-living species previously assigned to *Nodobacularia* as he considered the types of *N. tibia* to be broken end chambers of *Bullopora rostrata*.

N. tibia may either have been attached to seaweeds during life or enjoyed a free existence on the sea floor. Some specimens show no sign of the flattening of one surface (the under side) which usually characterizes attached forms. However, the fact that a few individuals were probably free-living should not be allowed to obscure the close morphological similarity between the species as a whole and those discussed above. The use of a separate generic title, such as *Nodobacularia*, for the unattached forms of the Jurassic is to be deprecated. It should be noted that the lectotype shows the flattening typical of attached forms on the under side of the terminal chamber.

Occurrence. ?Lower Lias, Upper Lias. A single attached specimen possibly referable to this species is known from the Lower Lias (Barnard collection P39965).

Nubeculinella tibia (Jones and Parker) var. *bacularis* (Issler)

Plate 23, figs. 14, 17–19; text-figs. 1H, I

1909 *Ophthalmidium bacularis* Issler, p. 44, pl. 1, fig. 25.

Description. The test is attached to a spicule. It comprises a subspherical proloculus, followed by a second tube-like chamber $\frac{1}{2}$–1 turn in length, and a series of elongate aludel-shaped chambers which leave the coil and meander over the surface of attachment.

Remarks. Issler (1909) stated that the stem (spicule) was formed of the same material as the test itself and could not be a sponge spicule. His specimen, which is now preserved in this museum (P21106), has been re-examined and found to be an attached form. However, mere attachment to a spicule, with its consequent reflection in the shape of the test, cannot constitute an adequate basis for the erection of a new species. This author regards all such specimens as variants of *N. tibia*, a species with which they are invariably associated.

Occurrence. Upper Lias. Fairly common in north Lincolnshire.

Nubeculinella tibia (Jones and Parker) var. *bulbifera* (Paalzow)

Plate 23, fig. 9

1860 *Nubecularia lucifuga* Defrance var. *tibia* Jones and Parker, p. 455, pl. 20, fig. 48 only.
cf. 1891 *Nubecularia nodulosa* Chapman, p. 573, pl. 9, fig. 2.
1932 *Nodobacularia bulbifera* Paalzow, p. 96, pl. 5, figs. 4–6.

Description. The test consists of two or three chambers forming a rectilinear series. The proximal end of each chamber is swollen and covered by pustulose outgrowths of the

wall. From the swollen region there extends a tubular neck which is quite smooth and which connects with the thickened end of the subsequent chamber. The under surface is slightly flattened and is not always completely closed by the ventral wall, a longitudinal slit being sometimes visible. Aperture terminal, simple. Wall calcareous, porcellaneous, imperforate.

Remarks. The tests of this foraminifer have almost invariably been found in a broken condition, the initial part (presumably a coil) never having been seen. So far as can be ascertained, this variant differs from *N. tibia sensu stricto* only in the pustulose swellings on the proximal portion of the chambers, a feature which may have been produced as an aid to fixation. It is possible that a pustulate and non-pustulate condition might exist in the same test, the proximal chambers being non-pustulate, the distal ones pustulate. This would account for the apparent absence of the initial stages in the samples so far examined.

N. tibia var. *bulbifera* seems to differ only in size from *Nubecularia nodulosa* Chapman of the Gault. Otherwise they are so similar that they must surely be closely related. In this connexion, it is worth noting that the initial stage of *N. nodulosa* has likewise never been described. Similar, though somewhat larger tests also occur in the Oxford Clay where they are found in association with *Nubeculinella bigoti*, to which species they are probably related.

Occurrence. Upper Lias, ?Oxford Clay, ?Lower Cretaceous.

Nubeculinella sp.

1937 *Nubeculinella infraoolithica* (Terquem); Bartenstein and Brand, p. 181, pl. 6, fig. 38*a–c*; pl. 8, fig. 35*a–f*; pl. 14B, fig. 18*a–b*; pl. 14*c*, fig. 15; pl. 15*c*, figs. 5*a–d*.
1941 *Bullopora rostrata* Quenstedt; Macfadyen, p. 25, pl. 1, fig. 16 only.

Description. The test is imperforate, calcareous, porcellaneous, and composed of

EXPLANATION OF PLATE 24

Figs. 1–3, 5, 6. *Bullopora globulata* Barnard var. *minima* var. nov. 1, 2, Lower Lias, Ashley Down, Gloucester. 1, ×25, P44669. 2, ×26, P44670. 3, ×25, P44671; Lower Lias, Barnstone, Notts. 5, 6, Thin sections showing fibrous wall structure. 5, P44673, relatively poorly preserved; Lower Lias, Ashley Down, Gloucester; ×65. 6, P44678; Lower Lias, Tolcis, nr. Axminster, Devon; ×143.

Fig. 4. *Bullopora rostrata* Quenstedt, ×25. Upper Oxford Clay, Oxford; P44672.

Figs. 7, 8, 10, 13. *Bullopora rostrata* Quenstedt var. *irregularis* var. nov. Tubercles can be seen on figs. 8 and 13: the irregular shape of the later chambers is illustrated by figs. 7 and 10. The basal wall can be seen in the broken terminal chamber of fig. 10 and in the first chamber of fig. 8. Finger-like calcareous processes forming the flange are visible in fig. 8. 7, P11803, ×24. 8, P11864, ×24. 10, P11798, ×22. 13, P11857, ×24. All from the Kimmeridge Clay of Rid's Hill, Brill, Buckinghamshire.

Figs. 9, 11. *Bullopora laevis* (Sollas). 9, Chambers infilled and therefore opaque; narrow flange present; P44674 [ex. P4447, G. R. Vine collection, = *Vitriwebbina sollasi* Chapman, Vine], ×24. 11, Thin section of the same specimen; the basal wall scarcely visible, ×65. Cambridge Greensand.

Fig. 12, 14, 15. *Bullopora tuberculata* (Sollas); Cambridge Greensand. 12, Section showing the radiate wall structure, the flange, and the basal wall; ×65. Unfortunately this section only passed through the edge of one tubercle which can just be seen on the right-hand side. P44675 (ex. P4447, G. R. Vine collection). 14, 15, Only the terminal chamber in fig. 15 is conspicuously tuberculate. Both specimens are flanged but this is not very clear in the photographs. 14, P44676 (ex. P28271 H. B. Brady collection), ×25. 15, P44677 (ex. P 4447, G. R. Vine collection), ×24.

numerous aludel-shaped chambers. It is invariably found attached to echinoid spines or shell fragments. Growth is very irregular. The later chambers tend to be much larger than any observed in the foregoing species. An initial coil is present but it has not proved feasible to study it in detail. It is possible that this is really a very large form of *N. bigoti*.

Remarks. Seibold and Seibold (1960) placed *B. rostrata* Quenstedt of Macfadyen (1941) in synonymy with *Nubecularia tibia* Jones and Parker, but a direct comparison of the original specimens described by these authors has revealed that they are quite different. The Seibolds' specimens are most like Macfadyen's, which are themselves best placed with *Nubeculinella*. It is possible that there is gradation between *Nubeculinella sp.* and *N. tibia* var. *bacularis*, but insufficient material is available to verify this. *Nubeculinella sp.* seems to be distinguished from all the others by its large size and inflated, elongate chambers.

Occurrence. Bathonian to Oxfordian.

Remarks on the species of Nubeculinella

The presence or absence of a wall on the under surface appears to be a feature of no taxonomic significance. Although almost always present, it is invariably so thin in the attached forms that it can very easily be destroyed. Attached specimens that have subsequently become loose are often found to be incomplete ventrally. This simply reflects the thinness and consequent weakness of the lower wall. The use of the generic title *Nodobacularia* is only justifiable if it can be shown that a population comprising forms morphologically indistinguishable from *N. tibia*, but all free living, has existed. Jones and Parker stated definitely that their specimens of *N. tibia* were attached during life.

Incertae sedis

Plate 23, figs. 15, 16

1941 *Bullopora rostrata* Quenstedt, Macfadyen, p. 25, pl. 1, figs. 17*a–c*.

Remarks. The initial part of the test is always missing; the remainder consists of two or three elongate, aludel-shaped chambers. Wall imperforate, porcellaneous: aperture terminal, simple.

Broken specimens of this type occur commonly in the Jurassic. They are often, perhaps always, associated with species of *Ophthalmidium* and/or *Nubeculinella*. In view of their wall structure they cannot represent the end chambers of any species of *Bullopora* and it is probable that they constitute a heterogeneous assemblage of terminal chambers belonging to various species of *Ophthalmidium* and *Nubeculinella*.

Occurrence. Lower Lias to Kimmeridgian.

CONCLUSIONS

Four genera of calcareous adherent Foraminifera occur in the British Jurassic. They are represented by seven species and five varieties. *Bullopora* and *Nubeculinella* occur throughout the Jurassic but *Nubecularia* has not so far been recorded below the Upper Lias.

Bullopora has a radiate fibrous wall but no initial coil. This author follows Barnard

(1958) in assigning it to the Lagenidae. *Nubecularia* and *Nubeculinella* both have imperforate porcellaneous walls and initial coils but differ in their modes of growth; they are nevertheless closely related, and are retained in the family Ophthalmidiidae together with *Carixia*. The differences between them are such that intermediate forms may yet be found. The attached forms of all species possess ventral walls, but these are usually thin and can easily be lost if the specimens become detached. None of the species described in this paper possesses septa. Chamber shape is highly variable and depends to some extent on the limitations imposed by the nature and size of the objects to which the specimens are adherent; it cannot be used satisfactorily as a feature in morphological diagnosis. It is theoretically possible for a specimen of *Nubecularia triloculina*, attached, for example, to an echinoid spine, to grow in such a manner as to be virtually indistinguishable from *Nubecularia tibia* var. *bacularis*. Similarly, it might prove impossible to differentiate between *Nubeculinella* and *Bullopora* (except by means of thin sections) if the initial ends of the tests were obscured by irregularly growing later chambers, as often happens when specimens are attached to spicules. Indeed, such is the variation amongst these species that no one should expect to be able to identify every specimen accurately. Only well-preserved, fully grown individuals that have had sufficient space to develop properly, and which do not have their juvenile stages obscured, are readily determinable.

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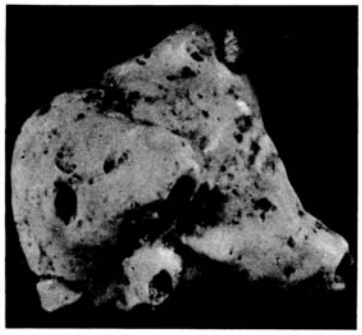

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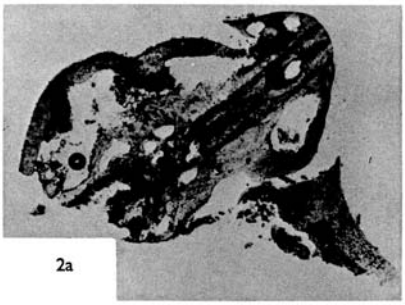

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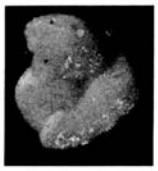

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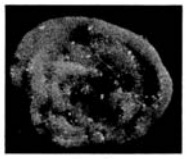

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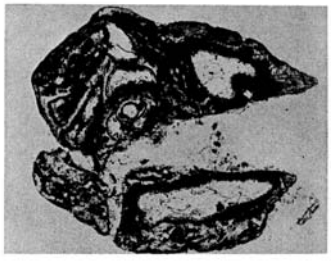

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ADAMS, Calcareous adherent foraminifera

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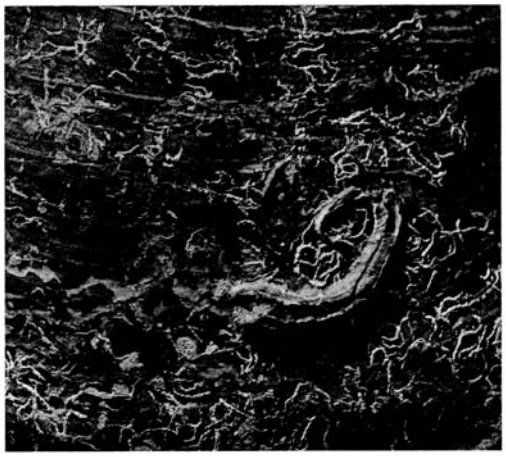

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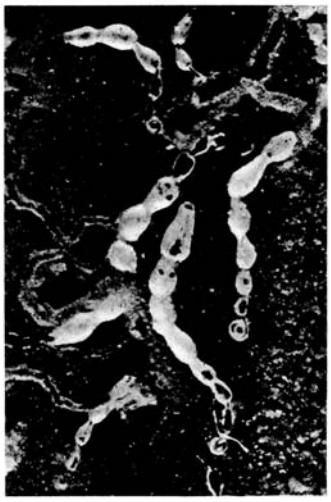

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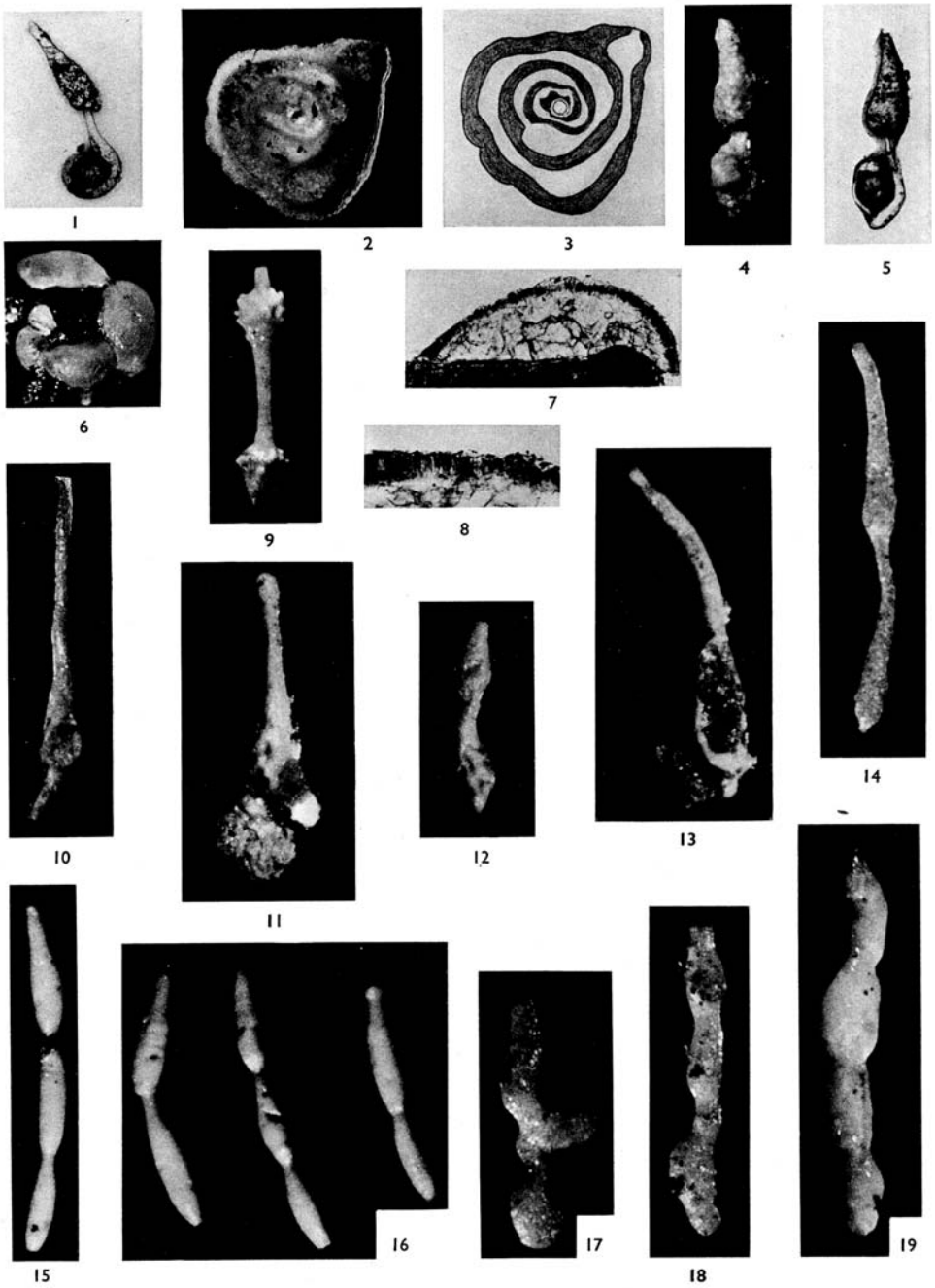

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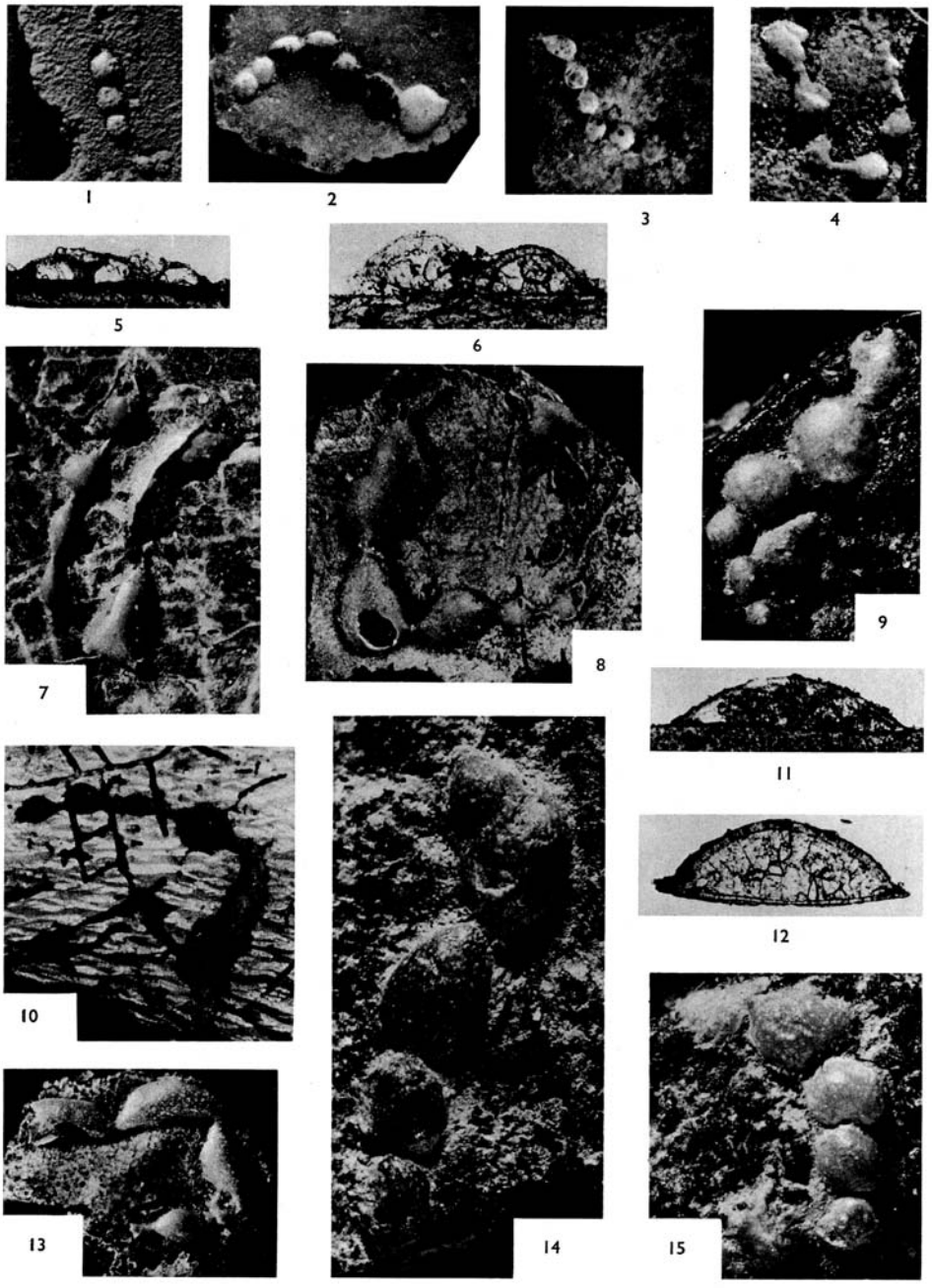

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