A MONOGRAPH

OF

CARBONIFEROUS AND PERMIAN

FORAMINIFERA

(THE GENUS FUSULINA EXCEPTED).

BY

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§ 1. INTRODUCTION.

A FEW words of preface seem necessary by way of commentary on the title,—at any rate an author may claim an opportunity at the very outset to explain the origin of his work, to state its aim and limitations, and to acknowledge, in part at least, the services of those who have helped him in its preparation.

The geographical extent of the geological formations, one minor phase of whose history the present memoir is intended to illustrate, forbids the idea of exhaustive treatment; but whatever approach to completeness it may possess, even within the present range of ascertained facts, is due to assistance proffered with no ordinary kindness from many different quarters.

In the year 1869 I was asked by my friend Mr. Charles Moore, F.G.S., of Bath, to determine for him a number of Foraminifera, which he had met with in "pockets" in the Mountain Limestone, during his researches on mineral veins. This was practically the origin of the present Monograph. I was at that time engaged upon the Liassic Foraminifera, and had little knowledge of those of earlier geological age beyond what was to be gained from transparent sections of Carboniferous Limestone rocks; and, in the absence of published observations, sufficiently detailed and accurate to serve as a key to the collection, Mr. Moore's specimens were studied rather from the standpoint furnished by a limited number of Liassic forms than on a fitting independent basis. The provisional determinations so made have naturally required much revision, as the relations of the fauna of the period to which they refer have come to be better known. The zoological

interest of the unstudied palæozoic types eventually induced me to lay aside the work I had been engaged upon, and to devote my scanty leisure to their elucidation, under the impression that the total number of species was very small, and that I should soon be able to revert to my former task—an idea by no means verified by experience.

Whilst Mr. Moore was pursuing his researches chiefly in the lead-mining districts of England, Mr. John Young, F.G.S., of Glasgow, had been forming a collection of the minuter fossils from the Scottish coal-fields, and on learning that I was occupied upon a portion of the subject, with characteristic kindness placed his gatherings of Foraminifera at my disposal.

Subsequently my friend Mr. W. W. Stoddart, F.G.S., of Bristol, proffered me the use of his fine collection of microscopical sections of limestone rocks, and rendered further valuable aid by procuring for me supplies of material from various localities in the neighbourhood of Clifton. To the more recent friendly offices of Mr. R. Etheridge, junr., F.G.S., and other officials of the Geological Survey of Scotland, I am indebted for the opportunity of working out the fossil Rhizopoda of a very considerable portion of the North-British Carboniferous area.

With the name of Mr. John Young it is natural to associate that of his assiduous colleague Mr. David Robertson, F.G.S., the results of whose microscopical researches, always most freely communicated, have served to fill many a blank in the Distribution Tables. Nor must I omit from this general acknowledgment my thanks, more particularly expressed on a later page, to Mr. G. A. Lebour, F.G.S., late of the Geological Survey of England and Wales, for his assistance in the more strictly geological portion of my work.

There are many others to whom I am under obligation scarcely less considerable than those who have been mentioned, either for supplies of rough material from places to which I have had no access, or for the loan of specimens. In a subsequent section (that headed "Geological and Geographical"), wherein each locality is separately named, opportunity is taken to acknowledge such contributions individually, and I trust that no omissions may have occurred through chance inadvertence.

It is to the hearty co-operation of so many scientific men who have had, from one cause or other, peculiar facilities for observation and for the collection of material in particular fields, that the present Monograph owes any claim it may have to be regarded as representative in respect to England and Scotland, and in so far as the term can be applied to a very meagre instalment, to Ireland also.

To the active interest of my friend M. Ernest Vanden Broeck, of Brussels, in all that concerns recent and fossil Protozoa, I owe the chance that I have enjoyed of examining some of the Carboniferous shales of Belgium, especially from the neighbourhood of Namur and Liége, and the results have so important a bearing upon the aspects of the Rhizopod-fauna of our own rocks that the original intention to restrict the scope of the synopsis to British fossils has been necessarily abandoned.

To the courtesy and kindness of General G. von Helmersen, of St. Petersburg, I am indebted for the means of studying the minute fossils of the white Carboniferous limestones of the neighbourhood of Moscow and elsewhere in Russia, the Foraminifera of which formed the subject of the researches of Fischer von Waldheim, Rouillier and Vosinsky, Ehrenberg, and d'Eichwald; and Dr. Herrman Abich, of Tiflis, in Georgia, has placed me under the like obligation for rock-specimens of similar age from the Caucasus.

To Dr. F. B. Meek, of Washington, Dr. C. A. White, late State-Geologist of Iowa, Professor H. L. Smith, of Geneva, New York, and Dr. S. B. Buckley, State-Geologist of Texas, I am beholden for similar attentions in respect to the Carboniferous strata of the United States.

With so large an accumulation of material, the question arose whether the whole subject of the Carboniferous Foraminifera might not be treated in a single paper, and, having gone through the minuter forms, my attention was naturally turned to the important group, not represented at all in our British fossiliferous rocks, constituting the genus *Fusulina*. I found, however, before I had proceeded far in this direction, that my friend Dr. Guido Stache, of Vienna, was already at work upon the genus in its geological relations; and it became evident that the zoological and structural details which had been in part worked out might with advantage be withheld for the moment, and the history of this generic type, in its extensive and varied aspects, reserved for a separate paper at some future time.

The intimate natural relationship which subsists between the limited Rhizopod-fauna of the Permian formations and the more extensive one of the Carboniferous epoch has necessitated their collateral study; and as this has resulted in some additions to the knowledge of the former group, and considerable revision of its nomenclature, the history of the two is presented, as it has been worked out, in one series. To the friendly co-operation of Dr. R. Richter, of Saalfeld, in a variety of ways, any completeness which the portions referring to the Thuringian Zechstein may possess is due.

Thus it has come about that what was originally projected as a Monograph of British Carboniferous Foraminifera only, has become the more comprehensive treatise, geographically and geologically, indicated by its present title.

One word more to finish personal matters. In the authorship of many previous papers, Professor W. K. Parker, F.R.S., and Professor T. Rupert Jones, F.R.S., have been my colleagues. Whilst my attention has been occupied with these investigations they have been engaged in other departments of science. None the less have I had the advantage of discussing with them questions of difficulty as they have arisen, and if their names do not appear very frequently in the following pages, it is only because I prefer to make this more general acknowledgment. After all, the present work is little more than a continuation of research on the lines which they laid down originally, and which we have so long followed in company; and their general approval of the conclusions it embodies is perhaps its best letter of introduction.

§ 2. GENERAL CONSIDERATIONS.

That the Mountain Limestone rocks, which constitute so striking a geological feature in the scenery of many parts of Great Britain, consist largely of chambered shells and other microscopic organisms, which, until a few years ago, were spoken of collectively under the indefinite term "Infusoria," is a belief that has probably existed ever since men first wondered at the "fossil animalcules" in Chalk; yet up to the present time nothing has been written concerning the Rhizopoda of the Carboniferous age that has any claim to be regarded as a history of the group. Perhaps, it is hardly too much to say that the relation of the Foraminifera to the calcareous rocks of the Carboniferous period has been assumed rather than studied; and, as is commonly the case, views which have gained currency under such circumstances are but partially substantiated by actual observation. Take them as a whole, the Carboniferous Limestone beds of Great Britain cannot be regarded as a microzoic formation in quite the sense in which the term is rightly applied to many Cretaceous rocks: indeed, as a rule, they owe their origin, so far as their organic constituents are concerned, much more to animals of higher organization and larger individual dimensions, such as Crinoids and Corals, than to Microzoa. As is well known, there are many important deposits of Secondary and Tertiary age formed almost exclusively of the remains of Foraminifera, such as, for example, the White Chalk of the South-east of England, the Nummulitic Limestones of Central Europe, the Leythakalk of the Vienna Basin, and the Miliolite limestones of Hampshire and elsewhere; and a similar condition exists also in certain massive deposits of Carboniferous age, to wit, the white limestones of Russia, Central Asia, and North America; but in the Carboniferous rocks of our own country no portion of the vast series of beds known in common parlance as "Mountain Limestone" has any claim to be placed in the same category, except it be the comparatively inconsiderable section in which the very simple form known as *Saccammina* is found.

At first sight some of the microscopical sections of Carboniferous rocks represented in the final plate of the present paper might lead to a different conclusion, but it must be remembered that the specimens from which these figures were taken were selected for the very reason that they contained unusual numbers of Foraminifera in a limited space—the object being to illustrate the various aspects of the Foraminifera themselves, *in situ*, rather than the general structure and composition of the rocks. It is very rarely indeed that such a nest of minute forms as that shown in fig. 2 is to be found; far more frequently the field of an inch or an inch-and-a-half object-glass reveals but two or three

specimens; and very often sections even of the most promising limestones do not show a single rhizopod test when submitted to microscopic examination.

So far from owing its origin, like the true Chalk, chiefly to Foraminifera; or indeed, to go further, so far from being a deposit formed *directly* and exclusively by the agency of animals secreting carbonate of lime, there are considerable areas of Carboniferous Limestone in which the sea appears to have deposited its excess of mineral constituents in accordance with chemical and physical laws, without the intervention to any great extent of animal life. This has been brought about by a process of precipitation and the subsequent coalescence of the impalpable particles of amorphous precipitate into minute spheroids, the result being a concretional or oolitic limestone (often fossiliferous at the same time), such as may be met with in formations of Devonian and Silurian as well as of Carboniferous age. The constituent spheroids of such rocks have generally a radiate structure, and in sections show one or more concentric rings; the centre is often occupied by a foreign body, such as a minute crystal, the fragment of a coral, or even a foraminifer, though more commonly there is no observable nucleus. The section represented in Plate XII, fig. 3, though showing a number of spheroidal concretions, is scarcely characteristic; it would require a much larger space and a lower magnifying power to give quite a correct idea of the general structure. The oolitic grains are normally nearly spherical, but they also assume ovoid, elongate, or quite irregular forms, such shapes resulting either from the partial coalescence of two or more spheroids, the distinct origin and structure of which are easily traced up to a certain stage in the process of coalescence, or else from the irregular outline of the foreign body upon which the precipitated carbonate of lime has begun to arrange itself, the accumulation not having gone on long enough to produce a complete sphere. There need be no difficulty in the acceptance of a physical explanation of this sort, even by those who hold most firmly the theory that all limestones have primarily an organic origin. It has repeatedly been urged that, to account for the azoic condition of the deep-sea bed, in areas where evidence of animal life might have been expected, it was necessary to remember the solvent power of water charged with carbonic acid;—that, especially under pressure, water so charged must dissolve the calcareous skeletons of organisms subjected to its action. Of this fact there can be no doubt: what does not appear to have been sufficiently taken account of is the converse, viz. that the solution so formed is a very unstable one, and that, on the diminution of pressure, the elevation of temperature, or other alteration of physical conditions, the carbonate of lime, so taken up, is as rapidly precipitated, the form in which it presents itself on precipitation being precisely the one most favorable to the process of spherical coalescence.[1]

[1] It is, perhaps, needless to refer particularly to Mr. Rainey's elaborate researches on spherical coalescence, as his papers are already well known, and they relate chiefly to the process as carried on in the animal economy. The manufacture of carbonate of magnesia on the large scale from magnesian limestone offers an excellent illustration of the solution of earthy carbonates in water charged with carbonic acid, their precipitation by increase in temperature, and the subsequent coalescence of the precipitated particles.

We need go no further than the magnesian limestone of the Permian system[1] to find deposits in which this phenomenon is exhibited in an exaggerated degree; but instead of a compact rock composed chiefly of spheroids of minute, but comparatively uniform size, the constituent masses vary in magnitude from a microscopic smallness to balls many ounces or even pounds in weight, and form a loose "pebbly" bed. Whence the carbonate of lime has been derived, in the case of the oolitic Carboniferous rocks, previous to its solution and precipitation, it is impossible to say, possibly from the calcareous skeletons of animals; all that it is sought to establish is, that the proximate origin of these particular beds has been dependent in great measure on physical agencies. That the process of precipitation was cotemporaneous with the actual life of marine animals there can be no doubt, from the frequent presence, amongst the spheroids, of perfect, delicate shells, such as would be the first to yield to the power of any active solvent, and the same fact also forbids the idea that the spheroidal structure may have been the result of physical changes at a later period of the earth's history.

The minute structure of the Carboniferous and Permian rocks only affects the subject incidentally; but it seemed necessary at the outset to state the great difference which exists between the calcareous beds of the Carboniferous period, as represented in our Mountain Limestones, and those of Cretaceous age represented by the White Chalk. In point of fact, the marine Carboniferous deposits of these islands seem to bear far more analogy to the preceding palæozoic formations—to the Devonian especially, with its multitude of Corals and Crinoids, and its scanty evidence of the minuter Protozoa, than to the microzoic rocks of a later epoch.

The lithological characters of the massive palæozoic limestones are the cause of the chief difficulties the palæontologist has to contend with. They are almost invariably hard and generally subcrystalline. They are often largely impregnated with silica, thereby possessing an uneven texture, which renders uniform grinding, whether for the purpose of microscopical sections or for the sake of obtaining a polished surface, almost impossible, and yet disintegration, under ordinary circumstances, cannot be effected by artificial means. When free from siliceous infiltration, it is not more difficult to cut thin slices from them than from other rocks of similar hardness; but the mere sections of Foraminifera so obtained are of little value, zoologically speaking, unless they can be identified by comparison with specimens in which the external characters are visible and readily determined, that is to say, specimens freed from the matrix.

But that which is so difficult to accomplish by artificial means is sometimes done for us on a large scale by natural agencies; that which chemical solvents, whether rapid or more gradual in their action, and physical processes, such as calcination, the efflorescence of crystallised salts, or treatment by superheated steam under high pressure, effect to only a limited extent when artificially applied, is brought about under favorable conditions by

[1] One of the beds at Fulwell Quarry, near Sunderland, for example.

slow meteorological influences, namely, by the gradual action of air, moisture, carbonic acid, alternations of temperature and the like, through long periods of time. So that in the absence of fossiliferous clays of marine origin, which in later geological formations are the most productive source of Foraminifera, recourse may be had to those particular portions of the limestone strata in which partial disintegration has been brought about by the means alluded to. Thus, the decomposed friable layer, which is often found overlying the hard rock, and between it and the superficial soil, may often be examined with advantage. The marly partings between the seams of limestone, weathered calcareous shales, or the thin earthy plates, such as are occasionally found interbedded with compacter rocks, yield similar valuable material. At best the sources of Foraminifera are very uncertain, and in the majority of cases, after much washing, drying and sifting, the result is nothing beyond a little grey heap consisting of the *débris* of Encrinites, Polyzoa, occasional molluscan Shells, and a few Entomostraca. Frequently, especially in the neighbourhood of ironstone deposits, the fossils, especially the minuter ones, are so corroded as to be identified with difficulty. But notwithstanding the large proportion of examinations that must be made with nothing but negative results, there is still a residuum sufficiently productive and interesting to reward the collector.

The method of the following pages has been determined by the conditions under which subject is approached. Clean specimens free from the matrix have been employed, as far as practicable, as the basis of description, both of external characters and internal structure; the principal, if not the only, exceptions being in the case by some two or three species accepted on the authority of other observers, in which there has been no available means of verification. In addition to the figures of external form, drawings of sections of individual Foraminifera have been as far as possible introduced with the object, primarily, of illustrating the structural features of each species, but also to facilitate their recognition as they present themselves in sections of hard limestones. With the exception of some half dozen figures of Permian specimens, which are in each case marked as "copied," the whole of the figures in the accompanying plates have been drawn direct from nature, and they represent actual specimens with all their imperfections, as they *are*, not what they *may* have been. They were for the most part originally drawn by myself, but practically they have been redrawn in their transfer to the stone by my friend Mr. A. T. Hollick. The fidelity of Mr. Hollick's work is now too well known to need commendation from me; and I have only to express my thanks to him for the care and pains which, in spite of considerable difficulties, have ensured results so satisfactory.

§ 3. ZOOLOGICAL CONSIDERATIONS.

The Rhizopod-fauna of the Carboniferous and Permian epochs is not without interest in some of its zoological phases. The relation of its various component types to each other will be better discussed when describing the individual genera, but the salient general features by which it may be compared with the corrresponding groups of other geological periods, the bearing of ascertained facts upon accepted theories of classification, and other kindred matters, form a subject for separate consideration.

Four distinct systems have been proposed at different times for the classification of the Foraminifera. That of D'Orbigny in 1826 had a purely artificial basis and has now fallen into disuse, whilst that of Professor Max Schultze, published in 1854, has never been extensively adopted. Neither of these need be dwelt upon.

The schemes of classification worked out independently by Professor Von Reuss in Vienna, and by Dr. Carpenter, Mr. W. K. Parker, and Professor T. Rupert Jones in this country, and published almost simultaneously (*i. e.* in 1861 and 1862), are alone in use at the present time,[1] and their essential features are practically identical, notwithstanding many differences in detail. Minute criticism would be out of place here, and is the less needed because amongst those who have worked much upon the subject there would be a pretty general agreement in the opinion that the English arrangement is laid down on broader lines,—that in it more importance is attached to the natural relationship of the series of forms traceable to a single type, and less to mere morphological variations;—whilst that of Professor Von Reuss, with its smaller groups and somewhat more artificial distinctions, has considerable advantages in the facilities it affords for the naming and arrangement of specimens. But the fact that concerns us at the moment is that in these two independent systems the basis of their primary divisions is the structure of the shelly investment or test.

In general terms Foraminifera are divided into the same two classes—those with non-porous or imperforate, and those with porous or perforate tests. The former of these two divisions ("Imperforata") is in both systems, subdivided into two sections, one including those types which have composite tests, that is, built up of sand-grains,

[1] Since the above was written Prof. T. Rupert Jones's paper on "Variability of Form in Foraminifera" has been published in the 'Monthly Microscopical Journal' (February 1st, 1876). It contains a list of genera arranged in smaller groups than the classification formerly proposed by the same author and his colleagues, though accepting the same general basis. It would be an injustice to express an opinion on so short an acquaintance, and the proposed scheme does not materially affect the arrangement of the Carboniferous species.

or similar extraneous bodies, more or less embedded in calcareous cement, the other having opaque, porcellanous shells, of fine texture.

In the division comprising the perforate or porous-shelled forms the agreement is less complete, as might be expected with the larger number of types to be accommodated and the greater diversity in their characters; but even in this the two classifications have very much in common.

Their general relationship will perhaps be best understood by a comparative table, such as the following:

Von Reuss, 1861.	Carpenter, Parker, and Jones, 1862.
A. Foraminifera with non-porous tests.	Sub-order—**Imperforata.**
	Family—Gromida.
A. With arenaceous tests.	Family—Lituolida.
1. *Lituolidea.*	
2. *Uvellidea.*	
B. With compact, porcellanous, calcareous shells.	Family—Miliolida.
1. *Squamulinidea.*	
2. *Miliolidea.*	
3. *Peneroplidea.*	
4. *Orbitulitidea.*	
B. Foraminifera with porous shells.	Sub-order—**Perforata.**
A. With glassy, finely porous, calcareous shells.	Family—Lagenida.
1. *Spirillinidea.*	
2. *Ovulitidea.*	
3. *Rhabdoidea.*	
4. *Cristellaridea.*	
5. *Polymorphinidea.*	
6. *Cryptostegia.*	
7. *Textilaridea.*	
8. *Cassidulinidea.*	

B. With exceedingly porous, calcareous shells. 1. *Rotalidea.*	Family—Globigerinida.
C. With calcareous shells, traversed by a ramified canal-system. 1. *Polystomellidea.* 2. *Nummulitidea.*	Family—Nummulinida.

Note.—Professor A. E. von Reuss's classification is taken from the "Postscript" to his paper 'Entwurf einer systematischen Zusammenstellung der Foraminiferen,' not from the body of the memoir. The primary division into "Foraminifera Monomera" and "Foraminifera Polymera," originally laid down, is abandoned in the postscript. His group *Gromidea*, corresponding with the Gromida of the English observers, is omitted entirely in the revised scheme. In the proximate correlation of the two classifications, given above, the principal discrepancy occurs in the sub-order **Perforata**. The Lagenida and Globigerinida together are almost exactly coextensive with Von Reuss's two sections **B**, *A* and *B*, but the (1) *Spirillinidea*, (2) *Ovulitidea*, (7) *Textilaridea*, and (8) *Cassidulinidea*, together with one or two genera from other groups, find place amongst the Globigerinida of the British classification, and the family Lagenida is correspondingly reduced in extent. The family Nummulinida corresponds exactly with Von Reuss's section **B**, *C*.

In his latest memoir ('Das Elbthalgebirge in Sachsen,' 2ter Theil, 1874) Professor Reuss again somewhat modified his classification, making three primary groups of equal zoological value, and reversing the order originally adopted, thus:—**A. Kalkschalige Foraminiferen, B. Porenlose Foraminiferen, C. Kieselschalige Foraminiferen**; but the general features of the classification are otherwise unchanged.

It will be seen at a glance that the "families" of the German arrangement are much smaller and more numerous than those adopted by the English naturalists, but this is counterbalanced by the more comprehensive "generic types" of the latter. The essential difference, not only between the two systems of classification, but in the entire methods of study and nomenclature, lies in the different values of their respective "genera" and "species." A purely artificial classification is ill adapted to the conditions presented by a class of organisms like the Foraminifera, largely made up of groups of which the modifications run in parallel lines. This "isomorphism," demonstrated chiefly by the labours of Messrs. Parker and Jones, whilst it is the source of most of the difficulties the systematist has to contend with, is at the same time the key to the natural history of the order as at present accepted. It exists not merely between a single series, in one of the larger divisions, and a single series in another, but often amongst several series even of the same family. It not unfrequently happens that a member of one group presents a greater similarity to its isomorph in another group with which it has no relationship, than it does to any other member of its own. Take a familiar illustration—suppose the fingers of the

two hands to represent the modifications ("species") of two such parallel types of Foraminifera, the thumb of one hand resembles more closely the thumb of the other hand than it does any other of the fingers on its own. In other words, the extreme member of one series bears greater similarity to its isomorph in the other series than it does to its own nearer relations, and so on through the remaining members of the respective groups. Under conditions like these, artificial subdivision based upon minor morphological characters is certain to infringe the order of nature, owing to its tendency in some cases to separate forms closely allied, and in others to place together such as have no natural affinity.

The disposition to variation in minor characters is another point that has not been sufficiently recognised, and an endless multiplication of "species," with almost hopeless confusion in nomenclature, is the result. Take, as an example, a series of forms belonging to the sub-order *Perforata*, say that of which the best central type is *Nodosarina* (*Marginulina*) *raphanus*. All the specimens referable to the type consist of a single row of segments joined end to end; the row may be straight, arcuate, coiled a little at the base (crozier-shaped), or helicoid; the individual segments may be rounded, cylindrical, somewhat compressed laterally, much flattened, or embracing; the general aperture may be central or excentric; the surface of the shell may be smooth or have an ornamentation of parallel ribs, spines, or tubercles; whatever the precise form of the investment, the *animal*, so far as we know, is the same—a single row of bead-like lobes of sarcode, with no power to build for itself other than a perfectly simple shelly covering. Between the extremes of character possible within the limits above laid down every conceivable intermediate condition has been found; and if the word "species" is anything more than a conventional term, the whole ought to constitute a single species; but governed by the exigencies of a partially artificial arrangement, the modifications embraced in this simple unbroken series constitute thirteen genera or almost two entire families in Professor Reuss's classification; and how many hundreds, if not thousands, of so-called "species" have been founded upon the trivial characters above enumerated it would need much patience to ascertain.

To revolutionise the present nomenclature of the Foraminifera is no part of the object of this essay; if that is ever attempted it must be from a broader standpoint than the Carboniferous Rhizopod-fauna affords. It is impossible to start *de novo*, and it is therefore only left for us to determine what course is open to the least objection under the conditions that at present exist. So far as "specific" names go, it is manifestly best to accept those that represent tolerably well-marked morphological characters, even when they are matters of *degree* and manifestly variable, but without attaching any true specific value to them. The advantages of a binomial nomenclature are universally admitted; but in the present state of natural history science it is impossible to express the details of zoological relationship thereby, and we must either use a trinomial or even quadrinomial method of designation, or be content with names whose uniformity does not

indicate that they represent assemblages of individuals of the same zoological distinctness collectively. Most of the generic terms which have come into general use have been applied to groups of Foraminifera more or less circumscribed, though often overlapping other similar groups in a way to render complete separation impossible; but to reject them entirely because they do not fulfil conditions that might properly now be exacted, would throw the whole nomenclature into confusion by necessitating the alteration of very many "specific" names. No harm is done by the employment of these quasi-generic terms so long as their significance is understood, though their acceptance is a compromise dictated by convenience. For similar reasons it seems best to avoid as far as possible the trinomial use of "varietal" names when the relationship of the subordinate forms has once been sufficiently indicated. But after making every allowance, and admitting the title of even slight modification of characters to recognition by a distinctive name, there are still enormous numbers of so-called "species" that are absolutely synonymous, and right of precedence once determined, the more completely the remainder are cleared away the better for scientific terminology.

It seems strange to have to insist on *zoological* characters as the only right foundation for species; but to judge by the sort of criticism which the results of the purely zoological treatment of fossil Foraminifera by my colleagues and myself in past years have called forth in some continental publications, one might suppose that it was an almost unheard-of proposition. The practice of re-naming organisms, zoologically identical, every time they present themselves at a fresh geological horizon is still largely adopted, on the ground that in the absence of any evidence of continuity a new creation must be assumed, and that a new specific name becomes a necessary consequence, conclusions alike untenable. It would be just as reasonable to found such an argument on geographical as on geological conditions. Widely different geological age may be admitted to have some weight in doubtful cases, but only as an addition to zoological evidence, not in contradiction to it.

These preliminary observations lead to questions more directly affecting the Carboniferous and Permian fauna; and in reviewing its general aspect and relations we shall find it convenient to take the larger groups of the English classification *seriatim*, and pretty much in the order in which they appear in the foregoing table. In following this course, however, I must guard against the supposition that this, or indeed any classification as yet proposed, accords quite satisfactorily with the existing state of our knowledge, though it may answer our present purpose as well as a more elaborate scheme.

Commencing with the *Imperforata*:—the family *Gromida* may be dismissed in a word, without even questioning its right to the position it occupies, inasmuch as no fossil Rhizopoda with chitinous tests have hitherto been recorded, and the very nature of their investment renders their discovery improbable. The *Miliolida* may be passed over almost in like manner, for no porcellanous forms have been met with in deposits

of Carboniferous or Permian age, the earliest known representatives of the family being the *Nubeculariæ* of the Triassic and the *Spiroloculinæ* of the Lower Liassic clays. But the entire absence of these two families is counterbalanced by the comparatively large representation of the second on the list, and some of the most noteworthy facts elicited in the course of these investigations are in connection with the history of the arenaceous and sub-arenaceous types constituting the *Lituolida*.

First in point of order stands the genus *Saccammina*, the only true rock-builder (using the term as it might be applied to *Fusulina* or *Nummulina*) amongst the British Carboniferous Foraminifera—structurally a most simple organism, standing apart from the rest of the group, interesting to the geologist from its stratigraphical limitations, and to the zoologist for its sudden disappearance with the Carboniferous period, and its reappearance in a new form as a Post-pliocene fossil, or living in the deep water of our northern seas. The three prominent genera of *Lituolida*,[1] namely, *Lituola*, *Trochammina*, and *Valvulina*, all appear in great strength, together with *Endothyra*, an essentially Carboniferous type, hitherto but little studied.

Lituola (proper) is represented by large rough examples both of its nautiloid and crozier-shaped varieties, and the non-labyrinthic *Haplophragmium* by a single small and delicate variety.

Of *Trochammina* there are no less than nine distinct modifications, mostly of the non-septate division of the genus, one variety only showing any regular segmentation. But the genus *Valvulina* obtains the most unexpected enlargement from the study of the palæozoic types. Ehrenberg many years ago figured a single species, first assigning it to *Textilaria*, and afterwards instituting a new genus, *Tetrataxis*, for its reception; but this is only one of a long series of forms which further research has brought to light. The mutual relations of these genera is best traced by the examination of recent specimens, and under favorable conditions all of them may be found off our own shores. The careful study of a large set of specimens obtained from dredgings taken on the west coast of Scotland has clearly shown, as I have elsewhere stated,[2] that the three groups form one unbroken series, in which the supposed distinctive characters of the genera become confused and lost. This applies chiefly to the feebler and smaller varieties, and need not affect the nomenclature in general use; but it is important in a zoological sense, and cannot be ignored in a scheme of classification.

The genus *Valvulina* in an especial manner has been a stumbling-block to systematists. In its normal and best developed condition it presents a thick, arenaceous

[1] That is to say, of the *Lituolida*, as constituted by Dr. Carpenter and his colleagues before the family had been enlarged by the discovery of certain recent deep-water types of Rhizopoda, the exact position of which cannot yet be very positively affirmed—such as *Astrorhiza*, *Botellina*, *Pilulina*, *Rhabdammina*, and others, some of them not even named as yet—none of which materially affect the present subject.

[2] 'Annals and Mag. Nat. Hist.,' ser. 4, vol. vi, pp. 289, 290. See also Jones, Parker, and Kirkby, *ibid.*, vol. iv, p. 391.

test, as stout and sandy externally as *Lituola;* but not unfrequently the sandy coat is found to be a mere incrustation upon a porous shell, and specimens often occur which are quite porous and smooth externally. So that, although assigned to the *Lituolida* from its close affinity to the typical Lituoline genera, *Valvulina* might with almost equal propriety have been placed amongst the *Globigerinida*, in the sub-order PERFORATA. The characters of the Carboniferous species strikingly confirm this view of *Valvulina* as an intermediate group. A large proportion of them are externally smooth: perhaps in the majority of cases they are none the less really arenaceous, but if so, the constituent sand-grains and the cement in which they are embedded are alike calcareous, and the composite structure of the test is less evident than when the sandy particles are siliceous. But in some of the species (notably *V. bulloides*) the test, though not always smooth, is usually distinctly porous, and a transparent section of the shell does not differ materially from that of corresponding members of the PERFORATA.

We are confronted with a new intermediate group in the genus *Endothyra*, a type hitherto unstudied, and known only from the section of a specimen figured by Professor Phillips thirty years ago. Somewhat higher in organization than *Valvulina*, and in its modifications strikingly isomorphic with the Rotaline series, *Endothyra* is never conspicuously sandy, never labyrinthic as to its interior structure, and even when the shell is thick and somewhat coarse in texture, it is still smooth externally. Normally the test is opaque and imperforate, but young examples of some species are often so hyaline that the interior arrangement of the chambers may be traced through the outer convolutions, and these thin-shelled specimens may occasionally be porous also.

To the list of intermediates must be added a number of uniserial forms which here receive collectively the generic name *Nodosinella*. They are not a little obscure in their structure and affinities, but seem to bear the same sort of relation to the Nodosarine genera that *Endothyra* bears to the Rotaline. They are, as has been said, uniserial, thicker-shelled than their hyaline isomorphs, and normally imperforate. What has been said of the structure of the test in *Valvulina* applies in most respects to the genus *Nodosinella* as found in the Carboniferous rocks, even to some minute particulars not needful to be entered upon here. In general terms the specimens differ in shell-texture from the moniliform *Lituolæ* in much the same degree as the typical *Trochammina* differs from the rougher Lituoline varieties.

There is yet one more of these ambiguous groups—that comprising the adherent forms to which I have given the generic name *Stacheia*, a group whose simplest modification consists of a single row of rounded parasitic segments, but which in its more complex development shows some degree of isomorphism with the Rotaline genera *Planorbulina*, *Tinoporus*, and *Polytrema*. The minute structure of the test in *Stacheia* in its complex forms cannot be satisfactorily decided from the specimens hitherto met with, owing to alterations in microscopic characters produced by the process of fossilization; but it may be assumed from that of the simpler varieties, which not only present the same sort of

ultimate structure as *Valvulina*—that is to say, for the most part subarenaceous and imperforate, though often thin-walled, but also show a striking similarity in the interior subdivision of the segments.

We have, then, in the Carboniferous fauna these four genera, embracing in their modifications a very remarkable series of forms, occupying a position *between* the two great sub-orders into which the Foraminifera are divided, not rightly belonging to the Imperforata, if the definition be strictly read, though in close affinity to the most strikingly imperforate types, but equally removed from the Perforata.

These intermediates, whether amongst individuals, species, genera, or larger groups, furnish the test under which artificial schemes of classification break down; but if the object in view be to trace the natural sequence of forms, rather than to establish a system of definitions, the evidence they yield is precisely that which is most valuable. It has been suggested that "the progress of knowledge will eventually break down all sharp demarcations, and substitute series for divisions" in zoological classifications;[1] and if it be so, as indeed can scarcely be doubted, intermediate forms have a significance too important to be ignored merely for the sake of upholding the current definitions of existing groups. Not that this need alter, at any rate in the present case, the general mode of treatment. The division of the Foraminifera into "Imperforata" and "Perforata" is exceedingly convenient, and in the main rests on a sound natural basis; and if increased observation tends more and more to break down this boundary-line in common with other sharp demarcations, any alternative that could be proposed in the existing state of knowledge would be open to objection of the same kind, varying only in degree. So long, therefore, as their true relation to the series is understood, it is not very material on which side of the line at present recognised the transition-group that has been described is placed; and accepting as a guide the position assigned to *Valvulina*, it follows naturally that genera so closely allied should be classed with it amongst the Imperforata.

There is another phase of this subject which must be alluded to in passing, namely, the relation of the intermediate types, the modifications of which form so important an item in the Carboniferous fauna, to the Rhizopoda of subsequent geological epochs. It is true that a few truly arenaceous species have been met with in Carboniferous rocks, and that all of the three families of the "Perforata" are also represented, though how sparingly, except for the genus *Fusulina*, we shall presently see; but the fact still remains, that by far the largest number of Carboniferous Foraminifera, both of species and individuals, belong to genera which under some conditions have arenaceous imperforate tests, and under others are smooth and in some cases perforate. That these should be followed in geological time by one set of isomorphs much more characteristically sandy, and by another set of isomorphs distinctively hyaline and porous, is a very significant fact. Take a single instance—the simple uniserial, quasi-Nodosarian type *Nodosinella*, found in the Carboni-

[1] Prof. Huxley, 'Journ. Linn. Soc. London,' vol. xii ("Zoology"), p. 226.

ferous beds, which is arenaceous, smooth, or only slightly rough as to its surface, and normally imperforate. In the Permian magnesian limestones this is largely replaced by the true Nodosarian type, but in its simplest modifications. A few lingering specimens of the older form still recur up to the Middle Permian beds, but except for their larger size and somewhat thicker tests, they are scarcely distinguishable from their hyaline isomorphs. In deposits of later age we have two distinct and well-defined series, the one normally much more arenaceous, the other much more hyaline, than their Carboniferous prototype. Direct evidence of continuity cannot be adduced in such a case; but, if we accept its possibility, it is not unreasonable to suppose that these early quasi-Nodosarians are the precursors, not to say the lineal ancestors, of two still living, and now widely separated, groups of Foraminifera.

It is not needful to press this argument by pursuing it through other Carboniferous genera and their more recent isomorphs; to do so successfully would require more knowledge than at present exists as to the relative age of Carboniferous beds widely separated geographically; but any one familiar with the various modifications of the Rotaline genera will not fail to be struck with the possibility of their common ancestry in the genus *Endothyra*.

Turning to the PERFORATA, we must be prepared for very different conditions of distribution, the contrast being possibly greater in the number of individuals (if we except the genus *Fusulina*) than in the number of species represented. Thus, in the family LAGENIDA the list embraces but three very rare and somewhat obscure Carboniferous forms of *Lagenæ* and a few simple Permian *Nodosarinæ*. The second family, GLOBIGERINIDA, has its principal development in the genus *Textularia*, the larger, rough varieties of which are common in the Carboniferous, the small, delicate, ambiguous examples being found very locally distributed in the Permian rocks. It is worth remembering that *Textularia* is almost as difficult a genus to place satisfactorily in any natural classification as *Valvulina*. Its best and most characteristic type, *T. agglutinans*, is as rough and sandy as *Lituola* itself, and frequently as labyrinthic in its internal structure; and between this and the transparent, delicate, perforate forms, the genus shows every gradation of texture. But in *Textularia* the thin-shelled, porous varieties constitute the larger part of the genus, whilst in *Valvulina* the reverse is the case. Were it determined to establish an intermediate sub-order for the reception of the variable genera at present classed with the LITUOLIDA, a course that would relieve the existing classification of many anomalies, *Textularia* would find its natural place in company with *Endothyra* and *Valvulina*, the common types of the Carboniferous age, with *Involutina* of the Lias, *Verneuilina* and *Bulimina* (*Ataxophragmium*) of the Chalk, and some other similar generic and quasi-generic groups.

Besides *Textularia*, the only representatives of the GLOBIGERINIDA in the Carboniferous fauna are very rare examples of three Rotaline genera, *Planorbulina*, *Pulvinulina*, and *Calcarina*, and their distribution is exceedingly limited, being confined to one or at most

two Belgian localities. As the recognition of these types at so early an epoch involves consequences of considerable importance, extreme care has been taken in the verification of the geological position of the rocks from which the specimens were obtained. Happily confirmatory evidence of considerable weight is supplied by their lithological condition, which under the microscope is almost exactly similar to that of the minute fossils of the Fusulina-beds of some parts of Russia and North America, and there is really no room to doubt that they are of Carboniferous age: but from a zoological point of view it would be very satisfactory to meet with the same species under conditions more favorable to the preservation of minute peculiarities of form and structure. The earliest occurrence geologically of any member of this group, previously recorded, is that of *Pulvinulina cassiana* (Gümbel) from the St. Cassian marls of the Alpine Trias, the earliest English example being the closely allied *Pulvinulina elegans* (d'Orb.), found by Messrs. Parker and Jones in the Upper Triassic or Rhætic Clay of Derbyshire. The Carboniferous specimens are unfortunately not only few as to number, but very obscure in their morphological characters, but they are of interest as carrying the history of the Rotaline genera into Palæozoic times.

The importance of the NUMMULINIDA as a family of Carboniferous Foraminifera rests chiefly on the genus *Fusulina*, which holds a similar position in the later Palæozoic fauna to that occupied by *Nummulina* and its allies at the beginning of the Tertiary epoch. As it is proposed that the genus *Fusulina* should form a subject for separate treatment, the facts which have been gathered from its fresh study need not at present be touched upon, though there is a great deal, especially in the characters of some of its less familiar varieties, of much significance in its bearing on the morphology and development of the Nummulite itself.

But in addition to *Fusulina*, the family is represented by minute specimens of three other genera, *Archæodiscus*, *Amphistegina*, and *Nummulina*. The first of these, *Archæodiscus*, a type as rudimentary in its organization as is compatible with Nummuline structure, makes perhaps the earliest appearance in point of time, and of the three it alone can be said to be even moderately common or widely distributed. *Amphistegina*, regarded hitherto as an essentially Tertiary and recent genus, is represented by one or two very minute but quite characteristic specimens, whilst *Nummulina* has only been obtained as yet from a circumscribed portion of the Belgian limestones. The absence of any known data for the determination of the relative age of the Carboniferous beds, of areas widely separated geographically, renders it impossible to draw zoological inferences with precision, as to the succession of species in the upper palæozoic rocks, and the Foraminifera themselves are scarcely available for anything more than collateral evidence.

From what has been said it will be gathered, that the principal points in the general aspect of the Carboniferous and Permian Rhizopod-fauna are:—1st. That the prevalent forms (except *Fusulina*) do not belong, in a strict sense, to either of the two suborders

into which the Foraminifera have been divided, but rather to intermediate types, which are neither invariably arenaceous nor uniformly perforate in their shell-texture. 2nd. That in the modifications of these primitive intermediate types some varieties occur which are conspicuously sandy and imperforate, others that are essentially hyaline and porous; and there are not wanting indications that their varietal peculiarities have been transmitted as permanent characters, thereby becoming the origin of the two parallel isomorphic series. 3rd. From negative evidence—that the porcellanous imperforate group (Miliolida) is of later creation. 4th. That the Permian Rhizopod-Fauna is very limited as compared with the Carboniferous, being confined to five generic types (*Trochammina*, *Nodosinella*, *Nodosaria*, *Textularia*, and *Fusulina*), representing, however, at least four distinct families of Foraminifera.

§ 4. HISTORY.

It would be profitless labour to attempt now to determine at what period the idea first gained credence that portions of the earth's crust were largely made up of the remains of minute testaceous animals; but that the fact was recognised in its full significance before the end of the last century, and in a measure understood, the beautiful folio volumes of the Abbé Soldani abundantly testify. The palæontological sections of Soldani's "Testaceographia" relate chiefly to the Sub-Appenine clays of Tuscany; but other observers followed, Fichtel and von Moll and Lamarck to wit, as exponents of the Foraminifera of various earlier Tertiary formations, and by the year 1840, thanks to the labours of d'Orbigny and Ehrenberg, the structure of many rocks of Cretaceous and even of Liassic age had been investigated, and their more or less microzoic character satisfactorily established.

Somewhat previous to this date, however, that is to say, in the year 1829, Fischer de Waldheim, in his 'Oryctographie du Gouvernement de Moscou,'[1] in giving an account of the white Carboniferous limestones of Russia, had described the important genus *Fusulina*. His description and figures are sufficient for purposes of identification; and, judged with due regard to the state of knowledge at the time, even the structural features of the genus are fairly rendered. Two other minute Carboniferous fossils regarded by Fischer as Foraminifera, and described under the names *Spirolinites sulcata* and *Sp. denticulata*, cannot now be identified. The figures do not represent any known type of Rhizopoda, and they have probably been erroneously classed by the author.

[1] For the sake of accuracy, and to avoid needless iteration of details, the titles of all works and papers referred to are given *in full* under the head "Bibliography."

It may here be stated that, for the reasons named in the "Introduction," matters pertaining to the genus *Fusulina*, when introduced at all, are throughout very cursorily treated.

Excepting this account of the genus *Fusulina*, the earliest mention of Carboniferous Foraminifera appears to be in a communication read by Dr. Buckland before the Ashmolean Society of Oxford in 1841, announcing the discovery of their remains by Mr. Darker and Mr. Tennant, in specimens of Mountain Limestone from Derbyshire. The following is the paragraph relating to the subject in the "Abstracts of the Proceedings of the Ashmolean Society."[1]

"A paper was read by Professor Buckland on the agency of animalcules in the formation of limestone. Dr. Buckland began by exhibiting some polished thin slices of Stonesfield Slate lately presented to him by Mr. Tennant, which Mr. Darker had discovered to be crowded with microscopic shells. He also announced that Mr. Darker and Mr. Tennant have discovered microscopic shells to abound in thin slices of certain strata of Derbyshire limestone, and proceeded to discuss the question how far the abundance of such remains in the Carboniferous and Oolitic limestones, and in the Chalk and Tertiary formations justifies the revival which has been attempted since the microscopic discoveries of Ehrenberg of the old and false dogma 'omnis calx e vermibus; omnis silex e vermibus; omne ferrum e vermibus.'"

Mr. Weaver,[2] in allusion to the same subject, states that this discovery was made by Mr. Tennant in 1839, and adds that in 1840 Mr. Lonsdale had also found Foraminifera in large numbers in thin slices of Kendal limestone.

In 1842 Dr. Ehrenberg presented to the Royal Academy of Berlin a notice of some Polythalamia from the Mountain Limestone of Lake Onega in Russia; and in the following year he reported to the Academy the results of his examination of a number of fossiliferous deposits, amongst them a "Mountain Limestone hornstone" from Tula. Little is to be gathered from the short abstracts of these papers which appear in the 'Proceedings of the Academy.' The whole of the determinations seem to have been revised for his great work, the 'Mikrogeologie,' published a few years later, and as no important question of precedence depends on the earlier communications, notice of the species named in them may be left till we come to speak of the latter memoir.

In 1845 Professor Phillips, in a paper on the "Remains of Microscopic Animals in the Rocks of Yorkshire," described and figured two Foraminifera from the Mountain Limestone of that county. One of these is a doubtful *Textularia* which is not named by the author, the other the horizontal section of a Rotaliform test, to which the name *Endothyra Bowmanni* is appended. At best a single transparent section of a shell is not a satisfactory basis on which to establish a species, still less as the foundation of a genus; but taking all the circumstances into account, there can be little doubt that the specimen figured does represent a type previously undescribed, and the generic term *Endothyra* may properly be accepted for it and its allies. Professor Phillips's specific name has been

[1] Vol. i, No. xvii, p. 35, March 2nd, 1841.

[2] 'Ann. and Mag. Nat. Hist.,' vol. vii, p. 398.

adopted in the present work for the particular modification which best agrees in general contour and septation with the figured section.

In 1849 MM. Rouillier and Vosinsky contributed to the 'Bulletin of the Society of Naturalists of Moscow' an account of a supposed Nummulite (*Num. antiquior*) from the white limestone of Miatschkovo. The paper is one of some interest, although, as suggested by d'Eichwald, who a few years later had the opportunity of seeing the original specimens, the authors were probably incorrect in assigning them to the genus *Nummulina*.

In the same year Prof. F. M'Coy described under the name *Nodosaria fusulinaformis* a Foraminifer abounding in the Carboniferous Limestone at Shivey in the north of Ireland. It is not improbable that this fossil may be the same as *Saccammina Carteri*, but the very brief description unaccompanied by any figure is scarcely sufficient to establish the fact, in the absence of collateral evidence.

Meanwhile the Foraminifera of the Permian limestones had begun to attract the attention of palæontologists and in the year 1848 Dr. H. B. Geinitz and Prof. William King described, independently, the species now well known as *Trochammina pusilla*. Two years later (1850) Prof. T. Rupert Jones contributed to Prof. King's 'Monograph of the Permian Fossils of England' descriptions and figures of some half dozen species. In 1854 Prof. Reuss added a single form from the Zechstein of Wetterau, and in the following year Dr. R. Richter, of Saalfeld, summarised the species found in the Zechstein of Thuringia, but without the addition of anything new.

Turning again to the Carboniferous fauna. In 1854 was published Ehrenberg's 'Mikrogeologie;' and in 1860 d'Eichwald's 'Lethæa Rossica.' In these two works may be found details of almost all the observations of any value which had been made up to that time on the microzoa of the Carboniferous limestones of central and southern Russia. The method of observation and of illustration adopted by the veteran microscopist are very unfortunate so far as the Foraminifera are concerned, and in this department of natural history at least, whether in respect to recent or fossil forms, his actual results must be accepted in some measure independently of his zoological inferences. His nomenclature also needs considerable modification before it is intelligible to those who are accustomed to the generally received generic and specific terms. Messrs. Parker and Rupert Jones ('Ann. and Mag. Nat. Hist.,' 4th ser., vols. ix and x) have performed the task of translating into the language of modern zoology the terminology of Dr. Ehrenberg's various memoirs, including that of the 'Mikrogeologie,' which may be regarded as the summary of his labours on fossil Rhizopoda. Unfortunately the beautiful figures of Carboniferous Foraminifera in the latter work, excepting those of an interesting group of *Fusulinæ*, are of little scientific value. Few of the representations of the minuter forms can be identified, for want of detail in the drawing; and, apart from the *Fusulinæ* referred to, only a single recognisable new species is gained to science.

D'Eichwald's synopsis of the Russian Carboniferous Foraminifera is based chiefly on

the labours of Rouillier and Vosinsky and Ehrenberg. He describes, however, four new species, the precise value of which it is very difficult to arrive at. It is to be regretted that there is now no chance of determining the doubtful forms by a comparison of specimens, for M. d'Eichwald states, in a letter to the author, that there were originally very few of them, and what there were have long since been given away and lost sight of.

In 1856 Prof. James Hall, of Albany, N. Y., described a foraminifer from the Carboniferous Limestone of Indiana and Illinois under the name *Rotalia Baileyi*. On examination the morphological characters of this species are found to be identical with those of *Endothyra Bowmani*, though the individual specimens are, on the average, of much larger dimensions, and are better developed than any hitherto met with on this side of the Atlantic. The difference, however, is only such as may be found in almost every species, and is to be looked upon as the result of more or less favorable conditions of growth, rather than as the expression of any more important zoological distinction.

In 1861 Dr. Geinitz, with the help of Prof. Reuss and Dr. Richter, summarised the Foraminifera of the Permian system of Central Germany, in his great memoir on the Dyas. He figures in all thirteen species, and of these seven are regarded as new to science, namely, five *Nodosariæ* and two *Textulariæ*. The minuteness and indistinctness of several of the figures are a great drawback to their usefulness, and in some instances leave one really in doubt as to what they are intended to represent. In 1867 the literature of the microzoa of the Zechstein formation received a further accession in a paper by Prof. E. E. Schmid, of Jena; but his drawings, so far as the Foraminifera are concerned, generally illustrate individual modifications of well-known forms rather than new species or important varieties. At the same time some morphological interest attaches to one or two of his figures, particularly to a non-septate *Trochammina*, partially unrolled and irregularly sinuous in contour, named by the author *Serpula filum*.

There remains but one other memoir in this division of the subject requiring notice here—Messrs. Jones, Parker, and Kirkby, 'On the Permian *Trochammina pusilla* and its Allies.' This is, in point of fact, a synopsis of the Permian species of the genus *Trochammina* with their synonymy, posted up to the date of publication—1869; and as such is a valuable contribution to the history of the group.

We turn once more to the literature of the Carboniferous fauna. In 1868 Principal Dawson, of Montreal, described a Nodosaria-like foraminifer from a Canadian white limestone under the name *Dentalina priscilla*, but not without some hesitation (expressed in a letter to the author) as to its generic affinity. A comparison of this little fossil with some similar organisms of Carboniferous age seems to indicate that its proper place is amongst the thick-shelled imperforate forms to which, for reasons that will be stated in due course, the new generic term *Nodosinella* has been applied.

In 1869 I essayed to prepare a list of the species of Foraminifera, Carboniferous and Liassic, collected by my friend Mr. Charles Moore, of Bath, during his researches on mineral veins. A new field seemed opened by the variety of forms brought to light by

Mr. Moore, and in the provisional report, which was hastily drawn up to be in time for the Meeting of the British Association for that year, there is much that now needs revision. The subarenaceous imperforate tests of nearly all the specimens then examined suggested their affinity to the Liassic genus *Involutina*, and names were assigned to the different species on this supposition. The priority of Professor Phillips's generic term *Endothyra* (since ascertained), by supplying a name for the Rotaliform series, renders it unnecessary, for the moment, to weigh minutely the value of the characters of Terquem's Liassic type, which at present appears to rest on a somewhat indefinite and unsatisfactory basis.[1] As will appear in due course, a considerable number of the specific names originally applied to Mr. Moore's specimens, may still be used without alteration.

In 1871 Mr. E. Parfitt, of Exeter, published a notice of a "Species of Arenaceous Foraminifer (?) from the Carboniferous Limestone of Devonshire," describing appearances in the weathered surfaces of certain limestones, which appeared to him to suggest the remains of a fossil Protozoon, either sponge or foraminifer, but most probably an arenaceous foraminifer. I confess that, upon very careful examination, after treatment in every way that could be thought of as likely to bring out structural features, I have been unable to find any satisfactory evidence of organic origin in the specimens kindly furnished to me by Mr. Parfitt; and as the matter so rests for the present, it is not needful to enter upon its further discussion. Transparent sections presented no unusual lithological characters, none that could not be accounted for without the introduction of any organic hypothesis.

Three papers published between the years 1871 and 1874, viz., "On Saccammina Carteri," "On Archædiscus Karreri," and "On a True Carboniferous Nummulite," together with the lists of species from Scottish localities, included in the Geological Survey publications relating to the Lanarkshire coal-field and in the papers of Messrs. Young and Armstrong, may be passed over with bare mention, as they practically form a part of the present Monograph.

Such, in outline, is the history of research in respect to the smaller Rhizopoda of the Carboniferous and Permian Epochs: that of the genus *Fusulina*, with its attendant zoological and geological problems, remains to be written.

[1] The recent paper by Herr L. G. Bornemann, jun. ("Ueber die Foraminiferengattung Involutina"), notwithstanding. This, though it contains observations of considerable value, is far from satisfactory in many ways, chiefly perhaps in the estimate of the relative importance of minute characters, and hence in the zoological treatment of the type.

§ 5. NOMENCLATURE.

The following summary exhibits in chronological order the materials upon which the nomenclature of the present Monograph is based. The list is in the main restricted to papers containing descriptions or figures of new species, real or supposed. Corrected names (when correction is necessary) are given in the right-hand column; and the first employment of the name taking precedence is indicated by printing it in capital letters.

Carboniferous.

1842. Ehrenberg, Bericht. k. Preuss. Akad. Wiss., vol. for 1842.	
Melonia (*Borelis*) *sphæroidea.*	*Fusulina*, sp.
Borelis constricta.	do. do.
Borelis princeps.	do. do.
Alveolina prisca.	do. do.
1843. Ehrenberg, ibid., vol. for 1843.	
Textilaria lunata, species indeterminable.	*Textularia*, sp.
Rotalia antiqua, a rotaliform cast wanting in detail, probably	*Endothyra*, sp.
Cristellaria (?) *mysteriosa*, no description nor figure.	Indeterminable.
Melonia (?) *labyrinthus.*	*Fusulina*, sp.
Tetrataxis conica.	*Valvulina palæotrochus* (Ehrenberg).
1845. Phillips, Proc. Geol. and Polytech. Soc., W. R. Yorks, vol. ii.	
Endothyra Bowmanni.	Endothyra Bowmani, *Phillips.*
1849. Rouillier and Vosinsky, Bull. Soc. Imp. Nat. Moscou, vol. xxii.	
Nummulina antiquior.	*Fusulina*, sp.
1849. M'Coy, Ann. and Mag. Nat. Hist, 2 ser., vol. xii.	
Nodosaria fusulinaformis.	Probably *Saccammina Carteri*, Brady.

1854. Ehrenberg, "Mikrogeologie."	
Genera, *Borelis* and *Alveolina* (many species).	*Fusulina*, sp.
Textilaria palæotrochus.	Valvulina palæotrochus (*Ehrenberg*).
Tetrataxis conica.	
Grammostomum bursigerum.	*Textularia*, species indeterminable, probably *T. gibbosa*, d'Orb., and *T. eximia*, d'Eichwald.
Textilaria falcata.	
Textilaria lagenosa.	
Textilaria lunata.	
Textilaria recurvata.	
Nodosaria index	Indeterminable.
Rotalia antiqua.	*Endothyra* (?), sp.
1856. Hall, Transact. Albany Inst., vol. iv.	
Rotalia Baileyi.	*Endothyra Bowmani*, Phillips.
1860. D'Eichwald, Lethæa Rossica, vol. i.	
Nonionina rotula, indeterminable, probably	*Endothyra*, sp.
Nonionina globolus.	Endothyra globulus (*d'Eichwald*).
Textilaria eximia.	Textularia eximia, *d'Eichwald.*
Fusulina cylindrica, Fischer.	
Orobias antiquior, Rouil. and Vosinsky.	*Fusulina*, sp.
Orobias æqualis.	
Cristellaria mysteriosa, Ehrb.	Indeterminable.
Rotalia antiqua, Ehrb.	*Endothyra*, sp. (?).
1868. Dawson, Acadian Geology, 2nd ed.	
Dentalina priscilla.	Nodosinella priscilla (*Dawson*).
1869. Brady, Brit. Assoc. Reports, Exeter Meeting.[1]	
Involutina cylindrica.	Nodosinella cylindrica, *Brady.*
Involutina incerta.	*Trochammina centrifuga*, n. s.
Involutina recta.	Haplophragmium rectum, *Brady.*
Involutina lobata.	*Endothyra Bowmani*, Phillips.
Involutina radiata.	Endothyra radiata, *Brady.*
Involutina crassa.	Endothyra crassa, *Brady.*
Involutina obliqua.	Endothyra obliqua, *Brady.*
Involutina vermiformis.	*Trochammina filum* (Schmid).

[1] A number of doubtful forms provisionally referred to Terquem's Liassic species were inserted in the lists furnished to Mr. C. Moore for his Report. Further investigation has shown some of these names to be unnecessary, and such as have no bearing on the present state of our knowledge are here omitted.

Involutina macella.	ENDOTHYRA MACELLA, *Brady.*
Carteria, sp.	*Saccammina Carteri*, Brady.
Nodosaria (?) and *Dentalina* (?).	*Nodosinella*, sp.

1871. BRADY, Ann. and Mag. Nat. Hist., 4th ser., vol. vii.

Saccammina Carteri.	SACCAMMINA CARTERI, *Brady.*

1871. YOUNG and ARMSTRONG, Trans. Geol. Soc. Glasgow, vol. iii, Suppl.

Textularia antiqua, Brady, MS.	CLIMACAMMINA ANTIQUA, *Brady.*
Involutina conica, Brady, MS.	*Valvulina palæotrochus* (Ehrenberg).
Involutina radiata, Brady.	*Endothyra radiata*, Brady.
Involutina lobata, Brady.	*Endothyra Bowmani*, Phillips.

1873. BRADY, Ann. and Mag. Nat. Hist., 4th ser., vol. xii.

Archædiscus Karreri.	ARCHÆDISCUS KARRERI, *Brady.*

1873. BRADY, in Memoirs Geol. Survey Scotland, Explan. sheet 23.

Archædiscus Karreri.	*Archædiscus Karreri*, Brady.
Climacammina antiqua, MS.	*Climacammina antiqua*, Brady.
Endothyra ammonoides, MS.	ENDOTHYRA AMMONOIDES, *Brady.*
Endothyra Bowmani.	*Endothryra Bowmani*, Phillips.
Endothyra globolus.	*Endothyra globulus* (d'Eichwald).
Endothyra ornata, MS.	ENDOTHYRA ORNATA, *Brady.*
Endothyra radiata.	*Endothyra radiata*, Brady.
Textularia gibbosa.	*Textularia gibbosa*, d'Orbigny.
Trochammina centrifuga, MS.	TROCHAMMINA CENTRIFUGA, *Brady.*
Trochammina gordialis.	*Trochammina gordialis*, Jones and Parker.
Trochammina incerta.	*Trochammina incerta* (d'Orbigny).
Valvulina decurrens, MS.	VALVULINA DECURRENS, *Brady.*
Valvulina palæotrochus.	*Valvulina palæotrochus* (Ehrenberg).
„ „ var. *compressa*, MS.	„ „ var. COMPRESSA, *Brady.*

Valvulina Youngi, MS.	VALVULINA YOUNGI, *Brady*.
„ „ var. *contraria*, MS.	„ „ var. CONTRARIA, *Brady*.
Valvulina plicata, MS.	VALVULINA PLICATA, *Brady*.
Webbina acervalis, MS.	STACHEIA ACERVALIS, *Brady*.

1874. BRADY, Ann. and Mag. Nat. Hist., 4 ser., vol. xii.

Nummulina pristina.	NUMMULINA PRISTINA, *Brady*.

PERMIAN.

1848. GEINITZ, Verstein. Zechst. Roth.

Serpula pusilla.	TROCHAMMINA PUSILLA (*Geinitz*).

1848. KING, Cat. Perm. Foss. Northumb.

Foraminites serpuloides.	*Trochammina pusilla* (Geinitz).

1850. JONES, T. R., in King's Monogr. Perm. Foss.

Serpula (?) *pusilla*.	*Trochammina pusilla* (Geinitz).
Spirillina, sp.	*Trochammina incerta* (d'Orbigny).
Dentalina permiana.	*Dentalina communis*, d'Orbigny.
Dentalina Kingii.	*Dentalina multicostata*, d'Orbigny.
Textularia triticum.	TEXTULARIA TRITICUM, *Jones*.
Textularia cuneiformis.	TEXTULARIA JONESI, *Brady*.

1854. REUSS, Jahresbericht d. Wetterauer Gesellsch. Vol. for 1851–1853.

Nodosaria Geinitzi.	*Nodosaria radicula* (Linné).

1861. GEINITZ, Dyas, vol. i.

Nodosaria duplicans, Richter.	Doubtful organisms.[1]
Nodosaria subacicula, Richter.	
Nodosaria Geinitzi, Reuss.	*Nodosaria radicula* (Linné).
Nodosaria Kingi, Reuss.	Varieties of *Nodosaria radicula*, Linné.
Nodosaria Kirkbyi, Richter.	
Nodosaria Jonesi, Richter.	
Dentalina permiana, Jones.	*Dentalina communis*, d'Orbigny.
Dentalina Kingii, Jones.	*Dentalina multicostata*, d'Orbigny.

[1] I have omitted these two and *Textularia Geinitzi* from the list of recognised Foraminifera with the full approval of Dr. Richter.

Textularia cuneiformis, Jones.	*Textularia Jonesi*, Brady.
Textularia triticum, Jones.	*Textularia triticum*, Jones.
Textularia multilocularis, Reuss.	TEXTULARIA MULTILOCULARIS, Reuss.
Textularia Geinitzi, Richter.	Doubtful organism.
Serpula pusilla, Geinitz.	*Trochammina pusilla* (Geinitz).

1867. SCHMID, Neues Jahrb. für Min., &c.—Jahrg. 1867.

Serpula Roessleri.	*Trochammina incerta*, d'Orbigny.
Serpula filum.	TROCHAMMINA FILUM (*Schmid*).
Nodosaria conferta.	Varieties of *Nodosaria radicula*, Linné.
Nodosaria ovalis.	
Nodosaria citriformis.	
Nodosaria Kirkbyi, Richter.	
Dentalina permiana, Jones.	*Dentalina communis*, d'Orbigny.

1869. JONES, PARKER, and KIRKBY, Ann. and Mag. Nat. Hist., 4th ser., vol. iv.

Trochammina incerta (d'Orb.).	*Trochammina incerta* (d'Orbigny).
Trochammina pusilla (Geinitz).	*Trochammina pusilla* (Geinitz).
Trochammina gordialis, Jones and Parker.	*Trochammina gordialis*, Jones and Parker.
Trochammina milioloides.	TROCHAMMINA MILIOLOIDES, *Jones, Parker*, and *Kirkby*.

§ 6. GEOLOGICAL AND GEOGRAPHICAL.

The geological relations of the limestones and other foraminifera-bearing rocks of the Carboniferous period form a subject altogether too wide and multiform to admit of treatment in any space that could be here devoted to it; but, inasmuch as the value of the information furnished under the head "Distribution" depends upon the care which has been exercised to obtain accurate knowledge of the locality and geological source of every batch of material examined, it seems essential that the palæontological portion of the memoir should be preceded by particulars sufficiently detailed to answer the requirements of the geologist and to ensure the ready identification of each habitat. I am especially indebted to my friend Mr. Geo. A. Lebour, F.G.S., for help in this matter. His wide and

intimate knowledge of all that concerns the Carboniferous rocks gives a high value to the assistance of which his ever-ready kindness has encouraged me to avail myself largely.

The following is a summary, arranged in approximately geographical order, of the localities which have yielded Carboniferous and Permian Foraminifera—the Carboniferous taken first—together with particulars as to stratigraphical position, and such other collateral information as I have been able to gather respecting them. A very large proportion of the material that I have had the opportunity of examining for fossil microzoa has been collected for me by scientific friends at home and abroad, and I have chosen this place to acknowledge the aid I have received and to thank the donors individually. The category of localities is a long one, but it only includes those which have yielded *positive* results; so that I must further express my thanks *collectively* to the many geologists who with equal care and pains have provided me with material which has not happened to contain the particular organisms of which I was in search. As probably three packages out of every four that have come into my hands have been barren of Foraminifera, the examination of unproductive material has formed no small part of my labour.

The numbers in the margin correspond with those in the heading of the Distribution Tables, and are intended to facilitate reference.

Carboniferous.

ENGLAND AND WALES.—Table I.

North of England.

In Northumberland the enormous thickness of beds lying between the Millstone Grit and the Calciferous Sandstone groups present no true division into Upper and Lower series. The thickness of the entire series (which Mr. Lebour proposes to name "Bernician," after the ancient name of Northumberland) is extremely variable, probably not less than 8000 feet in the middle of the county, and there includes a great number of limestone beds, which become fewer both to the north and to the south. From Alston southwards the Carboniferous Limestone rocks may be conveniently split into two divisions.

It will be seen that most of these English foraminifera-bearing beds belong to the Yoredale Rocks of Phillips. This being so, it seems necessary to call attention to the limits of that group, inasmuch as they do not appear to have been much studied hitherto outside of Yorkshire. Prof. Phillips included in his Yoredale Series the set of beds which lies between the Millstone Grit and the Great Whin Sill, or from the base of the Millstone Grit to the Tyne-bottom Limestone inclusive, along the Pennine escarpment and at Alston.

In Yorkshire, and indeed as far as Alston, the division is easily understood, but further north it can no longer be recognised, for two reasons—firstly, the Whin Sill ceases to be interbedded at the same horizon, and intrudes into higher levels; and secondly, the Tyne-bottom Limestone ceases to be specially recognisable owing to the intercalation of new beds of limestone and the thinning-out of old ones above and below it. The base line of the Yoredale Series, therefore, whether it be taken as the Great Whin Sill or the Tyne-bottom Limestone, fails altogether in the northernmost portion of its area. These remarks are needed because in geological maps, otherwise reliable, everything above the Whin Sill is coloured "Yoredale" as far as the Millstone Grit, and all below is coloured "Carboniferous Limestone" proper. The Little Limestone, Great Limestone, and Four-fathom Limestone, are all undoubted representatives of portions of the Yorkshire Yoredales, but in following the maps one may find an easily identified horizon, such as that marked by one of the beds containing *Saccammina*, sometimes coloured as Yoredale, sometimes as Carboniferous Limestone proper, and the Great Limestone is in much the same case.

Northumberland.

Foraminifera are found

In the "Ridsdale Ironstone Shale" (30 feet), a bed about two thirds down in the "Bernician" Limestone series [Scar] at

1. **The Ridsdale Ironstone workings,** in the shale heaps and old quarries. Material collected by Mr. Lebour.

In the "Bottom Limestone" (17 feet) *of the Ridsdale Ironstone district,* which lies above the shale, from which it is separated only by a bed of sandstone 11 feet thick [Scar], at

2. **Skellygate, Ridsdale,** from old pits. Material collected by Mr. Lebour, and specimens in the Rev. W. Howchin's collection.

In partings of calcareous shale in a thick bed of limestone, about 800 *feet above the last* [Scar], at

3. **Colster Cleugh**—in the bed and banks of the burn—about two miles east of Elsdon. Material collected by Mr. Lebour.

In a bed of limestone about 1000 *feet below the "Great Limestone"* [Scar] at

4. **Fallowlees**—friable calcareous shale, containing large numbers of singularly perfect siliceous crystals. Material collected by Mr. W. Topley, F.G.S., of the Geological Survey of England and Wales.

In the "Four-fathom Limestone" [Yoredale] at

5. **Harlaw Hill,** two miles north-east of Alnwick. Material collected by Mr. Topley.
6. **Brinkburn,** Coquetdale; from Mr. Topley.
7. **Forest Burn,** Coquetdale; from Mr. Topley.
8. **Elfhills Quarry,** near Scot's Gap. Specimens first communicated by Sir Walter C. Trevelyan, Bt.
9. **Hallington.** Material from Mr. Lebour.
10. **Newbrough,** near Fourstones. Material first collected by Mr. Lebour—locality, as in many other cases, subsequently visited by myself.
11. **Haydon Bridge** district—various quarries on the north side of the South Tyne surveyed by Mr. Lebour.

In the roof of the "Top Coal" of Newton-on-the-Moor—a very variable bed of shale above the "Four-fathom" and below the "Great" Limestone [Yoredale] at

12. **Newton-on-the-Moor.** Collected by Mr. Topley.

In the "Great Limestone" [Yoredale] at

13. **Newton-on-the-Moor.** Also collected by Mr. Topley.
14. **Langley,** above Haydon Bridge. One or or two microscopic sections of limestone in Mr. D. O. Drewett's collection.
15. **Green Leighton,** the finest exposure of the Great Limestone—rich in corals, &c. List of species drawn up from the Rev. W. Howchin's collection.

In the shale lying immediately above the Great Limestone [Yoredale] at

16. **Fourstones Quarry,** South Tyne. The Rev. W. Howchin has worked out the microzoa of this locality, and has not only furnished me with material for examination, but allowed me the free use of the specimens in his collection.

In the "Little Limestone" [Yoredale] at

17. Inghoe, near Matfen. List of species drawn up from the Rev. W. Howchin's collection.

18. Belsay. Two beds of limestone run through Belsay Park, the Foraminifera are from the lower of them. These two limestones, as well as a lower one, make no appearance south of the Tyne. List of species compiled from Rev. W. Howchin's collection.

In the "Fell-top Limestone" [Yoredale] at

19. Top Limestone, Coquet. Material collected by Mr. Topley.

DURHAM.

In the Four-fathom Limestone [Yoredale] at

20. Middlehope Burn, north of Westgate, Weardale. *Saccammina* observed by Mr. R. Howse, of Newcastle.

In the Great Limestone [Yoredale] at

21. Bollyhope, between two and three miles from Stanhope on the road to Middleton-in-Teesdale. Specimen also from Mr. Howse.

CUMBERLAND.

In the Four-fathom Limestone [Yoredale] at

22. Alston, and in various quarries southwards. Material collected by Dr. Savage and others—also specimens in Mr. Charles Moore's collection.

In limestone, exact horizon unknown, probably Yoredale, at

23. Wyebourne. Foraminifera observed on the surface of a piece of weathered dark grey limestone.

WESTMORELAND.

In the Melmerby Scar Limestone [Scar] at

159. Swindale Beck, near Brough. A band of earthy shale in the upper

part of the bed, collected by Mr. Lebour. This material came too late for the results of its examination to be included in the Table. It contained the following forms:—*Trochammina incerta*, *Valvulina palæotrochus*, *V. decurrens*, and *Endothyra Bowmani*.

24. "Kendal Limestone," Scar Limestone of Phillips, probably low down. Specimen in the Museum of the Geological Society of London, from the collection of the late N. Winch, Esq.

Shale in the upper part of the "Scar" Limestone about 400 *feet below the Hardra Limestone.*

25. Gaythorn, near Crosby Ravensworth.

The Hardra Limestone is generally accepted as the base of Phillip's Yoredale series, but it is not known how far it may be identical with the "Tyne-bottom Limestone." Specimens from Prof. Harkness, F.R.S.

YORKSHIRE.

In the "Yoredales" proper, without more definite horizons, at

26. Hurst, near the head of Swaledale. Material obtained by Mr. Edward Wood, F.G.S., of Richmond.

27. Downholme, in Swaledale; marly plates between limestone beds—also from Mr. Wood.

28. Grassington Lead Mine, Wharfdale.

29. Keld Head Mines, Wensleydale. The specimens from these two localities kindly lent by Mr. Charles Moore, F.G.S.

30. Gaping Gill, near Clapham Cave. Specimen of Limestone communicated by Mr. Jas. Thomson, F.G.S.

Midland Counties and North Wales.

I have unfortunately had but little opportunity of ascertaining the extent of the Foraminifera-fauna of the great range of limestone rocks of the central parts of England

or of North Wales, and the material which has presented itself has not been accompanied with detailed geological or geographical information. Still an imperfect record, correct as far as it goes, is better than none.

DERBYSHIRE.

In the Limestone Rock or Toadstone Series [Scar] at

31. Bakewell. One or two beautiful microscopical sections of limestone in the collection of Mr. H. C. Sorby, F.R.S.

STAFFORDSHIRE.

32. North Staffordshire. Microscopical sections in Mr. Sorby's collection, without particulars as to exact locality.

SHROPSHIRE.

33. Llan-y-Mynech, near Oswestry. Specimens in the collection of Dr. Harvey B. Holl, of Perdiswell, Worcester.

34. Steeraway. Mr. C. Moore's collection.

CARNARVONSHIRE.

35. Bangor. Two fine microscopical sections of Carboniferous Limestone in Mr. Sorby's collection.

36. Great Ormes Head. An outlier of the Carboniferous Limestone. Specimens in Dr. Harvey B. Holl's collection.

Bristol District.

The Avon section of the Carboniferous Limestone is divided into three principal groups, thus—

I. Upper shales or grits.

II. { *a.* Upper Mountain Limestone (coralline).
{ *b.* Middle Mountain Limestone (not very fossiliferous).
{ *c.* Lower Mountain Limestone (rich in Fishes, Brachiopoda, &c.).

III. Lower limestone shales (very fossiliferous).

These probably find their equivalents in the Yoredale rocks, but the beds below the true lower shales form a sort of intermediate group corresponding with those of North Devon. With one exception the beds which have furnished Foraminifera all occur in the Upper Mountain Limestone (II, *a*), the exception being a bed in the lowest part of the Middle Mountain Limestone (II, *b*) marked in the table "Great Quarry, near *Longispinosa* bed." To my friend Mr. W. W. Stoddart, F.G.S., of Bristol, whose name is identified with the geology of the Clifton Rocks, I am indebted for ample supplies of material from both sides of the River Avon, as well as for accurate geological information as to the localities whence they were obtained.

GLOUCESTERSHIRE.

In the lowest part of the Middle Mountain Limestone.

37. Great Quarry, near the **"Longispinosa bed,"** Bristol.

In the Upper Mountain Limestone.

38. Bridge Valley Road, near Clifton Down.

SOMERSETSHIRE.

In the Upper Mountain Limestone.

39. Leigh Woods, Foraminifera-bed.
40. Leigh Woods, between Foraminifera-beds.
41. Opposite Point, Leigh Woods, Foraminifera-bed and parting.
42. No. 2 Foraminifera-bed.

These four localities are all in the Clifton district.

43. Backwell, a single mounting of Foraminifera, probably of similar age to the foregoing in Mr. C. Moore's collection.

160. Bath. In Mr. C. Moore's collection are one or two specimens of a very granular variety of *Trochammina incerta* collected from the sediment of the Bath mineral waters. These are presumably Carboniferous, but it has not been thought worth while to devote a column in the table to them.

SCOTLAND.—Table II.

The comparative completeness of the Distribution Tables referring to the Scotch Carboniferous system is mainly due to the friendly aid of the officers of the Geological

Survey of Scotland, and especially of their palæontologist, Mr. R. Etheridge, junr., F.G.S. Through his kindness and interest in the subject I have had the opportunity of working over a very extensive series of washed shales collected from the Scotch Carboniferous beds by Messrs. J. Bennie and A. Macconochie, the collectors to the Survey, as well as of examining the mounted specimens belonging to the Museum of that body. A report upon the Foraminifera of the Lanarkshire Coal-field was drawn up two or three years ago for the use of the Survey, the substance of which was embodied in one of their memoirs,[1] and as far as Scotland is concerned, the present work may be regarded as an expansion of the results then furnished. I am also Mr. Etheridge's debtor for the accurate geological and geographical information upon which the tables are based, and without which they would have lacked the essential elements of order and geological reliability.

I am not less beholden to my friends Mr. John Young, F.G.S., and Mr. David Robertson, F.G.S., of Glasgow. The first Carboniferous Foraminifera from the Scotch beds that came to my hands were those of the beautiful collection formed by Mr. Young. They were lent to me without reservation long before I had any specimens of my own from localities north of the Border, and I have had the cordial co-operation both of Mr. Young and Mr. Robertson throughout my work.

Where no note is appended to the localities in the following list I have had my supplies of material from the stores of the Geological Survey of Scotland; in other cases the names of the contributors are added in parentheses.

Fife.

Lower Limestone Group.

Shale below No. 1 *Limestone, Midlothian Series* (= *Main or Hurlet Limestone*).

152. Abden, on shore east of Kinghorn. White and blue shales.

Shale above No. 1 *Limestone, Midlothian Series.*

153. Invertiel Quarry, north of Linktown, Kirkcaldy.

Shale above Linn Limestone (*probably equivalent to No.* 1 *Limestone, Midlothian Series*).

154. Cowdens Quarry, north-west of Dunfermline.

[1] 'Memoirs of the Geological Survey of Scotland,'—Explanation of sheet 23, Lanarkshire Central Districts, 1873.

Shale below No. 2 Limestone.

44. Seafield, on shore west of Seafield Tower, south-west of Kirkaldy.

Shale above Seafield Tower Sandstone.

155. Seafield, on shore east of Seafield Tower.

Shale above No. 1 or No. 2 Limestone.

45. Glenniston Quarry, four miles north-west of Kirkaldy.
46. Sunnybank Quarry, three miles south-east of Dunfermline.
47. Charleston Quarry, four miles south-west of Dunfermline.

Shale above No. 2 Limestone, Midlothian Series.

158. Roscobie Quarry, north of Dunfermline.

STIRLINGSHIRE.

Lower Limestone Group.

Shale below Main Limestone.

48. Glenwhapple Burn, Craigenglen, about one and a half mile south of Lennoxtown.
49. Craigenglen, Campsie (Messrs. Robertson and Young).
51. Millburn, Campsie (Messrs. Robertson and Young).

Shale connected with No. 2 Limestone.

50. Corrieburn, left bank near Cairnbrae, about two and a quarter miles from Kilsyth.

LINLITHGOWSHIRE.

Lower Limestone Group.

Shale above No. 1 Limestone (= Main, or Hurlet Limestone).

52. Whitebaulks Old Quarry, about two miles south of Linlithgow.

Shale below Bathgate Limestone (? = No. 2 Limestone of Midlothian field).

53. Galabraes Quarry, near Bathgate.

Bathgate Limestone (decomposed).

54. Sunnyside Quarry, near Knock, about three miles north-east of Bathgate.

Shale above No. 2 Limestone, Midlothian Series.

55. Murrayfield Pit, Blackburn, near Bathgate.

Upper Limestone Group.

Shale above Dykeneuk Limestone (= Gair Limestone).

56. Dykeneuk Old Quarry, Kinneil, two miles south-west of Bo'ness.

Shale above one of the Upper Limestones.

57. Avon Water, 100 yards below Kinneil Mill, near Linlithgow.

EDINBURGHSHIRE.

Lower Limestone Group.

Addiewell Limestone (= No. 1 or Hurlet Limestone).

58. No. 16 Mine, Addiewell, near West Calder; decomposed limestone.

No. 1 Limestone, Midlothian Series.

59. Crichton Quarry, near Pathhead.
60. Middleton Quarry, near Borthwick.

Shales between beds of No. 1 Limestone.

61. Middleton Quarry, near Borthwick.

Addiewell or Hurlet Limestone.

62. Baad's Mill, Harwood Burn, near West Calder.

Shale above No. 1 Limestone.

63. Hillhead Quarry, Cockmuir Bridge, near Penicuick.

No. 2 Limestone.

64. Fullarton Quarry, near Penicuick.

65. Fullarton Quarry, lower layer of shale *in sitû* between beds of limestone.

66. Fullarton Quarry, upper layer of the same.

67. Magazine Limeworks, near Pathhead.

68. Brunston Colliery, near Penicuick.

69. Mount Lothian Quarry, near Penicuick.

70. Mount Lothian Quarry, buff shale between beds of "No. 2 Limestone."

71. Currielee Quarry, near Gorebridge.

Shale above No. 2 Limestone.

72. Brunston Colliery, near Penicuick.

73. Cousland Quarry, near Dalkeith.

74. Blinkbonny Quarry, near Gorebridge.

Upper Limestone Group.

Shale above Gair Limestone.

75. Whitehouse Old Quarry, half a mile north-east of Levenseat, near Wilsontown.

Levenseat Limestone—highest of the Carboniferous Limestone series; by some placed in the Millstone Grit.

76. Levenseat Limestone pit.

Shale between beds of Levenseat Limestone.

77. Levenseat Quarry.

HADDINGTONSHIRE.

Lower Limestone Group.

No. 2 Limestone.

78. Kidlaw Quarry, near Gifford.

79. Dunbar. (Also Mr. F. M. Balfour's specimens.)

Shale above No. 2 Limestone, Midlothian Series.

80. Salton Limeworks, new quarry on east side of road near East Salton.

81. Quarry north of East Salton Village.
82. Burlage Quarry, two miles south-east of Dunbar.
83. East Barns Quarry, two miles south-east of Dunbar.
156. Spilmersford Quarry, near Salton Hall.
157. Lampland Quarry, near Pathhead.

Upper Limestone Group.

Shale above No. 5 Limestone (? = *Gair Limestone*).

84. Shore of Firth of Forth, opposite Prestongrange, near Prestonpans.

RENFREWSHIRE.

Upper Limestone Group.

Gillfoot or Belstonburn Limestone, next below Gair Limestone.

85. Orchard near Pollackshaws (list supplied by Messrs. Young and Robertson).

LANARKSHIRE.

Lower Limestone Group.

Main Limestone.

86. Fulwood Old Quarry, three miles south-east of Carluke.
87. Braidwood, near Carluke. (List compiled from Messrs. Young and Robertson's and Rev. W. Howchin's collections.)

Shales above Main Limestone.

88. Fulwood Old Quarry, three miles south-east of Carluke.
89. Fiddlers' Burn, near Carluke, on the left bank of the Burn, opposite Headsmuir.
90. Quarry on the South Shiells Farm, two and a half miles south-east of East Kilbride. (Including also Messrs. Young and Robertson's gatherings.)
91. Ponfeigh Burn, a little below turnpike road, about four miles north-north-east of Douglas.

92. Poniel Water, at Brockley, near Lesmahagow—shale exposed on the left bank. (Messrs. Young and Robertson's Brockley gatherings are included in this column of the table.)

Shale above the Hosie Limestone.

93. Hillhead Farm, near Carluke—shale heaps in an old quarry.

94. Head of Mouse Water, near Wilsontown.

Coralline band over No. 1 *Limestone, Calderwood Series.*

95. Capelrig and Brankumhall, shale heaps in old quarries on these farms, about one mile and a quarter north-east of East Kilbride. (Including also Messrs. Young and Robertson's specimens.)

Shale above the last-named coralline band.

96a, 96b. Capelrig and Brankumhall, near East Kilbride, two positions searched.

Shales above No. 1 *Limestone, Calderwood Series.*

97. Calderside Grounds, old quarry on the right bank of Calder Water, about one mile and a half east of East Kilbride.

98. Auchentibber, Broomhouse, and Newfield Farms, about two miles east by north of East Kilbride; shale heaps in quarries.

99. Boghead Farm, about four miles south-east of East Kilbride; shale heaps in old quarry. (Including also Messrs. Young and Robertson's specimens.)

Shale over No. 3 *Limestone, Calderwood Series.*

100. Limekiln House, near East Kilbride; old quarry, east of the house.

Shale over Birkfield Calmy Limestone.

101. Hairmyres, near East Kilbride, weathered shale *in situ* between Railway and Curling Pond. (Messrs. Young and Robertson's gatherings also included.)

Shales over Kinshaw Limestone Series.

102. Mouse Water, opposite Lambcatch, near Wilsontown.

Second Calmy Limestone.

103. Braidwood, near Carluke. (List compiled from Messrs. Young and Robertson's and Rev. W. Howchin's collections.)

Upper Limestone Group.

Cowglen, or Index Limestone = Rough Limestone of Carluke.

104. Climpy Quarry, one mile and a half north-west of Wilsontown.

Shales above Seven-foot Limestone.

105. Auchenbeg Old Quarry, about three miles south of Lesmahagow.

Shales above Gair Limestone.

106. Westerhouse Old Quarry, about two miles and a quarter north-east of Carluke. (List includes also Messrs. Robertson and Young's gatherings.)

107. Gair Old Quarries, about two miles north-east of Carluke. (List includes also the species in Messrs. Robertson and Young's and the Rev. W. Howchin's collections.)

108. Limekiln Burn Quarry, about three miles south-west of Hamilton.

109. Woodhill Old Quarry, north-east of Glasgow.

110. Barmulloch Old Quarry, north-east of Glasgow. (Also Messrs. Robertson and Young's collections.)

111. Robroyston House Old Quarry, north-east of Glasgow (shale over Gair or Robroyston Limestone).

112. Craigburn, near Lesmahagow, a few yards above turnpike road.

113. Kennox Water, about half a mile above Kennox House, south of Douglas.

114. County Boundary between Lanarkshire and Edinburghshire, old quarry one mile and a half north-west of Wilsontown.

Shale over Belstonburn Limestone.

115. Bed of Burn behind Gillfoot House, two miles south-south-west of Carluke. (Including also Messrs. Young and Robertson's specimens.)

116. Belstonburn, exact horizon wanting. (Specimens in the Rev. W. Howchin's collection.)

Shale above one of the Upper Limestones of doubtful position.

117. Meikle Earnock, on the right bank of the burn opposite Whitecraigs, about four miles east by south of East Kilbride.

AYRSHIRE.

Lower Limestone Group.

Probably shale above Main Limestone.

118. Trearne and Dockra, near Beith.

Upper Limestone Group.

Exact position not ascertained.

119. Garple Burn, near Muirkirk. (The lists from these two localities drawn up by Messrs. Robertson and Young.)

PEEBLESSHIRE.

Shale above No. 1 *Limestone.*

120. Whitfield Old Quarry, near Carlops.

Shale between beds of No. 2 *Limestone.*

121. Bents' Quarry, near Carlops.

Shale above No. 2 *Limestone.*

122. Carlops Quarry, Carlops.

DUMFRIESSHIRE.

LOWER CARBONIFEROUS OR CALCIFEROUS SANDSTONE SERIES.

Cement Stone Group.

123. Donkins' Quarry, at Kirthbridge Station, two miles and a half east of Ecclefechan—a greenish-grey limestone, weathering red.

124. Bonshawburnhead Quarry, east of Quarry Park, two miles and a half south-east of Ecclefechan.

125. Cauldronlee Quarry, five miles north-east of Ecclefechan—a red and white shale above the greenish-grey limestone.

IRELAND.—Table III.

The divisions of the Carboniferous Limestone series in Ireland are as follows, in descending order:

I. Yoredale Rocks and Millstone Grit (usually termed in Ireland "Coal-measures and Millstone Grit").
II. Upper Limestone. } No true boundary exists between these two
III. Middle Limestone or "Calp." } divisions.
IV. Lower Limestone—about 200 feet.
V. Lower Limestone shale.

Hitherto Foraminifera have only been found at two localities in condition sufficiently well preserved to admit of ready identification, and their discovery is due to my friend Mr. Joseph Wright, F.G.S., of Belfast, to whose kindness I am indebted for my specimens.

126. Castle Espie, near Comber, Co. Down, on the north-west shore of Strangford Lough. The material is a soft calcareous shale of the Lower Limestone series, from a detached patch of Carboniferous lying on the upturned edges of Silurian rocks.

127. Bundoran, Co. Donegall, three miles south-west of Ballyshannon. A Lower Limestone shale with bands of impure limestone. Material obtained from beds exposed along the shore.

161. Galway, a microscopical section of Carboniferous Limestone from the Galway rocks, in Prof. Wm. King's collection, contains a few small and somewhat indefinite *Endothyræ*, but not sufficiently representative to be catalogued.

BELGIUM.—Table IV.

The Carboniferous Limestone of Belgium is divided by M. Dupont[1] into six sets of beds, which have been named from the localities in which they are respectively best developed. They are as follows, in ascending series, beginning at the lowest:

I. Calcaire des Ecaussines—thickness 150 metres, composed of limestones with intercalated shales at the base, with phthanite at the upper part; the limestones with *Spirifer Verneuilli*, *Sp. mosquensis*, *Orthis crenistria*, and *Cyathophyllum plicatum*.

II. Calcaire de Dinant—thickness 60 metres, a black compact limestone with phthanite having conchoidal fracture. Fossils, *Productus Herberti* and *Pecten intermedius*.

III. Calcaire d'Anseremme—thickness 100 metres, a grey limestone with blue veins, more or less siliceous and with phthanite in the lower part. Fossils, *Productus Flemingi* and *Spirifer mosquensis* in the upper part, and *Orthis resupinata*, which is very characteristic of this division.

IV. Calcaire de Vaulsor—thickness 100 metres, a grey limestone, often magnesian; the beds full of radiated spathic nodules. Fossils, *Spirifer striatus* and *Sp. cuspidatus*; in the lower part *Conocardium alæforme*, and in the upper part *Rhynchonella pleurodon* and *Amplexus coralloides* are especially met with.

V. Calcaire de Namur—thickness 100 metres, is the black dolomitic limestone with large *Euomphali*. It is black and compact at the base, dolomitic in the upper portion; usually fissured in every direction. Fossils, *Euomphalus æqualis* and *E. acutus*.

VI. Calcaire de Visé—thickness 250 metres, confusedly stratified, variable in structure and colour; containing a brecciated limestone and rocks of which the structure has become sandy through the decomposition of the dolomite. Fossils, in the lower part, *Productus cora* and *P. undatus*; above, *Productus giganteus* and *Chonetes conoides*.

We are at present concerned with the two last named only, the Calcaire de Namur and the Calcaire de Visé, for in these alone have Foraminifera as yet been found. I am indebted to my friend M. Ernest Vanden Broeck, of Brussels, for his assiduous help in procuring for me material for examination from the various limestone beds of Belgium. Out of a very large series forwarded to me at various times only four in all have yielded

[1] "Essai d'une Carte Géologique des Environs de Dinant," 'Bull. Acad. Sci. de Belg.,' 2nd sér., vol. xix, p. 616 *et seq.*

any traces of fossil Rhizopoda, but the species obtained represent a fauna of very great interest.

The following are the localities :—

128. Carrière du Fond d'Arquet, near Namur, Belgium. A package of decomposed grey limestone from the Calcaire de Namur.

129. Carrière du Fond d'Arquet. Material of similar character from the same locality, marked "2me Couche inférieure."

130. Flemalle, near Liége. Grey, friable, calcareous material from the Calcaire de Visé.

131. Calcaire de Visé. Material from the dressing of the fossils of the Ryckholt collection in the Brussels Museum. I owe this to the kindness of Prof. de Koninck.

It remains only to say that the Calcaire de Namur is chiefly remarkable, from our point of view, as the habitat of the earliest Nummulite and also of the only specimens hitherto found pertaining to any of the Rotaline genera. It is much to be regretted that the subcrystalline nature of the calcareous rock at every position in which it has been examined microscopically has so obscured the characters of the minute fossils as to render the identification of many of them a matter of difficulty and doubt, and the list of species determinable has been much shortened thereby. The Calcaire de Visé is notable as the only position out of Great Britain in which *Saccammina Carteri* has been observed.

RUSSIA.—Table V.

The general classification of the Carboniferous and Permian rocks of Russia seems to be as follows:

Permian.	Permian limestone with gypsum and chalky limestone, alternating with Kupfer-Sandstein, of the Province of Perm. Fresh-water limestone, with gypsum. Pfeffer-Sandstein.
Coal-measures and Culm.	Donetz Coal-field?
Carboniferous Limestone, proper.	Chalky limestone with *Fusulina cylindrica*. White Dolomitic limestone. Bituminous limestone.

Tuedian (Calciferous Sandstone)?	} Stigmaria-grits of Russia.
Upper Devonian.	

According to Ludwig[1] the Fusulina-beds in the Donetz are on the horizon of the true Coal-measures (passing upwards into the Permian), but in other Russian districts, so far as can be made out, they are confined to the true Carboniferous Limestone, though probably to its upper part.

I am indebted to the kindness of General G. von Helmersen, of St. Petersburg, for specimens of Fusulina-limestones from several localities in central Russia. Some of these specimens, notably those from the first three localities in the following list, contain other species of Foraminifera as well as *Fusulina*. To Dr. Herrman Abich, of Tiflis, Georgia, I am under the like obligation in respect to the Fusulina-rocks of the Caucasus, which have also yielded evidence of the existence of some of the minuter types. The remaining localities on the list are given on the authority of Prof. Ehrenberg and M. Edw. d'Eichwald.

The whole of these may be regarded as pertaining to the Carboniferous Limestone proper.

132. Miatschkovo, near Moscow.

a. A grey, porous, crumbling limestone, with *Fusulina cylindrica*, Encrinites, and other fossils.

b. A white, compact limstone, with *Fusulina cylindrica* and *Chætetes*.

133. Ostaschkovo, on the Volga, in the province of Samara. A light-coloured friable limestone, with *Fusulinæ*.

134. Zærew Kurgan, a mountain on the left bank of the Volga, north of the town of Samara. A light-brown limestone, almost entirely composed of small and perfect specimens of *Fusulina cylindrica*.

135. Witegra, on Lake Onega, Government of Olonetz. White, friable Bellerophon-limestone of the Mountain Limestone. See Ehrenberg's 'Mikrogeologie.'

136. Toula, Hornstone of the Mountain Limestone, with *Spirifer mosquensis* (Ehrenberg).

137. Sloboda, a village in the Government of Toula. Yellow Carboniferous clay. See d'Eichwald's "Lethæa Rossica."

[1] Ludwig (Rudolf), 'Die Steinkohlenformation im Lande der Don'sche Kosaken,' Moscow, 1874.

138. Caucasus. Various specimens of compact black limestone, taking high polish, and containing *Fusulinæ*. A knowledge of the contents of these can only be obtained by means of thin sections, the list is therefore necessarily incomplete. I am not quite certain that I am right in classing them as Russian. Some of the specimens contain the *Fusulina sphærica* of Abich, which suggests the possibility of these at least being from the Armenian or northern Persian portion of the mountain range.

NORTH AMERICA.—Table VI.

United States and Canada.

Beyond the genus *Fusulina* but little is yet known concerning the Carboniferous Foraminifera of North America, and the instalment now offered towards the history of the minuter forms is not of sufficient importance to need any lengthy geological introduction. The American Fusulina-rocks pertain chiefly to the "Upper Coal-measures," but in the South-western States they extend into the strata which are regarded as representative of the Permian system; indeed, the largest variety of the genus hitherto described (*Fusulina elongata*, Shumard) has its habitat in the Permian Limestones of Texas and New Mexico.

Only two samples of material from the Fusulina-beds, in condition favorable for examination with respect to the smaller Foraminifera, have come under my notice, and both of them were from Iowa. They were forwarded to me by Dr. C. A. White, whose effective labours in connection with the geology of that State are well known.

I am indebted to Dr. F. B. Meek and Dr. C. A. White, of Washington, for interesting specimens of a microzoic limestone of much earlier age from the "Sub-carboniferous" rocks of Indiana, consisting almost entirely of the shells of a single species of Foraminifer, *Endothyra Bowmani*, Phillips (*Rotalia Baileyi*, Hall).

With respect to the single Canadian locality, I can add nothing to the published statement in my friend Dr. J. W. Dawson's 'Acadian Geology.'

Whilst the relation of the American Carboniferous rocks to those on the eastern side of the Atlantic is still a matter of debate amongst our ablest geologists, I may well be excused any attempt to correlate the few horizons marked by the occurrence of the smaller fossil Rhizopoda with particular portions of the Carboniferous series of this country or of continental Europe.

139. Southern Iowa—no precise locality. Labelled "Residue from clayey partings of layers of Fusulina-limestone. Upper Coal-measures."

140. Southern Iowa. Weathered and disintegrated Fusulina-limestone from near the point of junction of the Platte River with the Missouri. Upper Coal-measures.

141. Southern Indiana. A grey, friable limestone, composed almost entirely of minute fossils. Labelled "Warsaw Limestone of Hall = St. Louis Limestone of Owen. Subcarboniferous." The particular deposit is known as the Spergen Hill bed, and it appears to run through several counties,[1] the locality from which it takes its name being in Washington County.

142. Windsor, Nova Scotia. A white, friable Carboniferous limestone, with *Nodosinella priscilla* (Dawson).

Permian.—Table VII.

Foraminifera, though pertaining to a limited number of types, abound in the Permian or Zechstein formation of the north-east of England and central Germany, and their occurrence has been also noted in deposits of similar geological age over a small district in the north of Ireland. The constituent beds of the English and German Permian areas have been variously correlated; but without entering into debated points, the classification adopted by Dr. H. B. Geinitz may be accepted as sufficient for our present purpose. It is as follows ('Dyas,' p. vii):

Zechsteinformation or Permian (Dyas).

Germany.	England.
a. Oberer Zechstein.	*Upper Magnesian Limestone.*
I. Plattendolomit (Dolomitischen Kalkschiefer, Stinkkalk, Stinkstein).	Upper Yellow Limestone, Conglobated Limestone.
b. Mittler Zechstein.	*Middle Magnesian Limestone.*
II. Rauchwacke or Dolomite (Rauhkalk, Höhlenkalk, Riff-Zechstein, &c.).	Concretionary and Shell-limestone or Crystalline and Fossiliferous Limestone.

[1] According to my friend Dr. C. A. White the bed appears in three adjoining counties, viz. Munroe Co., Lawrence Co., and Washington Co. Its occurrence in Lawrence Co. is noticed in the 'Fifth Annual Report of the Geol. Survey of Indiana' (for 1873), p. 285, E. T. Cox, State Geologist, from which I gather that the name is also written Spurgeon Hill.

c. Unterer Zechstein.	*Lower Magnesian Limestone.*
III. Zechstein, next under the foregoing and overlying the bituminous Mergelschiefer.	Compact limestone.
IV. Kupferschiefer.	Marl-slate.
V. Weissliegendes.	Not represented in England.

Prof. Wm. King places the magnesian limestone of Tullyconnel, Co. Tyrone, Ireland, in the uppermost portion of the series.

Of these divisions the beds yielding Foraminifera are confined in England to Nos. I, II, and III, in Ireland to No. I, and in Germany to II, III, and IV.

My work in respect to the Permian species of Foraminifera has lain rather in the examination and comparison of specimens from localities already well known, the embodiment of information contained in many scattered papers, and the revision of the nomenclature of the group, than in the investigation of material from unsearched ground. To Dr. R. Richter, of Saalfeld, I am indebted for much assistance in this portion of the subject. Not only has he supplied me liberally with material from the Thuringian beds and with specimens from his own collection, but has further facilitated the determination of doubtful species by furnishing accurate drawings of well-marked examples, some of which are now reproduced as illustrations. Dr. Richter has also communicated the details from which the table of distribution, so far as it concerns the Thuringian species, has been drawn up.

My thanks are also due to Mr. J. W. Kirkby, whose labours in connection with the fossil microzoa of the English Permian beds are widely known and as widely valued, for the loan of specimens and for much exact information as to localities.

In the following list, both English and German localities have been numbered in groups rather than individually, the species being few in comparison to the number of stations at which they have been observed.

ENGLAND.

Lower Magnesian Limestone.

143. Durham—including
Hartley's Quarry, Millfield, Sunderland.
Pallion, a mile and a half west of Sunderland.
Westoe, near South Shields.
Offerton, three miles west of Sunderland.

Rough Dene, near Houghton-le-Spring.
Eldon, three miles south-east of Bishop Auckland.
Langton, two and a half miles east of Staindrop.
Morton Tinmouth, four miles east of Staindrop.
Summerhouse, six miles north-west of Darlington.
Thrislington Gap, Ferry Hill.
Running Waters, four miles east of Durham.
Moorsley, south of Houghton-le-Spring.
Walworth, four miles north-west of Darlington.
Limekiln Banks, two and a half miles north of Piercebridge.

144. Yorkshire—including
Nosterfield, near Masham.
Gybdykes, near Masham.
Chapel Houses, south of the Tees, near Gainford.
Thornton Watlass, south-west of Bedale.
Linderick, near Ripon.
Hampole Inn, north-west of Doncaster.

Middle Magnesian Limestone.

145. Durham—including
Tunstall Hill, one mile and a half south-west of Sunderland.
Humbleton Hill, one mile west of Sunderland.
Claxheugh, two miles west of Sunderland.

Upper Magnesian Limestone.

146. Durham—
Byers Quarry, on the coast between Sunderland and South Shields.

IRELAND.

Upper Magnesian Limestone.

147. Tyrone—
Tullyconnel, near Artrea.

GERMANY.

Unterer Zechstein.

Kupferschiefer (Bituminous Marl-slate).

148. Thuringia—at Königsee, Saalfeld, Pösneck, and Gera, and especially at Köpsen, Trebnitz, and Milbitz.

Zechstein proper.

149. Thuringia—at Sonneberg am Schlossberge, at Königsee and Saalfeld; in the Rothen Berge at Pösneck, in the neighbourhood of Neustadt on the Orla, at Gera in Zaufensgraben, and at Zschippern.

150. Selters, in the Wetterau; list compiled from Dr. E. E. Schmid's paper.

Mittler Zechstein.

Rauchwache or Dolomite.

151.[1] **Thuringia**—at Saalfeld, at Kamsdorf on the Rothen Berge, at Pösneck on the Altenburg, also between Königsee and Blankenburg.

§ 7. BIBLIOGRAPHY.

The following are the titles in full, and arranged in chronological order, of the various books and memoirs referred to in subsequent pages. The bibliography of the genus *Fusulina* has not been included, but with this exception the list has been made as complete a synopsis as possible of the literature connected with Carboniferous and Permian Foraminifera. In a few instances references are made in the text to papers which only affect the subject incidentally and have no important bearing upon it; and, as in these cases sufficiently detailed information is given where the quotation occurs, it has not been thought desirable to extend an already lengthy category by their insertion.

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[1] Numbers **152** to **161** have been inserted since the tables were drawn up. They will be found as follows:—**152, 153, 154,** on p. 35; **155** on p. 36; **156, 157,** on p. 39; **158** on p. 36; **159** on p. 31; **160** on p. 34; **161** on p. 43.

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1873. Etheridge, Robert, Jun., "On the Occurrence of Foraminifera (*Saccammina Carteri*, Brady) in the Carboniferous Limestone Series of the East of Scotland" ('Trans. Edin. Geol. Soc.,' vol. ii). *Edinburgh.*

1873. Brady, H. B., "On Archædiscus Karreri, a new Type of Carboniferous Foraminifera" ('Ann. and Mag. Nat. Hist.,' ser. 4, vol. xii). *London.*

Id. *Ibid.* Abstract ('Report Brit. Ass.,' Bradford Meeting). *London.*

1874. Reuss, Dr. A. E. von, in Dr. H. B. Geinitz's "Das Elbthalgebirge in Sachsen, 2ter Theil. Der mittlere und obere Quader.—iv, Die Foraminiferen, Bryozoen und Ostracoden des Pläners." *Cassel.*

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1874. Tute, J. S., "Organisms in Carboniferous Flint or Chert" ('Science Gossip,' August, 1874, p. 188). *London.*

1874. Bornemann, L. G., Junr., "Ueber die Foraminiferengattung Involutina" ('Zeitschr. d. deutsch. geol. Gesellsch.,' Jahrg. 1874). *Berlin.*

1875. Lebour, G. A., "On the 'Great' and 'Four-fathom' Limestones and their associated beds in South Northumberland" ('Trans. N. of Eng. Inst. Min. Engineers,' vol. xxiv). *Newcastle.*

1876. Bennie, James, "Note on the Range of Saccammina Carteri, *Brady*, in the Carboniferous Series" ('Geol. Mag.' N. S., Decade II, vol. iii, p. 47). *London.*

1876. Jones, T. Rupert, "Remarks on the Foraminifera, with especial reference to their Variability of Form, illustrated by the Cristellarians" ('Monthly Micros. Journ.,' Feb., 1876, p. 61). *London.*

§ 8. DESCRIPTION OF GENERA AND SPECIES.

Sub-Kingdom, PROTOZOA.

Class, RHIZOPODA.

Order, RETICULARIA.

(FORAMINIFERA.)

Sub-order, IMPERFORATA.

Family, LITUOLIDA, *Carpenter.*

Genus, Saccammina, *Sars.*

Nodosaria (?), *M'Coy.*
Saccammina, *Sars, Carpenter, Brady, Etheridge, J. Young, Lebour, Bennie, Rupert Jones.*
Carteria, *Brady.*

General Characters.—Test free; consisting either of a single subglobular or pyriform chamber with central, pouting aperture, or a number of fusiform segments joined end to end. Texture arenaceous, compact, smooth externally, or nearly so, more or less rugose or labyrinthic on the interior surface.

Professor Sars, in his paper on the results of deep-water dredging on the coast of Norway,[1] records the occurrence of a monothalamous Foraminifer, previously undescribed, to which he gives the name *Saccammina sphærica*, regarding it as the representative species of a new genus. No description, generic or specific, is given in the memoir referred to, nor indeed any further particulars respecting the organism, except that it was

[1] "Fortsatte Bemærkninger over det dyriske Livs Udbredning i Havets Dybder," in the 'Vidensk.-Selsk. Forhandlinger,' for 1868, p. 248.

dredged in 450 fathoms, at which depth it appeared to be abundant. Subsequently a number of specimens were forwarded to Dr. Carpenter, who described the type in general terms as having a "test of regular spherical form with a flask-shaped neck; the test composed of large sand-grains firmly cemented together so as to present a smooth exterior, whilst their angles project into the interior of the cavity, which is filled in the living state with sarcode."[1]

The Carboniferous form about to be described differs from the type thus characterised in its moniliform mode of growth and the consequent distomous condition of the chambers, but these may be regarded as mere morphological variations of little weight as compared with similarity in general and minute structure. The fossil species therefore has been placed in the same genus with the living deep-sea form, and the generic characters have been defined afresh, so as to include the polythalamous specimens.

SACCAMMINA CARTERI, *Brady*. Pl. I, figs. 1—7; and Pl. XII, fig. 6.

NODOSARIA FUSULINAFORMIS, (?) *McCoy*, 1849. Ann. and Mag. Nat. Hist., ser. ii, vol. iii, p. 131.
— — (?) *Id.*, 1854. Contrib. Brit. Palæont., p. 100.
CARTERIA, sp. *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, p. 372.
SACCAMMINA CARTERI, *Brady*, 1871. Ann. and Mag. Nat. Hist., ser. iv, vol. vii, p. 177, pl. xii.
— — *Id.*, 1871. Nat. Hist. Trans. Northumberland and Durham, vol. iv, p. 269, pl. xi.
— — *Etheridge* (jun.), 1873. Trans. Edin. Geol. Soc., vol. ii, p. 225.
— — *Id.*, 1873. Mem. Geol. Surv. Scotland, expl. sheet 23, p. 96.
— — *Young*, 1873. Trans. Geol. Soc. Glasgow, vol. iv, part iii, p. 259.
— — *Lebour*, 1875. Trans. N. of Eng. Inst. Min. Engineers, vol. xxiv, p. 141, pl. xxxiii, fig. 2.
— — *Bennie*, 1876. Geol. Mag., n. s., Decade II, vol. iii, p. 47.

Characters.—Test free, consisting of several chambers joined end to end in single series; chambers subspherical, fusiform or pyriform; texture arenaceous, compact; exterior surface nearly smooth; interior sometimes smooth but usually rugose, often more or less labyrinthic. Long diameter of the chambers about $\frac{1}{8}$th inch (3·2 mm.) in average specimens.

[1] 'Descriptive Catalogue of Objects from Deep-Sea Dredgings exhibited at the Soirée of the Royal Microscopical Society, King's College, April 20th, 1870,' by Dr. Carpenter, F.R.S., p. 5, No. 4.

This somewhat important fossil formed the subject of a paper by myself in the 'Ann. and Mag. Nat. Hist.' (*loc. cit.*) about five years ago. A few separated segments collected by Mr. Charles Moore, whilst engaged upon the fossils found in mineral veins, had been sent to me a year or two previously with other microzoa for examination, but these were insufficient for accurate description, and the provisional name *Carteria* was given to them with the idea that they were chambers of an organism belonging to a new type of *Lituolæ*. The bed of limestone on Sir W. C. Trevelyan's estate at Elfhills in Northumberland, which furnished the material for my paper, had been known for many years, and its physical peculiarities had not passed unnoticed, but it had not been submitted to microscopic examination, and had been generally regarded as a pisolitic or concretional rock. The particular layer of the Four-fathom Limestone, characterised by the presence of *Saccammina* has for generations been known to the Alston miners as the "spotted post."

I was not aware till long after the paper referred to was published that the organism had been previously recognised as a fossil, still less as a Foraminifer. I find, however, by Mr. Bennie's note in the 'Geological Magazine' for January, 1876, that *Saccammina* had been collected by Mr. R. Gibbs as far back as the year 1858 or thereabouts, and that the specimens were entered by the late Mr. Salter in the Jermyn Street Catalogue of Fossils, published in 1865 as "Foraminifera in Limestone; Cat Craig, Dunbar," though without further particulars.

My attention has also been called to Professor M'Coy's description in the year 1854, of a Carboniferous fossil which he names "*Nodosaria fusulinaformis*," collected in the Parish of Shivey, Co. Tyrone, Ireland. The brief verbal description answers fairly to the general characters of *Saccammina* as far as it goes, except in the statement that the organism "agrees almost perfectly with d'Orbigny's *Nodosaria rudis* and *N. rugosa*;" but it appears to me insufficient, in the absence of any assistance from figures, to identify the species. I have endeavoured to obtain further information from the officials of the Irish Geological Survey, and from other geologists likely to be acquainted with the subject, but hitherto without result. Under these somewhat difficult circumstances I have thought the course least open to objection and certainly that least likely to lead to confusion would be to retain the name by which the fossil has become generally known amongst geologists and palæontologists.

The characters of the Carboniferous *Saccammina* and its mode of occurrence will be more satisfactorily gathered from the figures on Pl. I than from any mere verbal description. It is essentially a rock-builder; that is to say, whole beds of limestone of large extent and considerable thickness appear to be chiefly, and in places entirely, composed of its remains. The description originally given of its occurrence in the two beds at Elfhills in Northumberland applies equally to rock specimens from other localities, and may be repeated without material alteration.

"The uppermost bed exposed in the Elfhills quarry appears to be entirely com-

posed of spheroidal or fusiform bodies, but so aggregated and infiltrated that they form an intensely hard dark-coloured limestone, the freshly fractured surface of which appears almost homogeneous and sometimes subcrystalline. It is, however, readily acted upon by the atmosphere; and the weathered portions reveal a spheroidal structure that might at the first glance be assigned to purely physical causes depending on some peculiarity in the mode of deposit. A fair idea of the characters of the rock forming this bed may be gained from Plate I, fig. 1, which represents an average specimen, with the upper surface considerably weathered. Very frequently the disintegration, instead of being merely superficial as in the figured specimen, extends to a considerable depth, leaving the stone in the condition of a crumbling mass of spheres. A layer in this state often exists between the surface-soil and the hard rock; and by a little treatment the fossil portions may be obtained from it quite clear of the matrix. A few feet below this upper layer (in the same section), is a second and more considerable bed, with the same sort of fusiform bodies distributed through its entire length and thickness. The individual specimens are larger than those occurring in the later deposit, but they do not constitute nearly so considerable a proportion of the entire rock. The segments do not appear to differ in structural characters from those found in the upper bed."[1]

Notwithstanding the black and to the naked eye almost homogeneous texture of the rock as exhibited by a freshly fractured surface, a section thin enough to be transparent shows exactly the structure that might be expected from the condition of the disintegrating portions—a mass of fusiform segments cut in various directions. Such a section is seen in Pl. XII, fig. 6.

The dimensions of the individual segments vary considerably in different localities, indeed even in the same bed specimens differing much both in size and shape may be found, as shown in Plate I, fig. 3. These, however, represent an extreme range, and in many rocks the chambers are exceedingly uniform in external characters averaging about $\frac{1}{8}$ inch (3·2 mm.) in length, and $\frac{1}{12}$ inch (2·1 mm.) in transverse diameter: large specimens may be found measuring $\frac{1}{6}$ (4·2 mm.) or even $\frac{1}{5}$ inch (5· mm.) by $\frac{1}{9}$ (2·8 mm.) or $\frac{1}{8}$ inch (3·2 mm.); but such are of rare occurrence. Sometimes they are more elongate; and extreme examples have been noted in which the conjugate and transverse diameters were in the proportion of 3 to 1. The two ends are usually produced and tubular, to permit the passage of sarcode stolons or pseudopodia: they are sometimes symmetrical, but more frequently one end tapers more gradually than the other.

Owing to the tenuity of the connecting stolons, the segments are almost invariably found separated. Occasionally the weathered surface of the rock reveals two or even three chambers united in a line, but this is quite an exceptional circumstance. The dissociation of the segments is probably entirely due to external agencies, for that the addition of chamber to chamber might go on indefinitely under favorable conditions can scarcely be doubted. Nor does this rest on mere assumption, as reference to Plate I, fig. 4,

[1] Ann. and Mag. Nat. Hist., 4 ser., vol. vii, p. 178.

will demonstrate. This figure represents a fossil shell (*Euomphalus?*) found by Mr. F. M. Balfour of Trinity College, Cambridge, in the Carboniferous Limestone of Haddingtonshire, about three miles from Dunbar. On grinding the specimen it was found that what had been the empty cavity of the shell was partially occupied by the remains of *Saccamminæ* which, when living, had taken up their abode there, and a chain of fusiform segments was exposed exactly as it appears in the drawing. Making a little allowance for the irregularity of the line of growth, it may be assumed that one segment has been out of the plane of the section and has been ground off, and if so this individual specimen has consisted of not less than eleven chambers united by stoloniferous tubes.

The test of *Saccammina* is essentially composite and arenaceous, the constituent particles being fitted and cemented together so as to give a nearly smooth exterior. The interior surface varies a good deal in different specimens. Sometimes it is nearly smooth, or roughened only by the projecting angles of the constituent sand-grains, which are usually much smaller in size than those selected by the recent species for shell-building purposes. In other cases the inner surface is covered with a network of short delicate labyrinthic growths, as seen in Pl. I, fig. 5.

Peculiar conditions of infiltration render it very difficult to speak in positive terms concerning the minute structure of the test. Plate I, fig. 6, represents a highly magnified tangential section which, though insufficient for the determination of the size or form of the constituent sand-grains, demonstrates clearly enough the arenaceous structure of the test both in its compact and labyrinthic portions.

There may frequently be observed on the exterior of the segments minute circular scars, of which Plate I, fig. 7, is an example. They are formed of three, four, or more slightly raised, granular, concentric rings, the outermost having a diameter of a thirtieth of an inch (0·85 mm.) or less. It is not easy to offer a satisfactory explanation in respect to them, but they are of too frequent occurrence and too uniform in character not to have a meaning, and therefore cannot be passed over entirely without notice—in some cases they look like the result of the repair of an injury to the test.

In the *Saccammina* limestone, the matrix is usually softer than the fossils embedded in it, and frequently the infiltrated matter which occupies the interior of the segments is harder than the fossilized test. Chemical analysis being resorted to for an explanation, it was found that some specimens of the rock contained a very large percentage of silica. If a number of segments of *Saccammina* from the disintegrated rock be broken, it will be found that the interior of each is occupied either by a smooth amorphous cast completely filling the cavity, or, much less frequently, by a loose tuft of crystals. The amorphous casts have been found to consist of colloid silica; the crystalline tufts (Plate I, fig. 5), of carbonate of lime. The mineral contents of a large number of chambers, taken at random from a piece of the weathered Elfhills Limestone, yielded more than 90 per cent. by weight of silica, whilst the tests themselves were almost purely calcareous.

The observations on this species have been made almost solely from Northumbrian specimens, but the same conditions appear to prevail very generally, though varying in degree.

Saccammina Carteri is not likely to be confused with any other fossil which we are at present acquainted with, but unorganized concretional limestones may very readily be mistaken for it, and indeed very frequently are so. I possess a considerable collection of oolitic and pisolitic rocks of Carboniferous, Devonian, and Silurian age, which have been sent to me from various parts of the world under the impression that the constituent spheroids, single or coalescing, were segments of this fossil or of some allied species. In many of these the general resemblance to *Saccammina* is very striking, and it has often been impossible to come to any conclusion as to the real structure of the rock without having recourse to thin microscopical sections.

Distribution.[1]—In England the occurrence of *Saccammina Carteri* is confined to the northern portion of the Carboniferous area. Throughout Northumberland and as far south as Alston in Cumberland, its appearance is limited to the Four-fathom Limestone, but in Weardale (Durham) it has been found in one locality at a considerably higher horizon—the Great Limestone. In Westmoreland only one locality has been noted, and this is regarded as belonging to the lower series of beds—the Scar limestone.

In Scotland its geological range is very great. It has been traced by the Survey collectors from the Calciferous Sandstone Series, through the Lower Carboniferous Limestone group, into the Upper Carboniferous Limestones, though in the later beds it has only been recorded from one or two localities.

From Belgium I have a number of quite characteristic specimens from the Calcaire de Visé, the uppermost division of the Carboniferous limestones of that country.

Genus, LITUOLA, *Lamarck.*

SERPULA (in part), *Schröter.*
LITUOLA, *Lamarck, Blainville, d'Orbigny, Reuss, Parker and Jones, Carpenter, Seguenza, Brady, G. M. Dawson, Robertson, Vanden Broeck.*
LITUOLITES, *Lamarck, Parkinson, Blainville.*
SPIROLINA (in part), *d'Orbigny.*
NONIONINA (in part), *d'Orbigny, Schultze, Williamson, Parfitt.*

General characters.—Test free, nautiloid or crozier-shaped, either entirely spiral, or spiral in the arrangement of the early segments and rectilinear in the later ones.

[1] For details concerning the distribution of the various species of Foraminifera see the Tables at the end of the paper (pp. 153—161). This and the corresponding paragraphs appended to the descriptions of the species are summaries only.

Interior labyrinthic, or having the chamber cavities subdivided by irregular, ramifying septa. Texture arenaceous, rough externally. Aperture irregular, compound, or dendritic.

It will be seen by the above brief summary of characters that the term (*Lituola*) is here employed very much in the restricted sense in which it is used by German systematists; that is, to the exclusion of the adherent Lituoline forms (*Placopsilina* d'Orb.), the uniserial, non-convoluted varieties (*Reophax*, Montfort), and those with non-labyrinthic chamber cavities (*Haplophragmium*, Reuss),—all of which hitherto have usually been included in the genus by English authors. On a previous page an outline of the general scheme of classification of Foraminifera propounded by Professor Reuss was given, and this may properly be supplemented by his views on the arrangement of the group "*Lituolidea*" as elaborated in his latest work, together with his preliminary remarks thereupon. The summary of which the following is a translation will be found in the second part of "Das Elbthalgebirge in Sachsen," p. 119, a memoir published in 1874, that is the year following the lamented death of its author.

"1. Lituolidea."

"Test free or attached, either entirely spiral or spiral in the earlier and rectilinear in the later portions, or else having the chambers strung together in a single, almost straight, or crooked line. The chambers often nearly regular, with simple undivided cavity, or sometimes having the interior subdivided by very irregular, shelly ingrowths. Aperture simple or compound, externally cribriform, perforated.

"The English investigators of the Foraminifera place together almost all the Lituoline forms under the genus *Lituola*, which thereby is endowed with a very wide range. I prefer, even on palæontological grounds, notwithstanding an undeniably close relationship to arrange them in a larger number of groups. This result is brought about in the following scheme:"

1. Test adherent: *Polyphragma*, Reuss.
2. Test free.
   - A. Chamber cavities simple, not subdivided: *Haplophragmium*, Reuss.
     - *a*. Entirely spiral, orifice crescentic, situated on the inner margin of the terminal chamber adjoining the previous convolution. (Nonionine forms.)
     - *b*. Test with spiral commencement, later chambers in straight series, crozier-shaped; aperture simple or compound, terminal. (Spiroline forms.)
     - *c*. Test completely spiral. Aperture rounded or elliptical, approximately in the middle of the convex septal plane. (*Orbignyina*, von Hagenow.)
   - B. Chamber cavities subdivided by irregular, ramifying septa, cellular.
     - *a*. Test spiral at the commencement afterwards straight, crozier-shaped; mouth dendritic, labyrinthic or compound. *Lituola*, Lamarck.

b. Segments joined together in a single row. Test straight and *Nodosaria*-like, or arcuate like *Dentalina*. The terminal aperture simple. *Haplostiche*, Reuss."

Minute criticism on this scheme of classification would be out of place for many reasons; partly in that it would occupy space that could not very well be spared for it, but much more because until the full bearing of the results of recent deep-sea dredgings is understood, it would be futile to suggest terms for its modification or revision. The vast additions to our knowledge of the arenaceous Rhizopoda which have accrued from researches made within the last few years on the deep-sea bed will, it is hoped, yield the basis for a more satisfactory arrangement of the entire group than has hitherto been practicable. One or two points, however, require notice. Professor Reuss's group "*Lituolidea*" must not be supposed to be coextensive with the family "*Lituolida*" of Messrs. Carpenter, Parker, and Jones, for in point of fact it scarcely even includes as much as the generic term "*Lituola*" as employed by English authors. The propriety of separating the labyrinthic and nonlabyrinthic forms seems confirmed by the strikingly distinct characters of the large deep-sea specimens, and this has led to the adoption of Professor Reuss's generic term, *Haplophragmium*, as distinct from *Lituola* proper, in the present paper.

If it be desirable to separate the moniliform or uniserial varieties from the helicoid forms by a generic or subgeneric term, de Montfort's name *Reophax* must take precedence of Reuss's *Haplostiche*. But it is unnecessary to dwell on points like these. *Lituola* (proper) is represented in the Carboniferous beds by the typical form, and by a very fine large nautiloid variety, both of them very rare.

LITUOLA NAUTILOIDEA, *Lamarck*, Pl. VIII, fig. 7 *a*, *b*.

LITUOLITES NAUTILOIDEA, *Lamarck*, 1804. Ann. Mus., vol. v, p. 243, No. 1;—vol. viii, pl. lxii, fig. 12;—1822, Anim. s. Vert., vol. vii, p. 604, No. 1.

— DIFFORMIS, *Id.* Ibid., vol. v, p. 243, No. 2;—vol. viii, pl. lxii, fig. 13, *a*, *b*; —1822, Anim. s. Vert., vol. vii, p. 605, No. 2.

— NAUTILOIDEA, *Parkinson*, 1811. Organic Remains, vol. iii, p. 161, pl. xi, fig. 5.

— DIFFORMIS, *Id.* Ibid., p. 161, pl. xi, figs. 6, 7.

LITUOLA NAUTILOIDES, *Lamarck*, 1822. Tableau Encl. Méth., pl. cccclxv, fig. 6.

— DIFFORMIS, *Id.* Ibid., pl. cccclxvi, fig. 1, *a*, *b*.

— (et LITUOLITES) NAUTILOIDES, *Blainville*, 1824. Dict. Sci. Nat., vol. xxvii, p. 81;—vol. xxxii, p. 190;—Atlas Conch., pl. xx, fig. 3;—1825, Malacologie, p. 381, pl. xi, fig. 3.

SPIROLINA NAUTILOIDES, *d'Orbigny*, 1826. Ann. Sci. Nat., vol. vii, p. 287, No. 6.
LITUOLA NAUTILOIDEA, *d'Orbigny*, 1840. Mém. Soc. Géol. Fr., vol. iv, No. 1, p. 29, pl. ii, figs. 28—31.
— — *Id.*, 1846. For. Foss. Vienne, p. 138, pl. xxi, figs. 20, 21.
— — *Parker and Jones*, 1860. Ann. and Mag. Nat. Hist., ser. 3, vol. v, p. 287.
— — *Reuss*, 1860. Sitzungsb. k. Akad. Wiss. Wien., vol. xl, p. 220, pl. x, figs. 5—8.
— — *Carpenter*, 1862. Introd., p. 144, pl. vi, fig. 44.

Characters.—Test free, elongate, compressed, crozier-shaped, rounded at the base, truncate or convex at the apex, margin rounded. Early chambers convoluted, later ones in straight series. Segments numerous, narrow. Aperture labyrinthic, or consisting of numerous, irregular orifices. Length $\frac{1}{10}$ inch (2·5 mm.).

What has already been said in the general description of the genus leaves little beyond matters of detail to be noticed concerning this its central type.

The dimensions of *Lituola nautiloidea* above given refer only to the Carboniferous specimens—it is in the microzoic rocks of Cretaceous age that the species appears to greatest advantage. According to d'Orbigny it attains the length of 7 millim. or more than a quarter of an inch in the White Chalk of the Paris basin, and Professor Reuss records even larger dimensions, viz. 9·87 mm., or nearly four tenths of an inch, in specimens from the Chalk of Westphalia. Not only does the species vary in size, but also in many other external features, such as the condition of the surface as to rugosity, the relative development of the spiral and straight portions of the test, and the convexity of the segments. It is necessary to bear these facts in mind in judging of specimens—few in number, and worn and obscure in their characters—as they appear in the Carboniferous beds, yet such forms as that represented in the plate are but little removed in morphological characters from some of those of Cretaceous origin figured by Professor Reuss.

Distribution.—Very rare; only known as a Carboniferous species by one or two specimens found in the Bottom Limestone at Skelly Gate, near Ridsdale, Northumberland.

LITUOLA BENNIEANA, *nov.*, Pl. I, figs. 8—11.

Characters.—Test free, nautiloid, subglobular, somewhat depressed at the umbilicus; margin rounded. Segments few in number, about five visible externally, inflated. Aperture compound, consisting of several orifices of various sizes, distributed irregularly over the face of the terminal segment. Interior labyrinthic. Diameter $\frac{1}{10}$ inch (2·5 mm.) or more, thickness $\frac{1}{12}$ inch (2·0 mm.).

In the collection of Carboniferous fossils formed by the Geological Survey of Scotland are a few examples of a large nautiloid Foraminifer of unmistakably Lituoline characters. They are by no means uniform in general contour and bear evidence of having undergone a certain amount of change from external causes. The specimen figured (Pl. I, figs. 8, 9) is perhaps the best of the set, and is probably in nearly its original condition in form and structure. Others appear to have been subjected to lateral pressure, and are of lenticular (biconvex) shape, whilst some few are merely casts, from which the test has entirely disappeared.

The finer specimens are perhaps the largest nautiloid Foraminifera of Carboniferous age hitherto met with, some of them being more than one tenth of an inch in diameter. The exterior surface of the test seems to have been a good deal worn, and the component sand-grains, which are remarkably uniform in size, are very clearly shown. The roughness and unevenness of its inner surface may be gathered from the appearance of some of the casts. One of these, from a smaller individual of the same species is represented in Pl. I, fig. 9. The minute structure of the test has in some instances been perfectly preserved by the completeness of the calcareous infiltration, and the transparent section of such a specimen, under a high magnifying power (Pl. I, fig. 11), shows the peculiar tubular or cancellated ingrowths, which, partially or entirely filling the cavities of the chambers, form what is known as "labyrinthic" structure. On the other hand, to the same complete infiltration may perhaps be attributed the difficulty of determining the nature of the general aperture. Depressions on the anterior face of the terminal segment seem to indicate the existence originally of a number of irregular perforations of various sizes; and a compound aperture of this sort is consistent with the known tendency of the *Lituolida*.

The only Carboniferous species to which *Lituola Bennieana* bears any great resemblance, or with which it is likely to be confused is *Endothyra crassa*. The latter, however, though larger than many of its congeners, is smaller and smoother in texture than the Lituoline form; it has also a much larger number of chambers, is more compactly built, has the simple aperture of its own genus, and has no labyrinthic structure: an array of characters sufficient to distinguish the two under any ordinary circumstances.[1]

The first specimens of *Lituola Bennieana* which came under my notice were obtained by Mr. James Bennie the assiduous collector to the Geological Survey of Scotland, whose name may well be associated with so fine a species.

[1] Since this has been in the printer's hands I have received a considerable supply of *Lituola Bennieana* from Mr. R. Etheridge, jun., and it now appears that the species is comparatively common in the Mount Lothian Quarry, where it is associated with *Endothyra crassa*. Further examination confirms the distinctive characters above enumerated in all essential points, and seems to indicate that the labyrinthic structure and cribriform aperture are the most generally reliable. But the labyrinthic or cancellated portion is often only a thin layer lining the inner surface of the shell-wall, and to observe it satisfactorily it is necessary to make horizontal sections very near the surface of the test.

Distribution.—Bents' Quarry, near Carlops, Peebleshire, and Mount Lothian Quarry, near Penicuick, Edinburghshire; in both places, in the shales connected with the No. 2 Limestone of the Lower Carb. Limestone group. In the Calcaire de Namur at Flémalle near Liége, Belgium, and in the Fusulina-limestone of Miatschkovo, near Moscow, Russia. In most of the localities very rare.

Genus.—HAPLOPHRAGMIUM, *Reuss.*

SPIROLINA (in part), *d'Orbigny, Roemer, Reuss.*
SPIROLINITES, *Northampton, Mantell.*
LITUOLA (in part), *d'Orbigny, Parker and Jones, Carpenter, Brady.*
HAPLOPHRAGMIUM, *Reuss, Karrer, Stache, Gümbel.*
PROTEONINA (?), *Williamson.*
POLYMORPHINA (in part), *Terquem.*

General characters.—Test free; either entirely spiral and convoluted, or spiral only in the earlier portion, the later segments being arranged in single rectilinear series. Segments numerous, usually distinct; cavities simple, undivided. Texture arenaceous, more or less rough externally. Aperture terminal, central; simple or compound.

As has been already stated, the distinction between *Haplophragmium* and *Lituola*, in Professor Reuss's arrangement, depends upon the labyrinthic structure of the interior in the latter genus as contrasted with the undivided chamber-cavities of the former. In the light of recent researches upon the large arenaceous types of deep-sea Rhizopoda, the significance of this peculiarity may be somewhat greater than has been hitherto recognised amongst us, and in spite of some difficulty attending its adoption, it may serve as a useful purpose in the subdivision of the class.

Only a single variety of *Haplophragmium* has been found in the Palæozoic formations, and this does not correspond satisfactorily in minor characters with any description hitherto published.

HAPLOPHRAGMIUM RECTUM, *Brady.* Pl. VIII, figs. 8, 9.

INVOLUTINA RECTA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382.

Characters.—Test elongate, crozier-shaped. Spiral portion depressed, relatively very small, margin rounded, septa somewhat indistinct: linear portion long, gradually increasing in diameter, sutures more or less excavated. Segments numerous, slightly

inflated. Aperture simple. Texture finely arenaceous, nearly smooth. Length about $\frac{1}{60}$ inch (0·43 mm.).

The delicate little fossil, to which the specific name now adopted was some years ago provisionally given, does not appear to have been otherwise figured or described. As a species it is similar in many of its morphological characters to *Haplophragmium Humboldti*, a Tertiary form described by Professor Reuss,[1] though it differs considerably in others. For instance, *H. Humboldti* has a stoutly made test 3 mm., or about one ninth of an inch in length, and with a much greater proportionate thickness than *H. rectum*, and is therefore many times the size of the slender Carboniferous form. Again, the spiral portion of the shell of the Tertiary species, besides being relatively very large, has a sharp angular periphery, whilst in the older form the helicoid chambers are of insignificant proportions and have their margins rounded. Other differences might be enumerated, but in the absence of intermediate varieties those which have been advanced are sufficient to warrant distinctive appellation, though a larger supply of specimens would be necessary to determine the range of variation to be included under the new name.

Distribution.—Carboniferous Limestone (Yoredale) at Grassington, near Skipton, Yorkshire,—very rare.

Genus.—Climacammina,[2] *Brady*.

Textularia, *Brady* (in part).
Climacammina, *Brady*.

General characters.—Test free, consisting of many segments of irregular contour and unevenly combined; typically, biserial or subspiral in the earlier, uniserial in the later stages of growth. Texture finely arenaceous. Interior more or less labyrinthic. Aperture irregular or cribriform. Septation obscure.

It has not been without considerable hesitation that the peculiar forms which were at first referred provisionally to the genus *Textularia* under the name *T. antiqua*,[3] have since been taken as the representatives of a generic group. That the specimens bear a close analogy to the "Bigenerine" varieties of *Textularia* will be seen by reference to the figures (Pl. II, figs. 1—5), especially to those of the less irregular examples such as figs.

[1] *Spirolina Humboldti*, Reuss, 1851, 'Zeitschr. d. deutsch. geol. Gesel.,' vol. iii, p. 65, pl. iii, figs. 17, 18. Subsequently as *Haplophragmium Humboldti*, 1866, 'Denkschr. math.-natur. Cl. K. Akad. Wiss. Wien,' vol. xxv, p. 119, pl. i, figs. 1—4.

[2] Derivation, Greek κλῖμαξ, κλίμακος, a ladder, and ἄμμος, sand.

[3] 'Trans. Geol. Soc. Glasgow,' 1871, vol. iii, Suppl., p. 13.

1 or 3, but more complete examination shows that the resemblance is that of analogy, rather than of relationship. The arenaceous exterior of *Bigenerina* (as of *Textularia* generally) is the result of sandy incrustation on a normally perforate shell-wall; the shell in that genus is regularly and neatly built, and the aperture takes the form of a single, rounded, central, terminal orifice. These are more important peculiarities than the mere order of the segments. On the other hand, the thick, finely arenaceous tests of the specimens under consideration, their irregular septation, labyrinthic chambers and compound apertures, are characters that necessarily give them a place amongst the *Lituolida*. In many particulars they bear considerable resemblance to varieties of the genus *Haplophragmium* figured by Reuss,[1] but the absence of the regular, depressed, spiral arrangement in the earlier chambers would, of itself, preclude their being associated with the typical members of that group; and observations especially on young and on monstrous specimens seem to indicate that these obscure Carboniferous forms are allied to *Valvulina* rather than to *Lituola* proper or *Haplophragmium*. In some young examples the earlier portion of the test, possibly at first the whole organism, is almost conical, and divergence from the *Valvulina*-like mode of growth begins in an uneven or oblique setting on of chambers. But the conical aspect of this part of the test is lost as the Textularian habit is subsequently developed. On the whole it seems clear that such forms could not with propriety be assigned to any previously recognised genus.

CLIMACAMMINA ANTIQUA, *Brady*, Pl. II, figs. 1—9.

TEXTULARIA ANTIQUA (*Brady*, MS.), *Young and Armstrong*, 1871. Trans. Geol. Soc. Glasgow, vol. iii, Suppl., p. 13.
CLIMACAMMINA ANTIQUA, *Brady*, 1873. Mem. Geol. Survey Scotland, Expl. Sheet 23, p. 94.

Characters.—Test elongate; subcylindrical, compressed or spathulate, unsymmetrical, sometimes curved at its commencement. Earlier chambers irregularly biserial or subspiral; later ones uniserial, often set on obliquely. Septation imperfect; sutures marked externally by depressed lines. Segments numerous, more or less ventricose externally; interior subdivided or labyrinthic. Shell-texture compact, firmly arenaceous. Aperture formed of several irregular orifices on the face of the terminal segment. Length $\frac{1}{25}$ to $\frac{1}{10}$ of an inch (1·0 to 2·5 mm.) or more.

A large number of specimens, presenting amongst them a wide range of variation in

[1] See especially *Haplophragmium irregulare* and *H. æquale* in the memoir on the Foraminifera of the Chalk of Westphalia ('Sitzungsb. k. Akad. Wissensch. Wien,' 1860, vol. xl, p. 74, pl. x, fig. 9, and pl. xi, figs. 2, 3).

external appearance, have been placed together under the single specific term *Climacammina antiqua*. Some of them are long and flat, spathulate, tapering almost symmetrically, as in Plate II, fig. 3; others are flat, curved at the commencement, with the segments throughout set on obliquely like fig. 1; some have the early Textularian chambers combined in a reversed manner, that is, with their broad faces in apposition, as shown in figs. 4, 5; whilst occasionally instances are seen in which, probably from irregular subdivision of some of the segments, the early portion of the test appears as though triserial, or confused in its order of growth. Casts of the interior of the later chambers have been found (figs. 6, 7), indicating that at times these must have taken the form of a string of thick, round-edged, circular disks, regularly superimposed.

A transparent longitudinal section (Pl. II, fig. 8) shows an interior with confused and imperfect septation; the chamber-cavities more or less subdivided, and filled by labyrinthic ingrowths of the shell-wall—the arenaceous structure of the investment, and the cancellated form of the supplementary growths, being readily made out under a high magnifying power, as shown in fig. 9.

The compound character of the aperture may be observed either from the test itself, as represented in fig. 4, or still better from the casts of the interior of the terminal chambers before alluded to (figs. 6, 7), which of course are exact models of the sarcode lobes of the animal, even to the little protuberances filling up the pseudopodial apertures.

Distribution.—Found in both the lower and higher series of the Carboniferous Limestone (Scar and Yoredales) of England, and in the Lower and Upper Carboniferous Limestone Groups of Scotland. Localities numerous, but the number of specimens never very large. Doubtful specimens have been noticed in the Fusulina-limestones of Russia.

Genus.—TROCHAMMINA, *Parker and Jones.*

NAUTILUS (in part), *Montagu, Pennant, Turton.*
WEBBINA (in part), *d'Orbigny.*
OPERCULINA (in part), *d'Orbigny, Reuss, Brauns.*
CORNUSPIRA (in part), *Reuss, Karrer, Schwager, Terquem.*
ORBIS (in part), *Strickland.*
SERPULA (in part), *Geinitz, Morris, Bölsche, Schmid.*
FORAMINITES (in part), *King.*
ROTALINA (in part), *Williamson, Alcock, Parfitt.*
SPIRILLINA (in part), *Williamson, Rupert Jones.*
TROCHAMMINA, *Parker and Jones, Reuss, Carpenter, Karrer, Brady, Miller and Vanden Broeck, Robertson, Siddall.*
AMMODISCUS, *Reuss, Bornemann*, jun.
INVOLUTINA (in part), *Terquem.*

General characters.—Test free or attached; very variable in form, consisting of one or many chambers: thin in substance, texture arenaceous, the sandy constituents embedded in a calcareous, often more or less ferruginous cement, and not projecting above the surface of the shell, which is nearly smooth. Polythalamous varieties are without proper septa, the division into chambers being effected by the constriction or of the primary shell-wall.

As already stated the genus *Trochammina*, in its structural relations, stands between *Lituola* on the one hand, and *Involutina*, *Valvulina*, and *Endothyra* on the other. The division of the series into these four quasi-generic groups is to be accepted as a convenient means of arranging, in something like intelligible sequence, a large number of varietal and subvarietal forms which could not be dealt with otherwise—not as the expression of a classification founded on morphological characters capable of definition in accurately distinctive terms.

Comparing *Trochammina* with *Lituola* the thick test and labyrinthic interior of the latter type are sufficiently distinctive, but the minute structure of the shelly investment is also different in the two genera. The true *Lituolæ* are ordinarily more or less rough externally from the excess of relatively large sand-grains employed in the building-up of the test, whilst the *Trochamminæ* with smaller and less angular constituent grains (Pl. II, fig. 14), and a much larger proportion of calcareous cement, have a comparatively smooth exterior surface. Whilst, therefore, both have composite tests, *Lituola* may be spoken of as "sandy," and *Trochammina*, in distinction, as "cemented," in texture. *Trochammina* inhabits shallower water than *Lituola*, and in estuaries and brackish pools its test becomes thinner and less calcareous, the mineral constituents being replaced by a sort of chitinous membrane.[1] The distinction between *Trochammina* and the Liassic genus *Involutina* of Terquem is still less easy to reduce to words. In general terms *Involutina* (accepting *I. liassica* as its representative) approaches much more nearly in structural features to the lower Rotalians. Its test is often a good deal thickened by the deposit of nearly homogeneous shell-substance and, occasionally at least, it shows, like *Valvulina*, a perforate primary shell-wall.

It is amongst the small recent specimens living in comparatively shallow water that the chief difficulties in separating the genera *Lituola*, *Trochammina*, and *Valvulina* are experienced; indeed, as has been stated both by Messrs. Parker and Jones[2] and myself,[3] a series of individuals referable to these three types may be readily got together forming a complete chain, showing no break or missing link to warrant specific, still less generic separation. It is true that in a chain so arranged many of the links might be supplied

[1] *Vide* 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. vi, p. 290, *Trochammina inflata*, var. *macrescens*, pl. xi, fig. 5.

[2] 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. iv, p. 391.

[3] Ibid., ser. 4, vol. vi, p. 290.

by poor, starved individuals, but such specimens cannot be ignored, as they exist in considerable numbers in some localities side by side with those that are well developed, and admit of no doubt as to their relationship.

The general history of the genus *Trochammina* is given in the 'Monograph of the Foraminifera of the Crag,' p. 25, and its structural features are minutely described in Dr. Carpenter's "Introduction," p. 141. Messrs. Jones, Parker, and Kirkby's paper on the "Permian *Trochammina pusilla* and its Allies,"[1] contains a comprehensive summary of what was known up to the date of its publication concerning the Palæozoic representatives of the genus; and it is a matter of some interest, that of the four species to which the memoir is chiefly devoted, three are now shown to have come down from Carboniferous times. Still more striking is the fact that at least two of these, viz. *Tr. incerta* and *Tr. gordialis*, are not only found in fossiliferous beds of many succeeding formations, but may at the present day be collected, living, at moderate depths in our European seas.

The brown colour of the test in *Trochammina*, due to the ferruginous constituents of the cement, is regarded by many as a character of almost generic significance; it is therefore necessary to remark, that the specimens from some of the Mountain Limestone beds are nearly pure white, and the same is often the case in those from Permian sources.

Professor Reuss applies the generic term *Ammodiscus* to the Spirilline non-septate varieties of *Trochammina*, and in this course he has been followed by some of his fellow-countrymen. I concur, however, with Messrs. Parker and Jones in regarding any generic or even subgeneric division of the group on this ground as undesirable. The distinction rests on an artificial basis, or rather on an idea, and any arrangement in which it is adopted leaves the numerous intermediate and partially septate varieties, which appear wherever *Trochammina* abound, quite unprovided for.

TROCHAMMINA INCERTA (*d'Orbigny*).[2] Pl. II, figs. 10—14.

OPERCULINA INCERTA, *d'Orbigny*, 1839. Foram. Cuba, p. 49, pl. vi, figs. 16, 17.
— CRETACEA, *Reuss*, 1846. Verstein. Böhm. Kreid., p. 35, pl. xiii, figs. 64, 65.
ORBIS INFIMUS, *Strickland*, 1848. Quart. Journ. Geol. Soc., vol. ii, p. 30, fig. *a*.
SPIRILLINA, sp., *Jones*, 1850. In King's Monog. Perm. Foss., pp. 18—20; and in Morris's Catal. Brit. Foss., 2nd edit., p. 42.

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[1] 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. iv, p. 386, pl. 13.

[2] In the lists of synonyms of the present species and also of *Trochammina gordialis* and *Tr. pusilla* I have made use of the materials collected by my friends Messrs. Jones, Parker and Kirkby for their paper before alluded to on the "Permian Trochamminæ" as far as they go, and am glad to make this practical acknowledgment of the value of their labours.

Spirillina cretacea, *Jones*, 1854. In Morris's Catal., Brit. Foss., 2nd edit., p. 42.

— infima, *Id.* Ibid.

— sp., *Id.* Ibid.

— arenacea, *Williamson*, 1858. Rec. Foram. Gt. Br., p. 93, pl. vii, fig. 203.

Trochammina (squamata) incerta, *Jones and Parker*, 1860. Quart. Journ. Geol. Soc., vol. xvi, p. 304.

Ammodiscus (species), *Reuss*, 1861. Sitzungsb. k. Akad. Wiss. Wien, vol. xliv, p. 365.

Trochammina incerta, *Parker and Jones*, 1862. In Carpenter's Introd. Foram., pp. 141, 312, pl. xi, fig. 2.

Cornuspira cretacea, *Reuss*, 1862. Sitzungsb. k. Akad. Wiss. Wien, vol. xlvi, p. 34, pl. i, fig. 10.

— — var. irregularis, *Id.* Ibid., figs. 11, 12.

Involutina silicea, *Terquem*, 1862. Mém. Acad. imp. Metz, for 1860, 1861, p. 450, pl. vi, fig. 11. (Deuxième Mém. Foram. du Lias.)

— aspera, *Terquem*, 1863. Ibid., for 1862—1863, p. 221, pl. x, fig. 21. (Troisième Mém. Foram. du Lias.)

Trochammina incerta, *Brady*, 1864. Trans. Linn. Soc. Lond., vol. xxiv, p. 72.

Cornuspira Hoernesi, *Karrer*, 1866. Sitzungsb. k. Akad. Wiss. Wien, vol. lii, p. 495, pl. i, fig. 10.

Serpula Roessleri, *Schmid*, 1867. Neues Jahrbuch für Min., Jahrg. 1867, p. 583, pl. vi, figs. 46, 47.

Cornuspira oolithica, *Schwager*, 1867. In Waagen's 'Ueber die Zone des Amm. Sowerbyi,' vol. i, part iii, p 655, pl. xxxiv (xi), fig. 4.

Trochammina incerta, *Jones, Parker, and Kirky*, 1869. Ann. and Mag. Nat. Hist., ser. 4, vol. iv, p. 388, pl. xiii, fig. 1.

Cornuspira granulosa, C. infraoolithica, &c., *Terquem*, 1870. Troisième Mém. Foram. du Syst. Oolithique, pp. 242—244, pl. xxv, figs. 12—20.

Operculina liasina, *Brauns*, 1871. Der Unterjura im nordwest. Deutschland, p. 447, &c. (*fide* Bornemann).

Trochammina incerta, *Miller and Vanden Broeck*, 1873. Ann. Soc. Malac. Belg., vol. for 1873, Table.

— — *Brady*, 1873. Mem. Geol. Survey Scotland, Expl. Sheet 23, p. 95.

— — *Id.*, 1873. (In Young and Armstrong's Catal.), Trans. Geol. Soc. Glasgow, vol. iv, p. 272.

Ammodiscus infimus, *Bornemann*, jun., 1874. Zeitschr. d. deutsch. geol. Gesellsch., Jahrg. 1874, p. 725.

Characters. — Test plano-spiral, discoidal, thin; consisting of numerous, narrow, more or less rounded convolutions of a non-septate tube of nearly uniform width. Aperture usually formed by the open unconstricted end of the tube. Diameter $\frac{1}{50}$th inch (0·5 mm.)

In the recent condition *Trochammina incerta* is very uniform in its general character and appearance; and, as stated by Prof. Williamson ('Monogr.,' p. 93), it is widely distributed but nowhere abundant. This however cannot be said of its occurrence in the Carboniferous rocks. Wherever it exists as a Palæozoic fossil, it appears in large numbers, and the specimens present a correspondingly wide range of variation in minor characters. Many specimens are just such as might be dredged at the present day on our own shores, consisting of five or six convolutions in one plane of a non-septate tube, the convolutions nearly uniform in breadth, and the tube having an approximately circular transverse section. The examination of a large number of individuals reveals many little modifications of these simple typical characters. Sometimes the number of convolutions is smaller and their width greater, forming a test of similar diameter and without increase of thickness (Pl. II, fig. 12), and in such the tube presents a long oval, instead of a circular transverse section. Other examples show a tendency in the successive convolutions each to embrace, to a limited degree, that immediately within it, and the section of the tube is then more or less crescentiform. In some of the larger complanate shells (fig. 11) the spiral tube increases in width with each succeeding circlet. Lastly, it is not at all uncommon to find the shell-wall thickened, especially near the centre of the disc, the excavated sutural line filled up, and the test assuming thereby a more or less lenticular or bi-convex figure. In these instances the calcareous cement is largely in excess of arenaceous material, the surface of the test is nearly smooth, and even permits, by a sort of transparency, the course of the spiral cavity in the interior to be traced (Pl. I, fig. 13). These modifications, in addition to many irregularities in external contour, arise from what may be regarded as accidental circumstances, and present no ground for specific or varietal subdivision.

It seems necessary to make passing allusion to some of the Mesozoic *Trochamminæ* figured by M. Terquem under the generic terms *Involutina* and *Cornuspira*. M. Terquem appears to stand alone amongst students of Foraminifera in his non-acceptance of shell-texture as the basis of the primary division of the order. Thus, *Cornuspira* with its imperforate porcellanous shell, *Trochammina* with its imperforate arenaceous test, and *Spirillina* with its brilliantly hyaline, porous walls, the isomorphic genera of the three primary groups of Reticularian Rhizopods, are regarded by him as one genus. M. Terquem has been good enough to send me, for purposes of comparison, type specimens of several of the species of *Involutina* described in his memoirs on Liassic and Oolitic Foraminifera, together with notes upon them indicating some change in his views concerning that genus; also specimens of the *Cornuspiræ* represented in pl. xxv of his third 'Memoir on the Foraminifera of the Oolite,' viz. *C. granulosa*, *C. infraoölithica*, *C. punctulata*, *C. concava*, *C. aspera*, and *C. occlusa*, figures 12 to 20 respectively. After a very careful examination of this series I may confess that I find nothing in their characters that seems to me to justify *varietal*, much less *specific* separation one from another. In his text, p. 242, the author objects to the generally received definition of the genus

Cornuspira, based upon a "test, calcareous, porcellanous, and compact," on the ground that with a magnifying power of eighty diameters he is able to demonstrate in a large number of specimens the existence of a multiplicity of pores. Supposing this to be the case, the specimens would be assigned by rhizopodists generally to the genus *Spirillina*, not to *Cornuspira*. The rigorous examination of the set of specimens M. Terquem has been good enough to furnish, with powers varying from twenty diameters to six hundred or more, has not enabled me to detect pores in the shell-wall in a single instance. Lest I should have been unconsciously influenced by familiarity with similar organisms, the "imperforate" character of which has never been questioned, the specimens were submitted to a friend of great experience in the use of high magnifying powers, though in investigations of another order, and his reply was decisive that no perforations existed,—that any appearance as of pores was caused by mere superficial rugosity or by minute tubercles, and that the illusion by which they appeared like pores was readily dispelled by varying the method of illumination. It should, however, be remarked, that the Mesozoic specimens are very minute, and the structural characters are much more obscure and difficult of determination than in individuals of larger dimensions. I must add that it is with great deference to the views of so assiduous a student of fossil Microzoa as M. Terquem that I give expression to conclusions differing from his on a somewhat important point.

Distribution.—Trochammina incerta is one of the most abundant of Palæozoic Foraminifera. It is found throughout the Carboniferous Limestones of England, and in the Lower and Upper Groups of Scotland. I have note also of its occurrence in the *Fusulina* rocks of the Caucasus.

In the Permian beds specimens are common, and often attain very fine dimensions. It is found in the Lower and Middle Magnesian Limestones of England, and in the Zechstein proper of Germany.

TROCHAMMINA CENTRIFUGA, *Brady*. Pl. II, figs. 15—20.

INVOLUTINA INCERTA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, p. 382.
TROCHAMMINA CENTRIFUGA, *Brady*, 1873. Mem. Geol. Survey Scotland, Expl. Sheet 23, p. 95.
— — *Id.*, 1873. (In Young and Armstrong's Catal.) Trans. Geol. Soc. Glasgow, vol. iv, p. 271.

Characters.—Test depressed, thin, plano-spiral; formed of a tube of uneven diameter, convoluted in its earlier, rectilinear in its later stages of growth. Aperture terminal, round, usually unconstricted. Length about $\frac{1}{50}$th inch (0·5 mm.); diameter of spiral portion about $\frac{1}{100}$th inch (0·25 mm.).

It may be doubted whether *Trochammina centrifuga* is more than a varietal modification of *Tr. incerta*, but it appears to be a well-marked form, and there is something distinctive in its mode of occurrence. Wherever it is found *Tr. incerta* is also present; but, on the other hand, out of fifty localities for the latter species, *Tr. centrifuga* has only been noticed in ten or twelve. In the localities where it does occur it generally exists in large numbers, not as a rarity. In applying to the form a distinguishing name I have, as in many other cases, been guided by convenience rather than by those strict zoological rules which seem inapplicable to the lowest types of animal life.

The test of *Trochammina centrifuga* begins its growth on the same plan as *Tr. incerta*, that is as a flat spire; but after a number of convolutions are formed, the course of the tube changes abruptly from spiral to rectilinear, and a straight arm of greater or less length is added to the previously discoidal test. The number of convolutions is very variable;—sometimes the primary portion consists of one or two turns of a wide, flat, irregular, spiral tube, at others (as in the section Pl. II, fig. 20) four or five revolutions may be observed, comparatively regular in outline and gradually increasing in width. In general contour the discoidal portion differs much in different specimens; sometimes it is nearly circular, often angular or altogether irregular; and the lateral surfaces are either bi-convex, depressed, or slightly concave with excavated umbilicus.

The rectilinear arm varies much in length. In what may be assumed to be adult specimens it projects to an extent about equal to the diameter of the disc. The end of the tube, which is usually open and unconstricted except by occasional slight thickening at the rim, forms the aperture.

The external inequalities of the tube led at first to the supposition that there existed some sort of spurious or imperfect septation, and with this idea Mr. Charles Moore's specimens were provisionally placed with the *Involutinæ*,[1] but horizontal sections show that the superficial irregularities are not connected with modifications of the shell-wall on its interior, and that the test is really, as shown in Pl. II, fig. 20, a non-septate tube. In transferring the species to the genus *Trochammina* it became necessary to alter its name, the term "*incerta*" being already occupied in that group, hence the adoption of the present name in the Catalogue of the Foraminifera of the Carboniferous beds of Lanarkshire, compiled for the "Memoirs of the Geological Survey of Scotland."

Distribution.—In the Lower Carboniferous Limestone beds (Scar) of England and of Scotland, *Trochammina centrifuga* is of very rare occurrence, having been noticed in only one locality in each country. In the Upper portion of the series, both in England (Yoredales) and in Scotland, it is much more frequently found, ten out of the twelve recorded localities pertaining to these higher groups of limestones.

[1] 'Report of the British Association,' *loc. cit.*

Trochammina anceps, *nov.* Pl. III, fig. 8, *a*, *b*.

Characters.—Test free, convoluted, discoidal, thin, consisting of a spuriously septate tube coiled in one plane. Septa marked externally by oblique slightly depressed lines. Diameter $\frac{1}{60}$th inch (·4 millim.).

A variety closely allied to *Trochammina incerta*, or perhaps better regarded as a transition form between the non-septate *Tr. incerta* and the segmented, almost Rotalian *Tr. inflata*. The septation depends, as in all the subdivided *Trochamminæ*, on the infolding of the primary shell-wall, not on the successive formation of chambers, each with its proper calcareous investment. It is a rare variety, and the specimens are nearly always of small size. They are chiefly interesting from the intermediate position they occupy.

Distribution.—Only noticed hitherto at a few localities in the higher Carboniferous Limestone (Yoredale) beds of England, and in the Lower Carboniferous Limestone Group of Scotland.

Trochammina annularis, *nov.* Pl. III, figs. 9, 10.

Characters.—Shell free, annular, spiral; formed of two or three convolutions of a non-septate tube. Convolutions irregular, seldom on one plane, but frequently more or less superimposed vertically; never commencing at the centre of the test, but leaving a space of about one third of the whole diameter quite open. Tube apparently twisted, especially at points in the earlier portion of its course. Diameter $\frac{1}{150}$th inch (0·17 millim.).

A very minute variety, intermediate in its morphological characters to *Tr. incerta* and *Tr. gordialis;* very rare, and, except that it is sometimes found with *Tr. gordialis*, little associated with other members of the genus. The two figures, Pl. III, figs. 9 and 10, drawn from different specimens, are fairly representative, the few examples which have been found being very uniform in character. From their small size, and extremely fragile nature, the specimens are probably often destroyed or washed away in preparing material for examination, and even when retained they are liable to be overlooked.

Distribution.—In the Four-fathom Limestone, Elfhills, Northumberland, and in the shale over No. 1, Limestone, Calderside, Lanarkshire. In both places rare.

TROCHAMMINA GORDIALIS, *Jones and Parker*. Pl. III, figs. 1—3.

TROCHAMMINA SQUAMATA, GORDIALIS, *Jones and Parker*, 1860. Quart. Journ. Geol. Soc., vol. xvi, p. 304.
— GORDIALIS, *Parker and Jones*, 1862. In Carpenter's Introd. Foram., p. 141.
— SQUAMATA, var. GORDIALIS, *Id.*, 1865. Phil. Trans., vol. clv, p. 408.
— PROTEUS, *Karrer*, 1866 (in part). Sitzungsb. k. Akad. Wien, vol. lii, p. 494, pl. i, figs. 1—8.
— SQUAMATA, var. GORDIALIS, *Jones, Parker, and Brady*, 1866. Monogr. Foram. Crag, p. 26.
— GORDIALIS, *Jones, Parker, and Kirkby*, 1869. Ann. and Mag. Nat. Hist., ser. 4, vol. iv, p. 390, pl. xiii, figs. 7, 8.
— — *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, p. 85, &c.

Characters.—Test convoluted, rounded, irregular; composed of a tube of nearly even diameter, coiled upon itself in an irregular manner and in varying directions. The tube (as shown by transverse section) variable in shape; sometimes contracted at irregular intervals, twisted, or spuriously septate. Diameter, $\frac{1}{100}$th inch to $\frac{1}{30}$th or more (0·25 to 0·85 millim.).

Whether the trivial name "gordialis" was originally selected for this curious little organism, on the ground of its exterior resemblance to a coiled and complicated knot, or with reference to its morphological intricacy, is of little moment, for in either case it is quite appropriate. The form designated is the centre of an anomalous sub-group occupying in its modifications the wide area between the compact closely coiled, often almost conical *Tr. charoides*, and the regular, spiral, septate type *Tr. squamata*. Dr. Karrer, in his interesting memoir on the Foraminifera of the older beds of the Vienna Sandstone Series, above quoted, associates under one specific name forms which with us have been distributed under three quasi-specific heads, viz., *Tr. squamata*, *Tr. gordialis*, and *Tr. charoides*. Whilst recognising and cordially agreeing in the general views which have guided him in this course, it appears more consistent with the plan hitherto adopted in the present paper, to retain trivial names for the more important and more permanent modifications of each type, without insisting on a standard of specific distinctness, which, however well adapted to animals of higher organization, it would be vain to attempt to apply to the Rhizopoda. Nor is the method which has hitherto been followed by my colleagues and myself in this respect inconsistent with the constant endeavour to simplify the nomenclature of the Foraminifera by expunging the multitude of useless trivial names

which have burdened this department of zoology—names which have had their origin either in deficient observation, or in a disposition to ignore the terms employed by earlier writers. The specimens figured by Messrs. Jones, Parker, and Kirkby, from Permian sources, though generally of larger dimensions than those from Carboniferous beds, are not so characteristic. The tube in the Permian specimens has a larger diameter, but it is correspondingly shorter, and the number of convolutions not so great.

The Carboniferous examples are usually very minute, often not more than $\frac{1}{130}$th of an inch (0·2 mm.) in diameter, and the test is correspondingly thin and delicate; but full-sized specimens, such as that represented in Pl. III, fig. 3, are found sufficiently often to sustain the connection of the series.

Distribution.—Nowhere very common. The only note I have of its occurrence in the English Carboniferous rocks is in the Four-fathom Limestone at Elfhills, Northumberland. In Scotland it has been found in two or three localities in the Lower Carboniferous Limestone Group, and in Belgium in the Calcaire de Namur.

As a Permian fossil it is confined, so far as is yet ascertained, to the Middle Magnesian Limestone of the North of England.

TROCHAMMINA PUSILLA (*Geinitz*). Pl. III, figs. 4, 5.

SERPULA PUSILLA, *Geinitz*, 1848. Verstein. Zechst. Roth., p. 6, pl. iii, figs. 3—6.
FORAMINITES SERPULOIDES, *King*, 1848. Cat. Perm. Foss. Northumb., p. 6.
SERPULA? PUSILLA, *Jones*, 1850. In King's Monogr. Perm. Fossils, p. 57, pl. vi, figs. 7—9; pl. xviii, figs. 13, *a*—*d*.
SPIRILLINA — *Jones*, 1856. In King, On Irish Permian Fossils,—Journ. Geol. Soc. Dublin, vol. vii, p. 73, pl. i, figs. 12, *a*, *b*.
— — *Geinitz*, 1861. Dyas, p. 39, pl. x, figs. 15—21, and pl. xii, fig. 1.
MILIOLA (?) — *Howse and Kirkby*, 1863. Synopsis Geol. Durham and Northumberland, p. 13.
SERPULA — *Bolsche*, 1864. Neues Jahrbuch für Min., Jahrg. 1864, p. 607.
TROCHAMMINA PUSILLA, *Jones, Parker, and Kirkby*, 1869. Ann. and Mag. Nat. Hist., ser. 4, vol. iv, p. 390, pl. xiii, figs. 4—6, &c.

Characters.—Shell free, oblong, convoluted; composed of a non-septate or spuriously septate tube, coiled or doubled on itself more or less regularly, but not on a uniform plane. Aperture taking the form of the open end of the tube; circular or, where the tube is embracing, crescentic. Length, about $\frac{1}{13}$th inch (2·0 mm.).

This is an exceedingly abundant and well known Permian fossil, but its zoological affinities, owing to the obscurity and variableness of its characters, have puzzled a suc-

cession of palæontologists. Increased knowledge of the arenaceous group of Foraminifera has led to a better understanding of such simple forms; and Messrs. Jones, Parker, and Kirkby's paper on the "Permian Trochamminæ," before referred to, will be generally accepted as setting at rest the doubt which has existed as to the relationship of the group. Of the various drawings of the species given by these authors (see figs. 2—6 of their plate, *loc. cit.*) numbers 2 and 3 may be regarded as transitional, taking positions between *Tr. incerta* and *Tr. pusilla*, whilst figs. 4 and 5 represent the full characters of the latter, and fig. 6 a specimen verging towards *Tr. gordialis*. Of the two drawings of *Trochammina pusilla* given in Plate III of the present work, fig. 5 is from the Magnesian Limestone (Permian) of Tunstall Hill, near Sunderland, whilst fig. 4 is a Carboniferous specimen from one of Mr. Robertson's Scotch gatherings. The latter is an unusually fine example, and possesses a somewhat singular character in the fringe of white subarenaceous shell-substance which lines the inner border of the convolutions. This is probably the effect of luxuriant growth, but I do not recollect having seen any other example of an arenaceous Foraminifer with precisely the same kind of limbation.

Distribution.—Though isolated specimens have been found by Mr. Robertson in a single locality of the Lower, and in one locality of the Upper Carboniferous Limestones of Scotland, *Trochammina pusilla* is essentially a Permian species. It occurs abundantly in the Lower and Middle Magnesian Limestones of England, and in the Kupferschiefer, Zechstein proper, and Middle Zechstein of Germany. Its presence in Ireland, in the bed regarded as pertaining to the Upper Magnesian Limestone, has also been recorded, but it does not seem to have been observed elsewhere in the highest division of the Permian rocks.

TROCHAMMINA MILIOLOIDES, *Jones, Parker, and Kirkby.* Pl. III, figs. 11—15.

TROCHAMMINA MILIOLOIDES, *Jones, Parker, and Kirkby*, 1869. Ann. and Mag. Nat. Hist., ser. 4, vol. iv, p. 390, pl. xiii, figs. 9—14.

Characters.—Test free, convoluted; oblong or broadly oval, compressed. Convolutions on one plane, few, broad, embracing. Aperture varying in form, corresponding to the transverse section of the tube, or only slightly constricted. Length $\frac{1}{14}$th inch (1·75 mm.).

The intermediate *Trochamminæ*, to which the name *Tr. milioloides* has been assigned, bear the same sort of relation *Tr. pusilla* that the Biloculine and Triloculine *Miliolæ* bear to the Quinqueloculine and Spiroloculine. The name is put forward by its authors

for the "passage forms between *Tr. gordialis* and *Tr. incerta* in one direction and *Tr. pusilla* in the other." The figures (Pl. III, figs. 11—15) are reproduced, with the assistance of specimens kindly lent by Mr. Kirkby, from the drawings accompanying Messrs. Jones, Parker, and Kirkby's paper.

Distribution.—Permian only:—occurs with the allied *Trochamminæ* in the Lower and Middle Magnesian Limestones of the North of England.

TROCHAMMINA ROBERTSONI, *nov.* Pl. III, figs. 6, 7.

Characters.—Test free, oblong, compressed; composed of a spuriously septate tube reflexed or doubled on itself more or less regularly in a manner analogous to the Quinqueloculine *Miliolæ*. Aperture relatively large, rounded or arcuate. Test, exceedingly thin and delicate; texture very finely arenaceous. Length $\frac{1}{120}$th inch (0·21 mm.).

For specimens of this exceedingly minute and delicate form I am indebted to my friend Mr. David Robertson, F.G.S., of Glasgow, who discovered it in some of the Carboniferous shales of the West of Scotland, and whose name therefore may very properly be associated with it. The specimens were at first assigned to *Tr. pusilla*, in the belief that their very small size, more regular structure, and delicate texture, were the result merely of different external conditions of life; but I have hitherto found no intermediate forms to justify this conclusion, and have therefore given to it a distinctive name. The resemblance of the specimens to minute *Quinqueloculinæ* is remarkable, not merely in the general form and manner of growth, but in the constriction of the tubular body near the ends of the test (especially noticeable in the outermost convolution) which imparts an appearance almost precisely like the segmentation of a true *Miliola*. It is scarcely necessary to dwell on the superficial nature of this resemblance. The non-porcellanous texture of the test is sufficient to separate the organism from its white-shelled isomorphs, whilst its cemented, finely arenaceous structure links it as clearly to the genus *Trochammina*.

Distribution.—*Trochammina Robertsoni* has only hitherto been found in beds of the Upper Carboniferous Limestone Group of Scotland. It may, however, have a wider range than we know of, for, from its very minute size and inconspicuous appearance, it may be easily overlooked in searching the dull-coloured material yielded by Carboniferous rocks.

TROCHAMMINA FILUM (*Schmid*). Pl. III, fig. 16.

SERPULA FILUM, *Schmid*, 1867. Neues Jahrb. für Min., Jahrg. 1867, p. 583, pl. vi, fig. 48.
INVOLUTINA VERMIFORMIS, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, p. 382.
TROCHAMMINA FILUM, *Jones, Parker, and Kirkby*, 1869. Ann. and Mag. Nat. Hist., ser. 4, vol. iv, p. 389.

Characters.—Test free; consisting of a long tube of gradually increasing diameter, irregularly bent, and often partially coiled at its commencement. Aperture formed by the open unconstricted wider end of the tube.

There can be no doubt, as Messrs. Jones, Parker, and Kirkby have demonstrated (*loc. cit.*), that the little vermiform Permian fossil figured by Dr. E. E. Schmid is an uncoiled variety of *Trochammina*. It differs considerably from the crozier-shaped Carboniferous form, *Tr. centrifuga*, in its general contour and mode of growth. In its very earliest portion *Trochammina filum*, if not entirely uncoiled, is confused rather than helicoid or spiral, and the linear portion of the test is irregularly twisted, and uneven in diameter. Its relationship seems to be rather with *Trochammina pusilla* than with the more regular *Tr. incerta*. The drawing, Pl. III, fig. 16, has been reproduced from Dr. Schmid's figure.

Distribution.—Although in the examination of Carboniferous material, minute tubular organisms bearing a resemblance to this species often present themselves, I have never, except perhaps from a single habitat (near Skipton, Yorkshire), met specimens that could without cavil be assigned to it; nor have I any record of its occurrence in the Permian rocks beyond Dr. Schmid's locality, the Zechstein of Selters in the Wetterau, Germany.

Genus, VALVULINA, *d'Orbigny*.

VALVULINA, *d'Orbigny, Parker and Jones, Seguenza, Carpenter, Brady, Robertson.*
TETRATAXIS, *Ehrenberg.*
TEXTILARIA (in part), *Ehrenberg.*
ROTALINA (in part), *Williamson, Parfitt.*

General characters.—Test free or adherent, spiral; trochoid, turbinoid, plano-convex or (in Clavuline varieties) sub-cylindrical; chambers arranged in a more or less regular spire, sometimes terminating in a single rectilinear series. Aperture (normally) in the

umbilical angle on the inferior surface of the last chamber, more or less protected by a valvular tongue.

The structure and affinities of the genus *Valvulina* have been very completely worked out by my friends Messrs. Parker and Jones, and to their general results, as stated by Dr. Carpenter ("Introduction," p. 146), I have little to add. But hitherto no specimens proper to the genus have been recorded as such from any formation older than the Chalk, and the discovery of a number of new forms pertaining to a much earlier geological period brings with it considerable accession to our knowledge of the modifications which the type assumes.

British rhizopodists have generelly accepted d'Orbigny's model of *Valvulina triangularis* (Modèle No. 25) as the best central type of the genus. This is a trifacial and triserial pyramid, somewhat rounded at the thick end and showing the characteristic aperture. Variations from the typical form run in two opposite lines—either the axis of the spire becomes shorter, giving rise to the trochoid and outspread varieties, in which the salient characters are only recognised in a sub-arenaceous texture, valvular aperture, or tendency to triserial arrangement of chambers, as in *Valvulina Austriaca* ('For. Fos. Vien.,' p. 181, pl. 11, figs. 7, 8[1]); or on the other hand, the spiral portion, retaining its original form, is supplemented by the growth of a line of chambers from its broad end, forming a cylindrical, uniserial column, with a pointed, triangular, triserial base, as in *Valvulina* (*Clavulina*) *Parisiensis* (Modèle No. 66). The latter modification finds its extreme expression in *Valvulina clavulus* (Modèle No. 2), in which the spiral end is entirely lost, and a rectilinear series of arenaceous segments with valvular mouth alone remains.

Wide as is the range of characters embraced in the above description, considerable latitude must still be allowed in its application to individuals or even to sets of specimens. I have long been convinced, from observations on recent specimens, especially from a series collected on the west coast of Scotland, that even the triserial habit of growth is not a character to be relied on, and it has been no matter of surprise to me to find that in the Carboniferous Limestone beds there exists a set of forms, more closely allied to *Valvulina* than to any other recognised genus, in which the number of chambers in each convolution is altogether variable, and of no significance as a generic peculiarity. Indeed, in the species about to be described, *four* is on the whole a more common serial number than *three*—a fact that seems to have been noticed by Ehrenberg and to have suggested the name *Tetrataxis* for the genus which he founded to embrace some of the varieties.

As to the position of the genus *Valvulina*, little need be added to what appears in Dr. Carpenter's work (*loc. cit.*). It is there referred to the sub-order "*Imperforata*"

[1] This is the *Rotalina fusca* of Williamson, 'Rec. For. Gt. Br.,' p. 55, figs. 114, 115.

rather than to the "*Perforata*" with the explanation that "it would perhaps be more correct to assign to it an independent position as the connecting link between the two." I am quite prepared to endorse this view and, as has been already stated in the Introduction, would further add to the same intermediate category the Carboniferous genus *Endothyra* and the Liassic type *Involutina*, although the relative positions of the three must be left an open question pending more accurate researches on the latter type. It is a well-ascertained fact that the freshly formed chambers in *Valvulina* sometimes appear hyaline and perforate, though subsequently they become thickened with arenaceous incrustation. Transparent sections show that in its best developed condition, notably in some of the large specimens of Tertiary age, the shell has throughout a perforate basis which has only become impervious by incrustation with extraneous matter; and the Carboniferous beds furnish at least one species, *V. bulloides*, with a not unfrequently porous test. I have myself observed indications of the same thing in *Involutinæ* derived from Liassic clays; and, though the existence of a similar condition has not been demonstrated in *Endothyra*, it is possible that this may be owing to the obliterating effects of infiltration; at any rate it is premature to say that it does not exist in any of the various modifications of that type.

In its distribution *Valvulina* has hitherto been regarded chiefly in the light of a Cretaceous and early Tertiary type, at least it has not been supposed to extend further back in geological time than the Cretaceous epoch. It has still living representatives in some of the trochoid and plano-convex varieties, but, if we except the fine adherent examples of *V. conica*, recently obtained from deep Atlantic soundings, they for the most part bear the impress of a degenerate race.

So far, however, from being subject to such limitations in point of time, it will be gathered from subsequent pages that the genus furnished some of the most abundant and characteristic species that are found in the microzoic rocks of the Carboniferous period.

VALVULINA PALÆOTROCHUS (*Ehrenberg*) Pl. IV, figs. 1—4.

TETRATAXIS CONICA, *Ehrenberg*, 1843. Bericht. d. k. Preuss. Akad., Jahr. 1843, p. 106.

TEXTILARIA PALÆOTROCHUS, *Ehrenberg*, 1854. Mikrogeologie, pl. xxxvii, § xi, figs. A' 1—4.

TETRATAXIS CONICA, *Id.* Ibid., pl. xxxvii, § xi, figs. 7, 8.

INVOLUTINA — *Brady*, 1871 (in Young and Armstrong's Catalogue). Trans. Geol. Soc. Glasgow, vol. iii, Suppl., p. 14.

VALVULINA PALÆOTROCHUS, *Id.*, 1873. Ibid., vol. iv, pt. iii, p. 273.

— — *Id.*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 61, 95, &c.

Characters.—Test free or adherent, spiral, trochoid; composed of several convolutions, each of which consists of from three to four thin, oblique segments, all more or less visible on the exterior. Chambers simple, not sub-divided into chamberlets. Septation externally obscure, sometimes marked by slightly depressed or excavated lines. On the inferior surface the outline of the three or four chambers of the last convolution may sometimes, though rarely, be traced, each chamber with a projecting lip directed over a sort of umbilical vestibule. Diameter, $\frac{1}{30}$ inch (0·86 mm.).

So far as the British Carboniferous beds are concerned, *Valvulina palæotrochus* is one of the most striking and best differentiated species of Foraminifera. In shape and habit it bears some external resemblance to the recent *Valvulina conica*, but its shell-texture is less coarse and heterogeneous, owing to the constituent particles being entirely or almost entirely calcareous, whilst in the living species the test is commonly built up of siliceous sand and ferruginous cement. There is quite sufficient evidence that, like the analogous recent form, *V. palæotrochus* is normally parasitic, though the fossil specimens are seldom found actually in that condition. This is probably due in part to the unevenness of the base of the shell preventing very close adhesion to foreign bodies, or perhaps to the muddy condition of the sea-bottom offering but few facilities for adherent growth. Professor Ehrenberg gives two sets of figures under different names on the plate above quoted, but there can be no doubt that they refer to the same species; those in Section X from the Bellerophon-limestone of Witegra, on Lake Onega, Russia, have apparently been obtained free from the matrix, whilst the drawings in Section XI of the same plate, of specimens from the Mountain Limestone[1] of Tula, Russia, represent transverse and perpendicular sections viewed by transmitted light.

Well-defined examples of *Valvulina palæotrochus* cannot be confounded with those of any other Carboniferous species, except it be *V. Youngi*. In external contour these two forms are exceedingly similar, but the characteristic sub-division of the segments of the latter into numerous chamberlets is generally indicated with more or less distinctness by superficial markings, and when this is not the case, a broken specimen, or still better a transparent section of the shell in a perpendicular direction, affords a ready means of diagnosis. *Valvulina palæotrochus* differs from *V. decurrens* and *V. plicata* in relative height and diameter, and in the mode of septation. Good specimens have a height nearly equal to the diameter of the shell at the base, and the spiral course of the chambers is much obscured by the extreme obliquity of the septation. On the other hand, *V. plicata* has but little more than half the relative height, the margin is rounded, and the septation almost Rotalian; whilst *V. decurrens* is still thinner, sometimes a mere scale, and its spiral growth is frequently rendered conspicuous by the partial or entire obliteration of septal lines and the consequent apparent absence of segmentation, as shown in Pl. III, fig. 18.

[1] Described as "Hornstone of the Mountain Limestone with *Spirifer mosquensis*."

Distribution.—Of all the smaller Carboniferous Foraminifera *Valvulina palæotrochus* is perhaps the commonest and most generally diffused—the only columns in the Carboniferous portion of the General Summary of distribution in which its presence is not indicated are those (but two in number) in which the quantity of material available for examination has been very limited. The species has not hitherto been found in beds of Permian or later age.

VALVULINA PALÆOTROCHUS, *var.* COMPRESSA, *Brady*. Pl. IV, figs. 5, *a*, *b*.

VALVULINA PALÆOTROCHUS, *var.* COMPRESSA, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 61, 95, &c.

In a few localities there occur, associated with the typical *Valvulina palæotrochus*, specimens presenting the same general characters, but having an elongated oval, instead of a circular, transverse section; in other words, having the form of a cone which might have been altered in shape by lateral compression. Such specimens are slightly smaller than those of the type; they are uneven, and one-sided at the base, more deeply excavated on the inferior surface at the umbilicus, and the sutural depressions marking the septa are somewhat stronger. There is no satisfactory evidence either in the external appearance or in the transverse section that the oval contour is really the effect of pressure. I have elsewhere[1] noted that, where change of shape in organisms of this sort has been produced by crushing, there is little difficulty in tracing the fact in the fracture or interruption of the spiral band at the ends of the longer diameter of the transverse section. In some habitats, where the circular, typical form is abundant, the oval variety is conspicuously absent, whilst in one or two localities they occur in almost equal proportions. There is no need to attribute more than subvarietal importance to these minor characters, but it may be well, till we know something more about them, to distinguish the compressed forms by a trivial name subordinate to *V. palæotrochus*.

Distribution.—Found in a limited number of localities, in the higher and lower division of the Carboniferous Limestone in England, and in the Upper and Lower Carboniferous Limestone Groups of Scotland; not recorded elsewhere.

[1] 'Phil. Trans.,' 1869, p. 754, pl. lxxx, fig. 2. (In *Loftusia*.)

VALVULINA YOUNGI, *Brady*. Pl. IV, figs. 6, 8, 9.

VALVULINA YOUNGI, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test free or adherent, obscurely spiral, trochoid; composed of several convolutions, of which the constituent chambers are all more or less visible on the exterior. Inferior surface concave, and more or less irregular. Chambers subdivided into one or more rows of chamberlets. Diameter, $\frac{1}{40}$ inch (0·64 mm.) or more.

In external configuration *Valvulina Youngi* closely resembles *V. palæotrochus*, for, although the sub-division of the chamber-cavities by secondary septa may usually be detected by markings on the exterior of the test, these structures are not of a nature to affect its general appearance or contour. The two species are indeed very closely allied. A glance at the figures of their respective transverse and perpendicular sections (Pl. IV, figs. 3, 4, and 8, 9) will show wherein the difference really lies. In some of the Carboniferous Foraminifera yet to be described the shelly ingrowths appear as though they might have a tubular character; but in the present case there can be little doubt, judging from the transverse section (fig. 9), that they are true secondary septa, formed of more or less continuous plates of shell-substance dividing the chambers into chamberlets. It will be seen that the shell-wall and the primary septa are much thinner in *V. Youngi* than in the forms with simple chambers, the secondary growths therefore probably serve to give the necessary strength and solidity to the test. The same sort of provision, but on a much more extended plan, is to be observed in some of the more complex arenaceous types of Foraminifera, notably in *Loftusia*.

I have much pleasure in associating with so interesting a form the name of one of the earliest students of British Carboniferous microzoa, my friend Mr. John Young of Glasgow. It was in his collection from the rich Brockley shale, that I first made acquaintance with the species.

Distribution.—In England only noticed hitherto at one locality in the Lower Limestone Series, *viz.* Fallowlees, Northumberland. In Scotland at several localities pertaining to the Lower Carboniferous Limestone Group, but not in any other portion of the Series. In all cases very rare.

VALVULINA YOUNGI, *var.* CONTRARIA, *Brady.* Pl. IV, figs. 7, *a*, *b*.

VALVULINA YOUNGI, *var.* CONTRARIA, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

This form bears exactly the same relation to *Valvulina Youngi* that *V. palæotrochus*, var. *compressa*, bears to its type; that is to say, instead of being shaped like a cone with a circular base, its transverse section is of a long oval form. The chambers are subdivided into chamberlets just as in *V. Youngi;* in other respects the divergence from the parent form is in precisely the same characters as detailed in the description of *V. compressa*, and for similar reasons a varietal name has been provisionally assigned to it. Both the circular and oval forms of *V. Youngi* are rare, but the number of specimens of the latter variety is sometimes larger than that of the form which has been regarded by analogy as its type, differing in this respect from the corresponding modification of *V. palæotrochus*.

Distribution.—Much the same as that of *Valvulina Youngi;* indeed, no very great care has been used to keep the record of the two distinct.

VALVULINA DECURRENS, *Brady*, Pl. III, figs. 17, 18.

VALVULINA DECURRENS, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test free or adherent, spiral, complanate; in the form of an outspread, much depressed cone, with circular base and thin, sharp, often irregular margin. Spiral band usually distinct; septation very obscure, partial, or often entirely abortive. Diameter, $\frac{1}{28}$ inch (about 1·0 mm.) or more.

The outspread forms, of which *Valvulina decurrens* is the representative, stand in somewhat the same relation to *V. palæotrochus* as that which *Trochammina incerta* bears to the regularly septate type of its own group. In neither genus can any hard line of demarcation be drawn between the successive "species."

Valvulina decurrens is a thin, complanate variety, often a mere scale-like disc, commonly much thinner than appears in fig. 17, *b*, which, owing to the upturned edge of the specimen, has a greater apparent solidity than is usually seen in characteristic examples. Sometimes its spiral structure is obscured, as in this figure, by confused, oblique septation,

but frequently, especially in weathered specimens, the whole course of the spiral band, unbroken and unsegmented, may be traced on the upper surface of the test, as in fig. 18.

The diameter of the shell is at least as great as that of *V. palæotrochus*, often greater; the height of the cone sometimes not more than $\frac{1}{200}$ inch (0·13 mm.) at the centre. The lower surface is usually flat and irregular, depending somewhat on the nature of the body to which it has been adherent during life. It is seldom possible to detect the aperture.

Distribution.—In the Lower Limestones of England, rare; in the Yoredale rocks much commoner. In Scotland found in the Calciferous Sandstones, and in the Lower and Upper Carboniferous Limestone Groups. It appears in the Lower Limestones of the North of Ireland and in the Upper Coal-measures of North America. Not a Permian species.

VALVULINA PLICATA, *Brady*, Pl. IV, figs. 10, 11.

VALVULINA PLICATA, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 66, 95, &c.

Characters.—Test free or adherent, spiral, quasi-rotalian consisting of about four convolutions; upper surface convex; lower surface flat or very slightly concave; margin rounded. Chambers numerous, more or less inflated, often irregular in size; septa oblique, curved, marked by slight depressions on the exterior. Diameter, $\frac{1}{50}$ inch (0·5 mm.) or less.

The term "spiral" as applied to the arrangment of the segments of any of the *Valvulinæ* is not to be read in quite the same sense as in the higher groups of Foraminifera like the true Rotalians. Specimens of *Valvulina plicata* are occasionally met with, like Pl. IV, fig. 11, so neat and regular in appearance that they might easily be mistaken for small *Discorbinæ*, but these are exceptional. Much more frequently it is impossible to trace any consecutive spiral series, and instead of a band of uniform and well-separated segments coiled regularly on itself, the effect is more like that of an oval tube twisted at intervals and so irregularly disposed that the order of the chambers may be a matter of doubt. Something of the obscurity may be attributable to the age of the fossils and the changes produced by the process of mineralization. In localities where the species is common there is generally a residuum of fairly marked examples, like figs. 10, *a*—*c*, possessing what may be looked upon as average characters, and upon such specimens its claim to a distinctive name is based.

Valvulina plicata is very closely related to *V. palæotrochus*, but its depressed, rounded, convex (rather than conical) shape, its plicate septation, smaller size and

general Rotalian aspect are sufficient for its identification. It is intermediate to *V. palæotrochus* and *V. bulloides*, the latter species having much fewer and more globular segments.

Distribution.—In England *Valvulina plicata* occurs, though very rarely, in both the Lower and Upper Carboniferous Limestones; in Scotland it is much more common in the Lower than in the Upper Group; and in the Fusulina-beds of Iowa, N. A., it is found associated with *V. bulloides*. It is not a Permian species.

VALVULINA BULLOIDES, *nov.*, Pl. IV, figs. 12—15.

Characters.—Test free (or adherent ?), oblong, rounded; composed of a few inflated segments, obscurely spiral in their arrangement. Superior surface, convex; inferior, flat or slightly concave, irregular, depressed at the umbilicus. Segments sub-globular, each succeeding one considerably larger than its predecessor. Diameter, $\frac{1}{80}$ to $\frac{1}{50}$ inch (0·3 to 0·5 mm.).

This little species, which is not uncommon in the Fusulina-limestones of North America, bears many points of similarity to the more modern type, *Globigerina*. Not only is the test made up in the same way of a few globose segments, somewhat rapidly increasing in size, but the excavation of the inferior surface often presents a striking resemblance to the umbilical vestibule of *Globigerina*. The superficial rugosity also bears some analogy to the sandy incrustation often observable in that genus. In point of fact the minute structure of the test of *Valvulina bulloides* is much more like that of some of the Tertiary members of the genus, than those of its own geological age. Notwithstanding its apparent arenaceous exterior—glistening in strong light with adherent white sand grains, the basis of the test is often distinctly perforate, as may be seen in the sections represented in Pl. IV, figs. 14, 15, a character that has not been satisfactorily demonstrated in any of its Carboniferous congeners. The aperture, which usually affords a generic feature of some importance, is scarcely ever discernible externally, owing to the infiltration of the test and the adhesion of particles of the matrix or of the body to which the organism may have been attached whilst living; but specimens are occasionally met with which show with sufficient precision its Valvuline peculiarities. The general structure of the test and the arrangement of its various parts may be readily made out from transparent sections.

Distribution.—Until comparatively recently I had supposed *Valvulina bulloides* to be confined to the Fusulina-beds of the Upper Coal-measures of North America, in which it is a common form, but I have since met with it sparingly in the Calcaire de Namur of Belgium and in the Fusulina-limestone of Miatschkovo, near Moscow. The Belgian

specimens are smaller than those from North America, but do not differ in any essential character, as may be seen by comparing the drawings.

VALVULINA RUDIS, *nov.*, Pl. III, figs. 19, 20.

Characters.—Test free or adherent, depressed, plano-convex. Exterior irregular, rough, giving no evidence of internal structure; margin thin. Interior doubtfully spiral; habit of growth obscured by the sub-division of the cavity into small irregular chamberlets. Diameter $\frac{1}{35}$ inch (0·75 mm.).

A less promising object for study than this obscure and rudimentary organism could not easily be found. Time after time it was taken in hand, as specimens presented themselves from various Carboniferous localities, with the conviction that it was an independent species, before any clue to its structure or affinity could be traced. Specimens were at length found of which it would be most correct to say that they were a little less devoid of character than those previously met with. These seem to furnish tolerably clear indication of relationship to the genus *Valvulina*, though representing the lowest condition of the type. They afford evidence of a sort of helicoid structure, the spiral band being very broad and thin, and so confused with shelly ingrowths, dividing the cavity into small, irregular, angular chamberlets, as to be traced with difficulty even under favorable conditions. True septa there are none, their place being apparently served by labyrinthic supplementary growths. The horizontal section commonly shows nothing but angular cavities bounded by subarenaceous walls; cavities and walls being alike devoid of regularity or order. In the dark coloured material, like the shales and earthly partings of our English Carboniferous beds, this species is easily passed over without recognition, but in the débris of the lighter coloured Fusulina-limestones it is more readily found.

Distribution.—In England *Valvulina rudis* has been met with in the Yoredale rocks only; in Scotland at two localities of the Lower Limestone Group. I also have specimens from the Fusulina-beds of Southern Iowa, N. A., and imperfect examples of what appears to be the same form from Miatschkovo in Russia.

Genus, ENDOTHYRA, *Phillips.*

ENDOTHYRA, *Phillips, Seguenza, Brady.*
ROTALIA, *Ehrenberg, Hall, d'Eichwald.*
NONIONINA (in part), *d'Eichwald.*
INVOLUTINA (in part), *Brady.*

General Characters.—Test free, spiral, rotaliform, more or less unsymmetrical bilaterally. Segments numerous. Texture subarenaceous, imperforate, though usually smooth externally. Aperture simple, situated on the inner margin of the terminal segment close to the periphery of the previous circlet of chambers.

The Rotaliform group, to which may be referred a considerable proportion of the Foraminifera of the Carboniferous beds, forms collectively a very distinct and well marked series notwithstanding the external resemblance that many of its members bear to analogous forms amongst the true *Rotalinæ*, and the consequent difficulty in laying down morphological characters, couched in brief zoological terms, that would not apply with almost equal fitness to members of other genera. There is perhaps not one of the ten "species" about to be described to which a parallel or isomorph might not be found either amongst the *Rotalinæ* or in the genus *Nonionina*, or sometimes in both. Still there are certain broad and important distinctions which are easily recognised. In general terms *Endothyra* is lower in the scale of organization than any true Rotaline, and though it might not be possible in every case to establish the relative position, say of two chance individuals, one belonging to each group, the distinction is none the less real and readily ascertained by the examination of a number of specimens.

The texture of the shell in *Endothyra* is to a greater or less degree arenaceous; that is to say, built up of minute particles of sand (necessarily in these limestone seas, of calcareous sand) embedded in a calcareous cement. The cement is not a dark ochreous material such as is commonly secreted by the rougher *Trochamminæ*, nor are the particles of sand large and angular, and in excess of the cement, as in some other Lituoline genera; but the grains are minute and rounded and set in a homogeneous material, so that it is often only by the weathered or fractured surface that the built-up nature of the test is rendered apparent. Sometimes the fine calcareous cement is in large excess, giving rise to specimens with sutures thickened by bands of clear shell substance just as in the hyaline Foraminifera. In comparison with true *Lituolæ* the test in *Endothyra* is generally very thin, and, so far as yet ascertained, never exhibits the tendency to fill up the cavities of the chambers with labyrinthic shelly growths from its inner surface.

On the other hand the investment seems to be normally, if not invariably, imperforate. It is impossible to speak with complete certainty, for the condition in which the specimens are found—infiltrated with calcareous material of the same composition as the test itself—is exceedingly unfavorable for the determination of minute characters. In point of fact it is very rarely that even the general pseudopodial aperture, which transparent sections show to be of considerable size, is visible externally, much less any minute perforations that may have existed in the shell-wall. Some of the more delicate varieties of the genus, such as *E. ammonoides* and *E. subtilissima*, not unfrequently have a dotted appearance, which at first sight looks very like shell-perforation; but the use of high magnifying powers and carefully adjusted light has always shown this to be due to a granular condition of the

surface. Precisely the same effect, arising from the same cause, is to be observed in some Jurassic *Trochammininæ*.

Moreover, in *Endothyra* the septation is never double as in the higher Rotalines; that is to say, each succeeding chamber is a mere tent-like covering of a lobe of sarcode lying directly upon the preceding segment, and not a complete investment of the lobe by a shell-wall proper to itself, as in *Rotalia* (Carpenter's 'Introd. Foram.,' p. 212).

Whilst these characters are sufficient to separate *Endothyra* from the Rotaline types, and also from the genus *Nonionina*, with which the isomorphism is less constant, the close resemblance in form, and analogy in range of morphological variation, indicate a similarity in laws of growth and in conditions of existence that demand recognition in any natural system of classification. There can be little doubt, notwithstanding the imperforate and, to some extent, cemented or composite structure of the test in *Endothyra*, that the type has a much closer relationship with the Rotaline series than with rough arenaceous genera, such as *Lituola* and its near allies. As has been already stated, the systems of classification of the Foraminifera at present in use whether in this country or in Germany, however otherwise differing, agree in the adoption of "shell-texture" as the basis of the primary divisions, and groups like the one under discussion, which seem to be somewhat out of place whatever position may be assigned to them, serve to remind us how rarely any classification having a claim to be considered natural can be arranged in a single linear series, with its constituent groups separated by definable lines.

With this explanation a place may for the present be assigned to *Endothyra* amongst the arenaceous Imperforata of which it may be regarded as the highest of the minute and simple forms, its nearest allies therein being the rotaliform *Valvulinæ* and the genus *Involutina*. Apart from schemes of classification, *Endothyra* may either be taken to represent a transition group intermediate to the spiral *Lituolida* and the true Rotalines, or, as there is much reason to think, it may represent a primitive type *from* which or *through* which, more than one series of Foraminifera, widely differentiated in their later developments, have had their origin.

So far as is known the genus *Endothyra* is confined to the Carboniferous Epoch, its nearest allies in rocks of later age being amongst the Rotaline genera.

Endothyra Bowmani, *Phillips*, Pl. V, figs. 1—4.

Endothyra Bowmanni,[1] *Phillips*, 1845. Proc. Geol. and Polytech. Soc. W. Riding Yorks., vol. ii, p.279, pl. vii, fig. 1.

Rotalia Baileyi, *Hall*, 1856. Trans. Albany Inst., vol. iv (p. 24 of the Memoir).

[1] By an oversight, of a sort unusual with the late Professor Phillips, this species, named after Mr. J. C. Bowman, appears as "Bowmanni." The slight correction made is, I believe, consistent with usage.

INVOLUTINA LOBATA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382.
INVOLUTA LOBATA, *Brady*, 1871. (In Young and Armstrong's Catal.) Trans. Geol. Soc. Glasgow, vol. iii, Suppl., p. 141.
ENDOTHYRA BOWMANNI, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test depressed, usually consisting of two or three oblique convolutions, of which but little more than the last is visible on the exterior. Margin thick, rounded, lobulate; septal lines depressed. Segments inflated; variable in number, usually from seven to ten in each whorl. Aperture single, simple. Diameter, $\frac{1}{45}$ to $\frac{1}{20}$ inch or more (0·6 mm. to 1·3 mm.).

The figure given by Professor Phillips in his paper "On the Remains of Microscopic Animals in the Rocks of Yorkshire," *loc. cit.*, and the very partial description appended to it, form, as already stated, the first record, of any palæontological value, of the occurrence of Foraminifera in the Carboniferous beds of England. The description amounts to very little, and the figure which represents a nearly complete horizontal section is not given with much detail. But it must be taken for what it is worth; and the comparison with a series of sections of determined forms, made for the purpose of distinguishing the species present in transparent slices of the harder limestone rocks, leaves little doubt that it is referable to the particular modification described by myself some years ago, under the name *Involutina lobata*. The horizontal section represented in Pl. V, fig. 4, corresponds very closely with Professor Phillips's drawing.

I have recently received, through the kindness of Dr. Meek, of Washington, some pieces of Sub-carboniferous Limestone from Southern Indiana containing the *Rotalia Baileyi* of Professor James Hall, in point of fact almost entirely composed of that species. Detailed examination has convinced me that, notwithstanding the somewhat stouter proportions presented by the American specimens, they do not differ in any important character from *Endothyra Bowmani*. I regret to have to sacrifice a specific term given in memory of one whom all microscopists delight to honour, but under the circumstances the name employed by Professor Phillips takes precedence of the others.

Endothyra Bowmani may be accepted as the best type of the genus. Not only was it the first described and first named, but morphologically it occupies about a central place in the range of modifications which the series presents: it is one of the largest in point of size, as it is also one of the most widely distributed species of the entire group.

The Indiana limestone before alluded to is a very remarkable microzoic rock. In appearance it is not unlike a whitish oolite, but almost every individual grain is a specimen of this rotaliform foraminifer; there is indeed scarcely enough of the calcareous matrix to cement the fossils permanently together. The mass crumbles down readily between the fingers, and the disintegrated grains are clean enough for mounting without further preparation. The average size of the American specimens is greater than any hitherto

found in British fossiliferous limestones, being one twentieth of an inch or more in long diameter when fully grown. The test is commonly thicker, and the septation in consequence often obscure; for the same reason they likewise present greater variation in external aspect and condition than those of less vigorous habit. British specimens, on the other hand, rarely exceed one thirty-fifth of an inch in diameter, and the chambers are rather more inflated and distinct. Their hue is darker, but this is due to the colour imparted by the shaley or marly material in which they are usually embedded.

The foregoing characters are sufficient to distinguish typical examples of *Endothyra Bowmani*, and the departures from them in minor particulars are easily recognised. Some of the thick-shelled examples have little or no depression at the umbilicus, and the margin of the test has no sharp constrictions. Others become bi-convex, have a rounded periphery and nearly even margin, the septa being only distinguished by slightly depressed lines, thus approaching *E. globulus* in general form; the latter, however, may always be recognised by its long narrow embracing chambers, and its more delicate proportions.

Distribution.—Of all the *Endothyræ*, probably *E. Bowmani* is the most widely diffused. In the Lower and Upper Limestones of England and Wales, and in the Lower and Upper Carboniferous Limestone Groups of Scotland it is alike common, and in Ireland it is not wanting. Sections of the Fusulina-rocks of the Caucasus attest its presence; and, as has been above noted, one of the limestone beds of Sub-carboniferous age in Indiana is almost entirely composed of its remains.

ENDOTHYRA AMMONOIDES, *Brady*. Pl. V, figs. 5, 6.

ENDOTHYRA AMMONOIDES, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test free, discoidal, complanate or slightly biconcave, nearly symmetrical bilaterally; composed of several (8, 10, or more) convolutions of a spiral line of chambers in one plane. Convolutions narrow, increasing gradually in width; regular, slightly embracing. Segments very numerous, somewhat oblique. Septa, marked in young shells by slightly excavated lines, and in larger specimens by conspicuous, broad, more or less limbate bands. Periphery rounded. Surface granular. Aperture small, distinct. Diameter $\frac{1}{50}$ inch (0·5 mm.).

A very pretty and distinct little species, not without some resemblance at first sight to the feeble recent varieties of the genus *Operculina*. In small specimens of *Endothyra ammonoides* the sutures are somewhat depressed, and the periphery is correspondingly constricted at each septum, but in larger ones the depressions are filled in by bands of

shell-substance, and the margin is even and regular. The surface of the test is finely granular. In some cases the granules are so minute and regular, as to be readily mistaken for perforations, but the thickness of the shell-wall and its compact arenaceous texture are readily seen in carefully prepared sections as represented in Plate V, fig. 6.

Distribution.—In England *Endothyra ammonoides* is comparatively rare, though less so in the Upper than in the Lower portions of the Carboniferous Limestone series. In Scotland it is tolerably common alike in the Lower and Upper Carboniferous Limestone Groups. Elsewhere I have no record of its occurrence.

In Mr. Charles Moore's gathering from Keld Head in Wensleydale it was singularly abundant, and the specimens very fine.

ENDOTHYRA GLOBULUS (*d'Eichwald*), Pl. V, figs. 7—9.

NONIONINA GLOBOLUS,[1] *d'Eichwald*, 1860. Lethæa Rossica, vol. i, p. 350, Esp. 24, pl. xxii, figs. 17, *a*, *b*, *c*.

ENDOTHYRA GLOBOLUS, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test discoidal, nearly symmetrical bilaterally, sometimes depressed at the umbilicus; consisting of several convolutions, each composed of ten or more segments, the last convolution only being visible. Periphery thick and rounded, but little if at all constricted at the sutures. Aperture, simple, crescentic. Diameter $\frac{1}{40}$ inch (0·65 mm.).

It is very difficult to arrive at a satisfactory conclusion as to precisely what species of Foraminifera are intended to be represented by d'Eichwald's figures bearing the names *Nonionina globolus* and *Nonionina rotula*[2] respectively. The drawings are given with a freshness and clearness characteristic of living specimens rather than of palæozoic fossils, and it is probably to their somewhat diagrammatic handling that the uncertainty in identifying actual specimens may be attributed. But it can scarcely be wrong to assume that the even, unconstricted, and rounded periphery, together with the depressed discoidal form of the shell, are the characters intended to distinguish his *Nonionina globolus*. In

[1] The specific term is so spelt in the 'Lethæa Rossica,' an obvious misprint, for which the necessary correction is now made.

[2] I have entirely failed to identify *Nonionina rotula*, though all the Russian material sent to me by General von Helmersen has been carefully searched for it. M. d'Eichwald states in a letter that his specimens of Carboniferous Foraminifera were very few in number, and have long since been given away and lost sight of, so that there is unfortunately now no means of verifying their characters. I have never seen anything amongst the Carboniferous species resembling the sutural orifices represented in his drawing, and the numerous apertures on the truncate face of the terminal segment are not suggestive of any affinity with *Nonionina*. I cannot help thinking (and the affinity to *Valvulina* remarked by the author would confirm the idea) that the specimen must have belonged to some species of *Endothyra* or of *Lituola*, in

all these particulars the British specimens coincide very well with the described Russian species. The only difference seems to be the presence usually of a somewhat larger number of segments in each convolution and the occasional filling up of the umbilical depression by the extension of the ends of the alar processes of the chambers and the thickening of the walls. There seems no reason for associating the species with the genus *Nonionina* especially in the absence of any other member of the group in the Carboniferous fauna. There is a very obvious resemblance between parallel modifications of the two genera, and *Endothyra globulus* may be regarded as the isomorph of *Nonionina depressula*, just as *E. crassa* is the isomorph of *N. umbilicatula*. It takes a place in the Endothyran series as the passage form between *E. Bowmani* and *E. radiata*, on the one hand, and *E. crassa*, on the other. The test though thin and smooth appears to be imperforate, and it sufficiently resembles the allied larger species to leave little doubt as to the similarity of its intimate structure, although it is next to impossible to lay down this character with entire certainty, so small are the specimens and so completely infiltrated with subcrystalline material. The cast of the interior of an unusually fine example, Pl. V, fig. 9, illustrates very clearly the form of the animal inhabiting the shell, and its segmentation.

There is no hard line of division between *E. globulus* and *E. radiata*, but they bear the same sort of relation to each other that we find amongst the modifications of many other helicoid types, *e.g.*, *Cristellaria* and *Polystomella*, which present one set of varieties with thick rounded margin and another with sharp periphery.

Distribution.—The earliest appearance of *Endothyra globulus* is in the Calciferous Sandstone Series of Scotland at which age it is rare; but it is common in the Lower and Upper Carboniferous Limestone Groups of that country, and in the Lower and Upper Limestone beds of England. It occurs in the Calcaire de Namur of Belgium, and M. d'Eichwald's specimens were found in a yellow clay from the Village of Sloboda in the Government of Toula, Russia.

which the sutural depressions have been bridged over at intervals, as occasionally observed in *E. Bowmani*. The anomalous apertures would be less noteworthy in an arenaceous or subarenaceous species.

I append M. d'Eichwald's description in the hope that some future student may be more fortunate in his search for specimens than I have been.

"NONIONINA ROTULA.

"*Testa microscopica, subglobosa, subæquilateralis, convexa, loculis* 8 *sensim magnitudine increscentibus, apertura semilunari, facie antica subtiliter punctata, suturis simplice pororum serie instructis.*

"Hab. *dans l'argile jaune carbonifère du gouvernement de Toula près du village de Sloboda.*

"Le test, qui ressemble un peu à un *Valvulina*, à $\frac{3}{4}$ de ligne de hauteur et $\frac{1}{2}$ ligne de largeur; les 8 loges a dos arrondi sont plus larges que longues, les sutures sont finement pointillées; l'ouverture de la dernière loge est semilunaire, étroite de la face antérieure, qui est au-dessus d'elle, est très finement pointillée.

"Le test est en général plus haut que large, par conséquent un peu comprimé des deux côtés; il ressemble à l'*Alveolina prisca*, qui en diffère par ses loges divisées interieurement en cavités plus nombreuses" (*Op. cit.*, vol. i, pp. 349, 350, Esp. 22, pl. xxii, figs. 18, *a*, *b*).

ENDOTHYRA CRASSA, *Brady*, Pl. V, figs. 15—17.

INVOLUTINA CRASSA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382.

Characters.—Test free, spiral, nautiloid, subglobular, slightly compressed laterally, nearly symmetrical; composed of several convolutions, of which the latest encloses all the earlier ones. Segments numerous, about ten in each convolution, broad, convex, embracing. Septa marked externally by slightly depressed lines. Texture distinctly arenaceous. Surface smooth except around the umbilicus. Diameter, $\frac{1}{20}$ inch (1·2 mm.).

For the nearest isomorph of this species we must turn to the genus *Nonionina*, and in the small thick subglobular varieties, such as *N. umbilicatula* and *N. pompilioides*, we may find almost exact morphological parallels. *Endothyra crassa* is, however, a somewhat larger organism than the corresponding modification of the Nonionine type, and the test is unmistakeably arenaceous in its minute structure. The surface generally is very nearly smooth, but near the umbilicus it is more or less rugose and granular, sometimes studded with little tubercles. But few of the specimens are perfect, the terminal segment being often incomplete or broken. Amongst the *Endothyræ* its nearest ally is *E. globulus*, but the smaller size and compressed form of the latter are sufficiently distinctive. The only Carboniferous Foraminifer likely to be confounded with *E. crassa* is *Lituola Bennieana*, a fossil of still larger dimensions, with fewer and more ventricose segments, and labyrinthic interior (see Pl. I, figs. 8—11). The three drawings, Pl. V, figs. 15—17, are from different individuals, all collected by Dr. Harvey B. Holl at Great Ormes Head.

Distribution.—*Endothyra crassa* is nowhere very common. In England and Wales it has only been found in the Lower Carboniferous Limestones; in Scotland only in the Lower Carboniferous Limestone Group. The finest set of specimens I have seen was collected from the Mount Lothian Quarry, Edinburghshire. In Belgium one or two specimens have been met with in the Calcaire de Visé. Similarly rare examples have been observed in the Fusulina-limestones of Russia.

ENDOTHYRA RADIATA, *Brady*. Pl. V, figs. 10—12.

INVOLUTINA RADIATA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382, &c.

— — *Id.*, 1871. (In Young and Armstrong's Catal.) Trans. Geol. Soc. Glasgow, vol. iii, Suppl., p. 14.

ENDOTHYRA — *Id.*, 1873. Ibid., vol. iv, pt. iii, p. 271.

— — *Id.*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test nautiloid, compressed, laterally unsymmetrical; excavated at the umbilicus, thin and angular at the periphery; consisting of several convolutions, of which but little more than the latest is visible externally. Segments very numerous, narrow. Septation usually marked by lines of lighter colour rather than by superficial excavation. Margin sharp, but little constricted at the sutures. Surface smooth. Diameter, $\frac{1}{50}$ inch (0·5 mm.).

Adult specimens of this little nautiloid variety are sufficiently marked in their morphological characters to be easily distinguished from their congeners. The same can scarcely be said of small and immature examples, which it is often difficult to separate from those of *Endothyra globulus*. The relationship between the two forms is, in point of fact, exceedingly close; but the smaller size, the sharp periphery, and more, the numerous segments of *E. radiata*, are features of easy recognition in fully grown individuals. The peripheral view, Pl. V, fig. 11 *b*, does not show so thin and sharp a margin as many examples present, but it very well exhibits the unsymmetrical contour of the segments, which is a character of some importance.

Distribution.—In England *Endothyra radiata* occurs with some frequency in both the Lower and Upper Limestones; in Scotland it is common in the Lower, and very common in the Upper Carboniferous Limestone groups. In the Calcaire de Namur of Belgium obscure specimens probably belonging to the species have been noticed.

ENDOTHYRA MACELLA, *Brady*. Pl. V, figs. 13, 14.

INVOLUTINA MACELLA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382.

Characters.—Test free, spiral, much compressed or complanate, oval or rounded, somewhat irregular; formed of a number of convolutions, of which the last only is visible on the exterior. Segments numerous, embracing, often depressed or concave rather than convex externally. Septation obscure, sometimes marked by excavated lines. Surface rough, irregular. Diameter, $\frac{1}{20}$ inch (1·3 mm.).

Under the name *Endothyra macella* have been grouped a number of large, thin outspread specimens, differing collectively from other members of the genus, but which, were it not for their dimensions, might almost be regarded as starved or otherwise emaciated individuals. Further observation may show that they represent merely a depauperated condition of some other species, but for the present there is nothing to demonstrate such a connection. The specimens have but few segments in each convolution, and the test is often so rough as to conceal the general structure

partially or entirely. Sometimes the surface of the chambers is nearly flat, and the sutures are marked by excavated lines; frequently the exterior of each segment is somewhat depressed or hollowed, and the septa are correspondingly raised. The edge-view, Pl. V, fig. 13 *b*, owing probably to superficial irregularity in the particular specimen, gives the idea of a much thicker contour and much greater solidity than the variety generally exhibits.

Distribution.—A rare form, whether in the number of localities or the frequency of the specimens. *Endothyra macella* has been found in the Yoredale rocks of Swaledale, and the Upper Mountain Limestone of the Bristol district; in the Lower Carboniferous Limestone Group of Scotland, and in the Castle Espie shale, Ireland.

ENDOTHYRA ORNATA, *Brady*. Pl. VI, figs. 1—4.

ENDOTHYRA ORNATA, *Brady*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, pp. 63, 95, &c.

Characters.—Test free, nautiloid, biconvex, rounded, nearly symmetrical bilaterally; composed of five or six regular convolutions, the last of which is alone visible on the exterior. Segments numerous, 14 or more in the final whorl of fully grown individuals. Sutures, showing as slightly limbate lines in immature specimens, as stout, irregularly radiating costæ in adults. Margin, sharp or carinate. Diameter, $\frac{1}{32}$ inch (0·8 mm.).

A handsome, strongly marked variety, the adult condition of which is well represented in figs. 1 *a*, *b*, of Plate VI, as a lenticular, carinate shell, with stout, curved, irregularly distributed, radiating costæ. The strongly marked exogenous shelly growths impart to the test its most striking character, and obscure all external indications of its interior structure. In the young condition the septal lines are marked by slightly limbate bands radiating from the umbilicus and nearly regular, as in fig. 2 of the same plate. The horizontal section, from a medium-sized specimen, fig. 3, shows how regular the actual septation is, and how uniformly radial in its direction, not set obliquely after the usual manner of helicoid Foraminifera. With these features *Endothyra ornata* is easily distinguished from any other Carboniferous species. The two forms following next in order, *E. tenuis* and *E. obliqua*, have some characters in common with it, which will be considered in their right place, the former of them is probably only a varietal modification.

Distribution.—In England, rare in the Lower, less rare in the Upper Carboniferous Limestones; in Scotland hitherto found in beds belonging to the Lower Carboniferous Limestone Group only, and very rare therein; occurs also in Ireland, in the Castle Espie shale.

ENDOTHYRA ORNATA, var. TENUIS, *nov.* Pl. VI, figs. 7, 8.

Characters.—Test free, nautiloid, irregular; oval or rounded, compressed, very thin; composed of several convolutions, of which the last only is visible externally. Septation obscure. Surface rough, broken up by very irregular and ill-defined costæ. Periphery sharp, uneven. Diameter, $\frac{1}{30}$ inch (0·85 mm.).

There can be little doubt that the thin emaciated specimens found in some few localities, and generally in company with *Endothyra ornata*, represent merely a starved variety of that species, though they appear very distinct at first sight. The test is outspread and extremely thin, often only like a crumpled scale, and has no traceable septation; the margin, sharp, without any distinct carina, and usually very irregular. The spiral structure is assumed from analogy, rather than indicated by external marks. It is difficult to give an idea of the tenuity of the shell by a drawing, owing to the irregularity of the surface; and fig. 7 *b* is by no means successful. Under the microscope the edge-view often appears as a mere narrow jagged line.

Distribution.—The occurrence of *Endothyra tenuis* does not exactly correspond with that of its type *E. ornata*. It is rare alike in the Lower and Upper Limestone rocks of England; it has been found, though seldom, in the Calciferous Sandstone Series of Scotland, and in the Upper Carboniferous Limestone Group, but is wanting in Lower; in Ireland it occurs in the Castle Espie shale.

ENDOTHYRA OBLIQUA, *Brady.* Pl. VI, figs. 5, 6.

INVOLUTINA OBLIQUA, *Brady*, 1869. Report Brit. Assoc., Exeter Meeting, pp. 379, 382.

Characters.—Test free, oblong or rounded, compressed; formed of several convolutions of a band of long arcuate segments, the axis being the long diameter of the test, and the convolutions presenting a long oval transverse section. Surface rough; with irregular ill-defined costæ, more or less parallel to the axis, indicating the position of the septa. Aperture curved, situated near the middle of the inner edge of the long terminal segment. Diameter, $\frac{1}{24}$ inch (1·0 mm.).

Whether the assemblage of forms grouped under the name *Endothyra obliqua* owe their anomalous characters to external physical agencies or to inherited peculiarity is possibly still open to doubt. Their close relationship to *Endothyra ornata* does not admit of question; but, after the careful examination of a large number of specimens from various sources, I am unable to see how the characters in which they differ from

that species can be the result of pressure or other force acting from without, or indeed can be other than morphological variations in the ordinary sense. The trivial name originally given to specimens in Mr. Charles Moore's collection has therefore been retained, pending more satisfactory evidence as to the zoological value of their conspicuous characters. The salient peculiarity of *Endothyra obliqua* is the relation of the axis of the test to the spiral band of chambers. In the other *Endothyræ* the axis of the spiral is the shortest diameter of the test; in the present species it is either directly or obliquely through the long diameter, and the spiral, instead of being round, is oval or compressed. A reference to the figures (Pl. VI, figs. 5, 6) will do more than many words to explain these structural features. A similar change in the relation of the axis to the body of the shell is observable in many other genera of Foraminifera, and something approaching a parallel to *Endothyra obliqua* may be found in such species as *Biloculina contraria*,[1] or in the curious modification of *Textularia* named by d'Orbigny *Cuneolina pavonia*.[2]

Distribution.—Hitherto *Endothyra obliqua* has been observed in but few localities, though it is by no means an uncommon form where it does occur. In England it appears in both the Lower and Upper portions of the Carboniferous Limestone Series; in Scotland it seems limited to the Calciferous Sandstone or lowest division; in Ireland it is associated with allied species in the Castle Espie shale.

ENDOTHYRA SUBTILISSIMA, *nov.* Pl. VI, fig. 9.

Characters.—Test free, nautiloid, complanate, flat or only slightly convex; composed of a few regular convolutions rapidly increasing in width, the last almost entirely enclosing the earlier ones. Segments, about seven or eight in the outermost or visible whorl. Sutures and margin limbate. Periphery blunt, somewhat rounded. Surface granular, especially at the umbilicus. Diameter, $\frac{1}{75}$ inch (0·34 mm.).

A very pretty and neatly made variety, with some *primâ facie* likeness to the *Planorbulina* (*Planulina*) *Ariminensis* of d'Orbigny. As far as can be made out, however, from the single example I have had to work upon, the test is imperforate and the shell-texture precisely that of the smaller *Endothyræ*, so that it may safely be regarded as another instance of the isomorphism of which almost every modification of the Endothyran type furnishes an example.

Distribution.—I know of only a single specimen, that from which the figures are drawn, which was found by Mr. Robertson in the rich Lower Carboniferous shale of Brockley, in Lanarkshire. It is not the only case in which my friend Mr. Robertson's quick eye has detected minute inconspicuous forms that have escaped the notice of other observers.

[1] 'Foram. Foss. Vienne,' p. 266, pl. xvi, figs. 4—6. [2] Ibid., p. 253, pl. xxi, figs. 50—52.

Genus—NODOSINELLA, *gen. nov.*

DENTALINA (in part), *Dawson, Brady.*

General characters.—Test free; straight, arcuate, or crooked, never spiral; formed either of a tube constricted at intervals, or of a single series of segments variously combined. Test imperforate, texture finely arenaceous, though sometimes smooth externally. Aperture variable, simple or compound.

The uniserial Foraminifera which have been brought together to constitute the genus *Nodosinella* are a somewhat anomalous set of forms, and their association in one group has been adopted because it seemed open to fewer objections than any other course that could be suggested.

The Carboniferous uniserial species, as far as can be made out, are all imperforate; their texture is subarenaceous, and their septation rudimentary. These characters, if confirmed, are sufficient to separate them at once from the true *Nodosarinæ*. The only other genus to which they could be supposed to belong is that termed by Prof. Reuss *Haplostiche*, the characters of which as laid down by its author might with a little modification be taken to include most of the Carboniferous specimens. But Prof. Reuss appears to accept the *Reophax scorpiurus* of de Montfort as the type of his genus, thereby indicating a set of Foraminifera essentially different in shell-structure from those now under consideration. De Montfort's species is a characteristically rough organism, with a test built up of coarse siliceous sand-grains, fitted together with but little calcareous cement. It is quite true that all Prof. Reuss's figures do not conform to this typical character, and that they show considerable range of modification, some being more, some less rough externally, and the texture of others is indeterminable from the drawings; but as in any case the name *Reophax* takes precedence of *Haplostiche*, whatever the zoological value assigned to either term, it is not needful to criticise the nomenclature of the Tertiary forms described under the latter appellation. That it may be found convenient to reintroduce de Montfort's name for the rough, sandy, Nodosariform *Lituolæ* is possible; but the Carboniferous specimens have little in common with these, and it therefore becomes necessary to establish a genus for their reception.

Notwithstanding some range of variation in shell-structure, the relation of the new type *Nodosinella* to the genus *Reophax* (or *Haplostiche*) is almost precisely analogous to that which subsists between *Trochammina* and *Lituola* (proper) or *Haplophragmium*, the one characterised by a nearly smooth arenaceous shell, in which the calcareous cement is largely in excess of the constituent sand-grains, the other by a coarse test, externally rough, with the angular siliceous grains held together by the minimum of calcareous

material. Such, in general terms, are the relations of *Nodosinella;* the details may best be gathered from the specific descriptions.

In observations on the structure of the tests of Foraminifera it is needful to bear in mind the conditions under which the animals have lived. A creature of low organization and limited selective power, building its investment chiefly of extraneous materials, and secreting only the cement by which such materials are incorporated, forms a test which must necessarily vary with the nature of the sea-bottom on which it lives. During the Carboniferous Limestone period the sea-bottom was for the most part a fine calcareous mud, seldom containing any appreciable quantity of siliceous material in the form of sand, so that the composite tests of minute organisms must of necessity have been chiefly made up of calcareous particles incorporated by calcareous cement, and as a natural result the texture, which under other conditions would have been heterogeneous and granular, is compact and nearly homogeneous.

But notwithstanding the smooth exterior which these, in common with other Carboniferous subarenaceous forms, often possess, there is seldom much difficulty in proving their composite structure, and the absence of any trace of shell-perforation is a confirmatory fact of some importance. Although the tendency of calcareous infiltration is to obliterate minute markings, specimens would surely have been found, to judge by the *Nodosariæ* of the Permian Magnesian Limestones, affording some evidence of shell-perforation if it existed; but, notwithstanding rigid examination, nothing of the sort has been detected in any of the species which have been assigned to this group. That these smooth subarenaceous Carboniferous forms were the precursors of the true *Nodosariæ* of the Permian is an interesting and significant fact, whatever may be their zoological relationship.

NODOSINELLA DIGITATA, *nov.* Pl. VII, figs. 1—3.

Characters.—Test elongate, tapering; straight or only slightly curved; cylindrical or somewhat compressed. Segments irregular, more or less inflated. Aperture single, simple. Length $\frac{1}{25}$ to $\frac{1}{12}$ inch (1·0 to 2·0 mm.).

The coarse imperforate test alone distinguishes this form from the *Nodosariæ*, for the septation, though often partial and obscure, is sometimes at least as well defined as in *Nod.* (*Dentalina*) *pauperata*, and other similar varieties of the hyaline type. Figures 1, 2, and 3 of Plate VII are all from Permian specimens:—fig. 2 is a neatly septate, somewhat flattened variety, but connected by gradational links with the stouter, rounded type; whilst fig. 3, by its indistinct septation, approaches in character the group of Carboniferous forms which immediately follow it in the plate. As has been repeatedly stated, it is

impossible to mark off the successive terms of such series by hard lines. The difference in shell-structure between these specimens and the perforate, true *Nodosariæ* of a neighbouring locality, but of somewhat later geological age, is readily demonstrated by microscopical sections.

Distribution.—Middle Permian Limestone of Tunstall Hill, Durham, rare. Specimens which may be assigned without much hesitation to the same species have been found in the Yoredale Rocks of Wensleydale, and near Skipton, Yorkshire, and somewhat doubtful examples in the Calcaire de Namur of Belgium.

NODOSINELLA CYLINDRICA, *nov.* Pl. VII, figs. 4—7.

Characters.—Test cylindrical, nearly straight, sometimes irregular in outline. Segments numerous, cylindrical, but little inflated, usually short. Septation imperfect; sutures marked externally by slightly depressed lines. Interior of the chambers sometimes more or less labyrinthic. Aperture variable, simple or compound. Length $\frac{1}{25}$ inch (1·0 mm.).

A large and somewhat varied series of fossils, agreeing in their irregular, cylindrical contour and their subdivision into numerous short segments, with but little external constriction at the sutures, are included under the name *Nodosinella cylindrica*. Many of the specimens are nearly smooth superficially, others quite granular. The smooth varieties are often distinguished with difficulty from fragments of fossils of widely different zoological origin, such as the spines of *Echini*, or of molluscan Shells, or even portions of minute Encrinites. Thin microscopical sections often furnish the only means of determining the foraminiferal nature of such organisms.

The rough varieties, like Pl. VII, fig. 7, bear considerable resemblance to some of the recent large deep-sea types of Rhizopoda, especially to *Botellina*, the difference being chiefly in their comparatively minute size and the consequent finer texture in the labyrinthic lining of the test.

These slender elongate forms are seldom found quite entire in the Carboniferous beds, and it is necessary to speak with some caution of their minute characters. It is even possible that the group now described may contain representatives of two distinct species. With an insufficient range of specimens it is difficult to apportion a right value to each structural peculiarity, and at present there is not evidence to justify the division of a group which is tolerably uniform in external morphological features.

Distribution.—Hitherto *Nodosinella cylindrica* has only been recognised in the Carboniferous beds of England and Wales, viz. at Elfhills, and Grassington, in the Upper, and at Bangor, in the Lower division of the Series.

NODOSINELLA PRISCILLA (*Dawson*). Pl. VII, figs. 8, 9.

DENTALINA PRISCILLA, *Dawson*, 1868. Acadian Geology, 2nd edit., p. 285, fig. 82.

Characters.—Test slender, moniliform, formed of several more or less elongated cells separated by only slight constrictions. Length (?). Diameter $\frac{1}{40}$ inch (0·64 mm.).

I think I cannot be wrong in associating this little fossil with the other imperforate uniserial Carboniferous Rhizopoda comprised in the group *Nodosinella*. Dr. Dawson states that he does "not feel at all certain as to its affinities, more especially as in the longitudinal section it does not show true septal plates, but only slight constrictions at the nodes." I am indebted to Dr. Dawson for authentic specimens, and have made them the subject of careful examination. They fully confirm his view as to the extreme simplicity of the organism, which seems to be nothing more than a tube of indefinite length, constricted at intervals. The test is thicker than is usual in the true *Nodosarinæ*, and I am convinced that the minute structure is more akin to that of *Trochammina* than to any perforate type—the texture being, in fact, just that which *Trochammina* would assume on a sea-bottom of white calcareous mud. At the same time I do not doubt that there is a very close genetic relationship between these "*Protonodosariæ*," if one may call them so, and the analogous hyaline forms of later age. The septation of the sub-arenaceous Foraminifera differs both in extent and character from that of the hyaline types. In *Trochammina*, for instance, the animal may be monothalamous or segmented; in the latter case the subdivision is the result of the mere infolding or constriction of the shell-wall, or else of the investment of the individual chambers taking the form of tent-like coverings placed one over the other. An interesting illustration is furnished by Pl. VII, fig. 1 *a*, which represents a specimen of *Nodosinella digitata*, the earlier half of which has no septa whatever, whilst the remainder is divided into three segments. In *N. cylindrica* the septation is of the most variable and partial nature, and in *N. concinna* it is effected by the rapid narrowing of the investment, without the interposition of any septal plate.

I have found no specimens myself that can quite satisfactorily be assigned to *Nodosinella priscilla*. Fig. 10 represents one out of a number of similar slender forms, both Carboniferous and Permian, that in some degree resemble it; but the test is thicker and rougher, and the sutures more sharply defined. Such characters are more apparent in dark-coloured fossils like the subject of the drawing than in the constituent organisms of a pure white limestone; but this specimen is probably referrible to *N. digitata*.

Distribution.—"This little shell is very abundant on the surfaces of bed *b*, Windsor [Nova Scotia, N. A., White Carboniferous Limestone], but always in fragments."—Dawson, *loc. cit.*

NODOSINELLA CONCINNA, *nov.* Pl. VII, figs. 11—15.

Characters.—Test sub-cylindrical or compressed, composed of few (one to three) well defined, ventricose segments. Segments variable in contour, rounded; usually compressed laterally, perpendicularly, or obliquely. Aperture single, simple. Length $\frac{1}{25}$ inch (1·0 mm.).

This is perhaps the most striking and best differentiated species of the genus, but very limited in distribution. The test consists of a series of segments, without intervening septal plates, separated only by constrictions, and bearing a strong resemblance in shell-structure to the compact *Trochamminæ*. A large number of the Foraminifera from the Yoredale Limestones of Swaledale, in which *Nodosinella concinna* most abounds, are very siliceous, and the Trochammina-like appearance of the specimens extends even to those in which the original test has been entirely replaced by colloid silica.

The individuals vary a good deal in contour; perhaps the largest number have two segments, but many have three, and on the other hand some single segments occur which bear no sign of fracture or incompleteness; whether these represent different stages of growth or are alike perfect organisms, it is difficult to say.

Distribution.—In England *Nodosinella concinna* is confined, so far as is known, to the Yoredale Rocks of a very few localities. The Rev. W. Howchin has met with it in the Belstonburn limestone, its only recorded occurrence in Scotland.

NODOSINELLA LINGULINOIDES, *nov.* Pl. VII, figs. 24, 25.

Characters.—Test elongate, tapering, compressed or complanate, straight or only slightly curved. Segments numerous, successively increasing in width; sutures but little excavated. Surface rough and irregular. Aperture variable. Length $\frac{1}{17}$ inch (1·5 mm.).

Certain large, rough, flat specimens, occurring rarely, and often imperfect in their later segments, may be conveniently distinguished under the name *Nodosinella lingulinoides*. Their exterior is rugged and irregular, and the interior of the chambers more or less labyrinthic. These characters are usually sufficient for their recognition.

A few individuals (figs. 22 and 23, for example) of smaller size and somewhat less compressed laterally were at first associated with the foregoing, but their internal structure seems to indicate that they belong rather to the genus *Stacheia*.

Distribution.—A rare species; it occurs in both the Lower and Upper Carboniferous Limestones of England, but in a very limited number of localities; in Ireland, in the Castle Espie shale; possibly also in the Calcaire de Namur of Belgium, but in the latter case the specimens are more than usually obscure and doubtful.

Genus—STACHEIA, *gen. nov.*

WEBBINA (in part), *Brady.*

General Characters.—Test (normally) adherent, composed either of numerous segments subdivided in their interior, or of an acervuline mass of chamberlets, sometimes arranged in layers, sometimes confused. Texture subarenaceous, imperforate.

From time to time during the examination of foraminiferous material from Carboniferous beds, minute parasitic structures, bearing some sort of resemblance to Rhizopodtests, attracted my attention, but the specimens were so ill-defined and wanting in character that they were of necessity laid aside. Amongst the Lanarkshire shales, for which I am indebted to Mr. R. Etheridge, jun., specimens at length appeared, chiefly adherent to fragments of Polyzoa or of Molluscan Shells, sufficiently well preserved and distinctive enough in their peculiarities to be assigned with confidence to the Foraminifera. These belonged for the most part to one species; and from its resemblance in shell-texture and habit to the adherent varieties of *Trochammina* known under the subgeneric term *Webbina*—differing chiefly from the hitherto described species in the irregular, heaped arrangement of its tent-like segments, it was assigned provisionally to that subtype, and it appears in the Survey Memoir on the South Lanarkshire Coal-field (Expl. Sheet 23) under the name *Webbina acervalis*.

Thus encouraged, the search for parasitic forms was renewed, and the examination of minute Encrinites, spines, pieces of Zoophytes, and the like, eventually yielded, after setting aside a multitude of doubtful organisms, a number of interesting new forms,—my friends, Mr. John Young and Rev. W. Howchin, having materially assisted to this result. Closer microscopical examination showed that one or two species which had been previously supposed to be free-growing were essentially parasitic, and that one form, at least, which might have been passed by as pertaining to the Polyzoa was in fact an encrusting Polytrema-like Foraminifer. Whether future research may confirm the course that has been taken in treating these various forms as modifications of one polymorphic type, it is, of course, impossible to say; but they have so many characters in common, and

they form together so natural a series, that I have had but little hesitation in associating them provisionally under a single generic term, and have employed for their distinction the name of my friend and collaborateur Dr. Guido Stache, of Vienna.

A brief survey of the present extent of our knowledge of parasitic Foraminifera in general may help to a right appreciation of the characters of those now to be described; indeed, all the accessory assistance which can be obtained is needed for the proper reading of the obscure, often nearly obliterated, features of these very early fossil microzoa.

Amongst the porcellanous Imperforata (family *Miliolida* of Carpenter, Parker, and Jones) the genera *Dactylopora*,[1] *Acicularia*, and *Nubecularia*[2] are, as a rule, parasitic. The two former are elongate, typically cylindrical forms with more or less regular plan of growth. *Nubecularia*, on the other hand, is a polymorphic type which was long regarded as a zoophyte from its encrusting habit. It occasionally shows a tendency to assume a spiral form, but in reality conforms to no definite plan. It spreads over the stones or shells upon which it grows, and adapts itself to their contour, sometimes producing a single layer of misshapen chambers, sometimes an irregular acervuline mass, and in these characters bears considerable resemblance to some of the Carboniferous specimens.

The genus *Squamulina* of Max Schultze is assigned by both Carpenter and Reuss to the porcellanous *Imperforata*, but the researches of Mr. Carter[3] indicate that its proper place may be in the arenaceous series. According to Max Schultze's diagnosis it consists essentially of a plano-convex test adherent by its flat surface and with a single wide orifice on the convex side. In one species described by Mr. Carter the normal lenticular form is supplemented by a tall columnar growth. The shell is calcareous and opaque, and, in some of its varieties at least, largely built up of siliceous sand and sponge spicules.

Passing to the arenaceous Imperforata (family *Lituolida*), the genera *Trochammina*, *Lituola*, and *Valvulina* have each their parasitic representatives, and to these must be added the more recently described *Polyphragma* of von Reuss.

The typical *Trochammina squamata* is itself an outspread trochoid and probably adherent form, but the better known attached varieties are those of simpler character to which the sub-generic term *Webbina* is applied. They consist of simple, circular or oval, convex tests, subarenaceous in texture, but having a smooth surface, growing either singly or in irregular lines over the broad surface of stones or shells. These oval tent-like segments

[1] Dr. Gümbel, in his memoir "Die sogenannten Nulliporen," 2ter Theil, 'Abhandl. k. bayer. Akad. der W.,' II Cl., vol. xi, pt. 1, subdivides *Dactylopora* into five generic groups, *Haploporella*, *Dactylopo-rella*, *Thyrsoporella*, *Gyroporella*, and *Uteria*, but this does not sufficiently affect our present purpose to need consideration here.

[2] Prof. Reuss does not appear to have been conversant with the genus *Nubecularia*, for he associates it with *Webbina* and *Placopsilina*, and places all together amongst the arenaceous *Imperforata*.

[3] 'Ann. and Mag. Nat. Hist.,' ser. iv, vol. v, p. 309, *et seq.*

may be joined end to end more or less compactly, or may be connected by delicate tent-like stoloniferous tubes, single or branching; or each individual segment may represent an entire animal, the test sometimes having an aperture placed at the end of a tadpole-like tail, sometimes having no visible orifice. The adherent rougher *Lituolæ* have received the sub-generic name *Placopsilina*, and they present much the same range of morphological variation as the adherent *Trochamminæ*, but they are always coarse and rough in shell-texture. The segments are also usually more closely packed, and in early growth they show a tendency to take a spiral arrangement. The trochoid and plano-convex species of *Valvulina* appear to be all constructed for parasitic growth, but except the very conical forms they are seldom found actually adherent.

The genus *Polyphragma*[1] represents typically an irregularly cylindrical, sub-arenaceous test, attached by one end, and growing in a curved or nearly erect line. It is composed of a single series of superimposed discoidal segments, the aperture taking the form of a number of perforations, arranged in more or less regular rings, on the convex face of the terminal chamber.

Turning now to the PERFORATA,—in the first division (family *Lagenida*), the genus *Polymorphina* alone presents adherent forms, and these appear as aberrant modifications of well known free varieties. In the *Polymorphina concava* of Williamson the adhesion is effected by the convex side of the shell, whilst in the "rooted" forms figured in the Monograph of the genus,[2] the attachment is secured by the fistular shelly outgrowths.

In the family *Globigerinida* the most prominent parasitic types are *Carpenteria*, *Planorbulina*, and *Polytrema*, though the smaller *Discorbinæ* and perhaps other plano-convex and trochoid Rotalians may occasionally be found growing upon foreign bodies.

Carpenteria is essentially an irregular encrusting *Globigerina*, its relationship at times attested by a disposition to assume a spiral arrangement in some of its segments; but more frequently consisting of a confused mass of chambers with large conspicuous perforations. The plano-convex and outspread *Planorbulinæ* are probably normally parasitic, as well as a section of the sub-generic group *Truncatulina;* and even the allied genus *Tinoporus* possesses an adherent variety, noticed on a later page as an isomorph of one of the varieties of *Stacheia*.

"Of all Foraminifera" observes Dr. Carpenter (Introd. p. 235) "there is none so decidedly Zoophytic in its form and habit as *Polytrema*, for although it sometimes spreads itself on the surfaces of shells, corals, &c., it not unfrequently rises from those surfaces in an arborescent form, whilst sometimes its stalk instead of branching, swells into a globular protuberance, which leaves a strong resemblance in size and general aspect to the

[1] *Polyphragma cribrosum*, Reuss, 1872, 'Das Elbthalgebirge in Sachsen,' 1ter Theil, p. 139, pl. xxxiii, figs. 8—10.

[2] Brady, Parker, and Jones, 'Trans. Linn. Soc. Lond.,' vol. xxvii, pl. xlii, figs. 38, *i*, *j*.

globular form of *Tinoporus*." But I must refer the reader to the description itself, which is too long to quote entire; much of it would apply almost equally to the more complex modifications of the genus *Stacheia*.

Lastly, amongst the *Nummulinida*, if the position assigned to it by Dr. Dawson, Dr. Carpenter, and others be considered as established, appears the largest of all adherent Rhizopods—that bone of contention, *Eozoön*.

We shall have but little need to refer more particularly to the various types which have been alluded to, except perhaps to *Nubecularia*, *Tinoporus*, and *Polytrema*, but the bare enumeration will have served to show how important a section of Foraminifera the adherent varieties constitute.

In external form the specimens grouped under the generic name *Stacheia* present a wide range of variation. In *S. marginulinoides* the test closely resembles that of a more or less curved, tapering, few-chambered Nodosarine shell; and its originally parasitic condition is assumed, on grounds which will be stated in their proper place, rather than quite positively demonstrated. The closely allied *S. pupoides* consists also of a simple line of segments, varying in contour according to the nature of the object to which they are adherent—plano-convex and outspread if the surface be broad and flat, but concave on the under side and embracing if the object be narrow or cylindrical. On the other hand *S. fusiformis*, whilst quite circular in transverse section and tapering symmetrically, almost always retains the evidence of its parasitic habit. In the few-chambered acervuline variety (*S. acervalis*) the segments, instead of taking a uniserial line as in *S. pupoides*, are irregular in size and piled one upon another without apparent order. These four varieties all have relatively large chambers, divided in their interior by partial, secondary septa. In *Stacheia congesta* a somewhat different condition obtains; and instead of the large segments there appears a confused mass of minute chamberlets crowded round a foreign body, which is usually of long cylindrical shape. The general contour of the organism depends on the nature of the body round which it is built, but it is usually irregularly cylindrical or fusiform, sometimes constricted near the middle. The exterior is granular or nearly smooth, in places exhibiting the sort of reticulation that is noticeable on the smooth (non-radiate) varieties of *Tinoporus*. Lastly, there are the wild-growing, encrusting modifications, named *S. polytrematoides*, somewhat resembling in habit the porcellanous type *Nubecularia*, but much more the normally perforate *Polytrema*, yet differing from both in the minute structure of the shelly investment.

There is much about the history of the genus *Stacheia* that is still far from satisfactorily made out. The specimens are as a rule of very small dimensions, and hitherto the number that have been found has been comparatively limited. Neither the size nor the number would have been any serious obstacle to the complete study of their structure, had they been in the recent state, but, taken in conjunction with age and the effect of fossilization in obliterating minute characters, the want of sufficient material and the

mechanical difficulties attendant on its condition preclude exhaustive treatment and necessitate a certain amount of reservation in respect to many points of detail.

The disposition of the parts and their relative significance are readily seen in the simpler forms by means of longitudinal sections. The segments arranged in linear series are either distinct and convex, circular in section, and partially embracing,—or else each succeeding segment almost entirely encloses those that have preceded it; in all cases the chamber cavities are subdivided by more or less regular secondary septa. The most careful examination fails to yield any trace of true shell-perforation; and, though in these simple varieties the surface of the test is nearly smooth, there can be little doubt that its texture is precisely similar to that of *Trochammina* and the allied arenaceous types in which the calcareous cement is largely in excess of the embedded sand-grains. In point of fact, the external appearance of the test closely resembles that of the fossil *Valvulinæ* of the same beds, and the analogy between the peculiar subdivision of the segments in the simpler varieties of *Stacheia* and the condition of the chambers in *Valvulina Youngi* is too striking to be overlooked.

This analogy is important in another point of view, for it suggests the solution of a question of considerable difficulty, namely, the position and character of the aperture. Were we dependent on Carboniferous specimens alone, it would not be easy to speak with any certainty of the aperture in the genus *Valvulina;* but by the aid of recent specimens its characters are easily determined, and we know that it takes the form of a curved slit on the under surface of the test, hidden by a tongue-like shelly projection. It is not possible to demonstrate the same condition in *Stacheia*, but there is quite sufficient evidence to justify the assumption that the nature and position of the orifice are not very widely different. In *S. acervalis*, for instance, it is pretty certainly on the under surface of the test, and it has even been noticed in the form of a produced neck (*Planorbulina* fashion) apparently springing from the lower side of the last segment. It would seem to follow, therefore, that in varieties like *S. marginulinoides* and *S. fusiformis*, in which the segments are ring-shaped and embracing, the pseudopodia would protrude at the end of the test around the sides of the body upon which the organism has grown, or, in case of the decay or disintegration of the columnar support, sarcode would occupy its place and the open end would form the general aperture. This would furnish a not improbable explanation, the only one I am able to suggest of the otherwise obscure characters of the simpler modifications of the type.

The interior structure of the two species which are formed of a large number of minute chambers is more obscure, and it is possible that further investigation may show reasons for placing them in a subordinate group by themselves. Of the two, *Stacheia congesta* is the more complex, and it will be best understood by reference to what is known of the compact varieties of the Rotaline genus *Tinoporus* (especially *T. lævis*, P. and J.), to which it bears considerable analogy, the fact of its growing in adherent masses

having no primary significance. The infiltrated condition of the specimens and consequent obliteration of structural details preclude the determination of anything beyond general characteristics; but the appearance of thin sections (Pl. IX, fig. 5), and the reticulation which may often be noticed over portions of the surface (fig. 1 &c.), alike indicate that the organism is composed of a multitude of minute closely packed chambers, though what is the nature of the communication between them I have been unable to determine.

The internal appearance of *S. polytrematoides* is much less difficult to understand. Not only are the specimens less altered by time and external agencies, but we have the guidance of two almost isomorphous recent types, whose structure is already well understood, namely, *Polytrema* and *Nubecularia*. Both these genera were classed by the earlier naturalists amongst "Zoophytes," and the knowledge of their real affinity and their position in the animal kingdom is due to the observations of a succession of naturalists, notably of Dujardin, Parker and Jones, Carpenter, and Max Schultze.[1] Without the data furnished by their researches, the minute fossil organisms which have been grouped under the generic term *Stacheia* would naturally have fallen into the same category. Any doubt which I might at first have entertained on the ground of their somewhat ambiguous characters was dispelled by submitting the specimens to Dr. Carpenter and Prof. W. K. Parker, in the desire to have an entirely independent judgment upon them. After examination both these gentlemen unhesitatingly confirmed the views I had arrived at, adding somewhat by their remarks and comparisons to the elucidation of the structural characters. Curiosity, rather than necessity for further confirmation, led me to submit a considerable number of mountings of fossil parasitic microzoa to my friend, the Rev. T. Hincks, whose varied and minute knowledge of the Polyzoa and Hydrozoa seemed likely to cause him to approach the subject from the side of his own especial studies. It was therefore with much gratification that I watched his separation of the forms I had already set down as Foraminifera from others which he regarded as presumably Polyzoa.

That other adherent species will be found, as the friable calcareous shales of the Carboniferous beds come to be more closely searched, I have no doubt, and I can only hope they will be met with in condition more favourable for the determination of questions of minute structure than those which it has been my lot to examine.

STACHEIA MARGINULINOIDES, *nov.* Pl. VII, figs. 16—21.

Characters. Test free (?) or adherent, uniserial; elongate, curved, subcylindrical, tapering; composed of a number of convex, more or less embracing, superimposed segments. Sutures depressed. Interior of the chambers cancellated, or subdivided into

[1] And more recently Mr. Carter, see 'Postscript.'

chamberlets. Exterior, granular or nearly smooth. Aperture terminal. Length $\frac{1}{28}$ inch (0·9 mm.).

It may be a point still open to debate whether the uniserial subcylindrical forms which constitute the group now to be considered should be regarded as pertaining to the free moniliform type *Nodosinella* or to the essentially adherent *Stacheia*. The external morphology taken by itself would lead in the former direction, and the species was named at first in accordance, with that view; but as material accumulated, and with it the opportunity for more complete examination in respect to minute structure, the analogy to the adherent type became more and more apparent. But even in external conformation it is not difficult to trace a relationship between the *apparently* free species and the simpler parasitic forms. In *Stacheia pupoides* for instance (Pl. VIII, figs. 17—27), it often happens that when the test grows upon any body narrower than itself, it becomes more or less embracing, sometimes to such an extent that the ends of the segments nearly meet on the other side. It seemed possible, therefore, that the cylindrical *Marginulina*-like tests might have been originally parasitic, and have begun life with the support of a central foreign body, which had subsequently more or less completely disappeared either by disintegration or decomposition. The probability of this view was strengthened by collateral facts, especially by the discovery of a much smaller species, stouter in proportion to its length, and tapering symmetrically at both ends (*S. fusiformis*), having similar internal structure, but with the foreign body frequently remaining as an axial support. Supposing this explanation of the characters of *Stacheia marginulinoides* to be the true one, the aperture still remains to be accounted for. If, as it is safe to assume, the aperture of *S. pupoides*, like that of the trochoid *Valvulinæ*, is on the under surface of the test, and *S. marginulinoides* represents typically a similar form with the segments completely embracing, it would follow that the aperture should be in the interior close to the central column; and in that case the pseudopodia would issue from the end of the test. The actual structure is precisely in accordance with such a supposition. Longitudinal sections show the central portions of the test confused in arrangement, the septa often broken and not continuous, especially at the narrow end. This cannot be gathered from any single specimen, for the sections must needs be axial, and the axis in *Stacheia marginulinoides* is scarcely ever straight; but it is not difficult to obtain clear evidence from a series of preparations. The external orifice being, in point of fact, the space left by the disappearance of the foreign body which formed the central support, it is manifestly not essential that it should be at the broad end of the test, and specimens actually occur (Pl. VII, fig. 18, *a*, *b*, is an example) in which there is no trace of aperture on the surface of the large terminal segment, whilst there is one at the narrow end; and again, as shown in fig. 20, specimens may be found which have two apertures, one at each end of the shell.

It will be readily seen that, notwithstanding their close exterior resemblance to the

free Nodosariform group, such specimens as those which have been described have a much nearer relationship to the adherent forms which constitute the genus *Stacheia*. There may at times be some difficulty in recognising them by external characters, but the differences in minute structure supply a certain means of distinction.

Distribution.—In England *Stacheia marginulinoides* has been only found in the higher beds of the Carboniferous Limestone, and it is by no means common. In Scotland I have note of its occurrence in but two localities, both in the Lower Carboniferous Limestone Group.

STACHEIA FUSIFORMIS, *nov.* Pl. VIII, figs. 12—16.

Characters.—Test adherent, short, stout, rounded, tapering at both ends; composed of layers of chamberlets (or subdivided segments) more or less regularly and symmetrically disposed round a thin columnar foreign body, each layer embracing the previous one except at its peripheral margin. Test sometimes marked with slight transverse constrictions over the sutural lines. Surface granular or nearly smooth. Length $\frac{1}{40}$ inch (0·6 mm.).

As usually found, growing round a straight axis, *Stacheia fusiformis* is a nearly symmetrical body, not unlike the Nodosarine genus *Glandulina* in general external aspect. It is broader at the centre, and relatively shorter than other varieties of the type; circular in transverse section, and almost devoid of those depressions, excavated lines, or other superficial markings which in most Foraminifera serve to indicate to a greater or less extent the structure of the interior. The chambers are very numerous, very thin and regular, and are subdivided into minute chamberlets. The transverse secondary septa are thinner than the proper chamber-wall, and apparently subordinate in importance to it, as shown in Pl. VIII, fig. 16. In most of the sections that have been made, in which the specimens are well enough preserved to exhibit anything of internal structure, the remains of the central column can still be traced. Altogether *Stacheia fusiformis* is very closely related to *S. marginulinoides*, and what has been written of the structural relations of the latter species is in general terms true of the former.

Distribution.—In England *Stacheia fusiformis* is found in both the higher and lower divisions of the Carboniferous Limestone Series; in Scotland it is present in both the Lower and Upper Carboniferous Limestone Group, but the condition of the specimens from the latter renders them difficult of recognition.

STACHEIA PUPOIDES, *nov.* Pl. VIII, figs. 17—27.

Characters.—Test adherent, elongate, tapering, uniserial; composed of a line of irregular convex segments, either lying flat on the surface of a foreign body, or embracing it to a greater or less extent. Segments inflated; interior cancellated, or subdivided more or less regularly. Surface granular or nearly smooth. Length $\frac{1}{25}$ inch (1·0 mm.).

Typically, *Stacheia pupoides* consists of a line of convex, tent-like, adherent chambers, each chamber embracing its predecessor somewhat, and subdivided in its interior. The external aspect of average specimens is well shown in Pl. VIII, figs. 20 and 22; their internal structure in figs. 26 and 27. Modifications of the normal form probably depend more on the nature of the body that serves for a support than on any inherent tendency of the animal. If the support be thin and slender, the shell embraces it more or less completely, and the margins of the chambers approximate on the opposite side, as in figs. 24, 25, &c. The central body may have been a fragment of organic matter which has been speedily decomposed; and in this case, which is not an unusual one, the margins of the segments may meet and form a nearly cylindrical test, the line of union being only indicated by a slightly excavated longitudinal suture, as in figs. 21 and 23.

Some two or three specimens have been found pertaining to this category, but with thin and compressed, rather than cylindrical, contour (fig. 17). These appear to have lost all trace of the central support, except, perhaps, just at the narrow end, and the interior of the test is filled up with cancellated shelly growths. Longitudinal sections exhibit the minuter structure very beautifully; they bear a high magnifying power with advantage (fig. 19), and show the communication between the chambers much more satisfactorily than any similar sections yet obtained from the commoner variety.

The general aperture of the test of *Stacheia pupoides* is probably analogous in its nature and position to that of *S. marginulinoides;* and, if what has been suggested with regard to that species be correct, it should be on the under or inner surface, near the margin of the terminal segment.

Distribution.—In England this species has been met with both in the higher and lower division of the Carboniferous Limestone rocks, in Scotland, in the Lower Limestone Group only; but in none of the six localities in which it has been found is it at all common.

STACHEIA ACERVALIS, *Brady*. Pl. IX, figs. 6—8.

WEBBINA ACERVALIS, *Brady*, 1873. Mem. Geol. Survey, Scotland; Expl. Sheet 23, pp. 69, 95, &c.

Characters.—Test adherent, forming minute, rounded, or elongate patches, composed of comparatively few segments. Segments inflated, varying much in size in the same specimen, arranged in an acervuline or indefinite manner. Surface smooth. Length $\frac{1}{30}$ inch (0·8 mm.).

So far as external form is concerned a more striking analogy could scarcely be found than that of the imperforate *Stacheia acervalis* and a few-chambered adherent variety of the genus *Tinoporus*,[1] in the perforate series. It also bears considerable resemblance to some of the less regular *Planorbulinæ*.

Stacheia acervalis was the first variety of the type that could be identified with any certainty as a Foraminifer; and its smooth imperforate test seemed to suggest an affinity to the adherent *Trochamminæ*, hence its association at that time with the sub-type *Webbina*. Further study, and the discovery of several allied species, necessitated the establishment of a distinct genus for its reception.

In external contour this species is very variable, both in the number and form of the segments, and their mode of combination. The cavities of the chambers are often subdivided in the same way as those of *S. marginulinoides* and *S. pupoides*; indeed, the relationship to the latter species is in all respects exceedingly close. The general aperture appears to be situated on the under surface of the test close to the margin, and in one or two examples has been noticed in the form of a slightly produced, bordered neck, as is sometimes seen in the genus *Planorbulina*.

Distribution.—In England *Stacheia acervalis* has only been met with in two localities, both pertaining to the Yoredale Series. In Scotland it occurs in both the Lower and Upper Carboniferous Limestone Groups, though it is much less rare in beds of the former than of the latter age.

[1] *Tinoporus lucidus*, Brady ('Cat. Brit. Foram. Edin. Mus. Science and Art,' 1870, p. 8, mentioned by name only), a form first noticed in dredgings from the West Coast of Scotland, and since repeatedly found by Mr. Robertson and the Rev. A. M. Norman, as well as by myself. It is a delicate *Planorbulina*-like variety, sometimes commencing growth with tolerable regularity, but afterwards becoming acervuline, or else spreading into superficial patches of considerable size.

STACHEIA CONGESTA, *nov.* Pl. IX, figs. 1—5.

Characters.—Test adherent, forming minute, elongate, subcylindrical, rounded, or fusiform masses clustered around foreign bodies, preferring those of slender columnar shape. Chambers very numerous; irregular in shape, closely packed, confused in arrangement; the boundary-walls of those composing the superficial layer sometimes indicated by the areolation of portions of the exterior of the test. Surface otherwise granular or nearly smooth. Length $\frac{1}{36}$ to $\frac{1}{16}$ inch (0·7 to 1·5 mm.).

This species bears considerable resemblance to the smooth variety of the Rotalian genus *Tinoporus* (*T. lævis*, P. and J.), not only in general external appearance and occasional superficial areolation, but also in the mode of aggregation of its constituent chamberlets, the *primâ facie* difference being that the one is, the other is not, a parasitic form. Not that the adherent condition is unknown in the genus *Tinoporus*: a variety has already been alluded to which bears the same sort of resemblance to *Stacheia acervalis* that *Tinoporus lævis* bears to *Stacheia congesta*. Such analogies are not merely interesting, but are of considerable value as collateral evidence in an order of animals characterised by the tendency to isomorphism amongst its constituent groups.

The drawings, Pl. IX, figs. 1—4, are good representations of average examples of this obscure organism; fig. 5 is its longitudinal section, as seen by transmitted light; the magnifying power employed is the same throughout, 50 diameters. The further enlargement by means of higher powers brings out but little additional detail, owing partly to the granular texture of the test and partly to the obliterating effect of the mineral infiltration. Specimens areoccasionally met with having prominences like the arborescent growths of *Stacheia polytrematoides*, but these appear to have taken their form from that of the foreign body upon which the shell has grown.

Distribution.—Specimens of *Stacheia congesta* have been found in a single locality in the lower division of the English Carboniferous Limestones, but in the higher portion of the series it is much less rare. In Scotland, on the contrary, it has been observed in two or three localities of the Lower Limestone Group, whilst its presence in later beds has only been clearly established in a single habitat.

STACHEIA POLYTREMATOIDES, *nov.* Pl. IX, figs. 10—13.

Characters.—Test adherent, irregular in growth and outline; composed of a multitude of minute chambers, either confused or arranged in more or less regular layers; forming encrusting masses of uneven thickness, spreading over the surface of foreign bodies, sometimes swelling into mammillate or arborescent protuberances which are pierced at the top with large orifices. Surface areolated, blistered or granular. Dimensions indefinite; in patches usually less than $\frac{1}{4}$ inch (6·0 mm.) in diameter.

The relation of *Stacheia polytrematoides* to the other members of the genus may be seen by a comparison of two specimens such as those represented by figs. 8 and 9, Pl. IX, the former being taken from a good example of *S. acervalis*, the latter from a specimen, somewhat similarly circumstanced, of *S. polytrematoides*. Notwithstanding a certain resemblance in external contour, considerable difference exists between the two; for, whilst *S. acervalis* has a few, large, distinct chambers, which are subdivided into chamberlets, *S. polytrematoides* consists of a wild-growing mass of small chambers sometimes disposed in layers, but more frequently arranged in no particular order, spreading indefinitely over the surface of any object to which it has attached itself. In other words the distinction rests between the large-chambered, *Planorbulina*-like habit of the one form, and the small-chambered, confused, *Polytrema*-like growth of the other. Morphologically speaking the analogy that exists between *Stacheia polytrematoides* and corresponding organisms in the porcellanous and perforate series, namely, *Nubecularia* and *Polytrema*, is very striking; but, rather than occupy space with the repetition of details, I would refer the student, as I have already done on a former page, to Dr. Carpenter's excellent account of these types,[1] for the explanation of many of the singular and apparently anomalous features of the present species. It has been found very difficult to obtain transparent sections of the Carboniferous organism, showing its internal structure with any degree of distinctness, but Mr. Hollick's drawing, from a fairly good preparation, Pl. IX, fig. 13, is sufficient to demonstrate that the analogy to *Polytrema* is borne out in interior arrangement as well as in external configuration. I have not been able in any case to detect true shell-perforation, that is to say, such tubulation of the shell-wall as is characteristic of the hyaline Foraminifera. Some specimens at least show a more or less composite structure of the test, with embedded sand-grains of appreciable size, but in the majority of cases the investment is nearly smooth, and its minute structure is partly assumed from analogy to closely allied forms in which the arenaceous character is more distinctly traceable.

Distribution.—In England and Scotlanda like, *Stacheia polytrematoides* has been

[1] 'Introd. Foram.,' pp. 71 and 235, *et seq.*

obtained from both the Lower and Upper Groups of Carboniferous Limestones, though it differs much in its relative frequency in the older and newer beds of the two countries, as will be seen by reference to the Tables of Distribution. It was first noticed by Mr. John Young in the rich Lower Carboniferous shale of Hairmyres in Lanarkshire.

Sub-order, PERFORATA.

Family, LAGENIDA, *Carpenter.*

Genus—Lagena, *Walker and Jacob.*

Serpula (Lagena), *Walker and Jacob.*
Oolina, *d'Orbigny, Reuss, Bronn, Egger, Terquem, Bornemann, Costa, Karrer.*
Lagena, *Williamson, Morris, Parker and Jones, Carpenter, Reuss, Brady, Stache, Gümbel, Karrer, Robertson, Kübler, Vanden Broeck, Blake, Wright, &c.*
Serpula, Vermiculum, Lagenula, Miliola, Cenchridium, Entosolenia, Ovulina, Ovolina, Apiopterina, Fissurina, Amphorina, Amygdalina, Phialina, Tetragonulina, Trigonulina, Obliquina, *auctorum.*

General Characters.—Shell free, consisting of a single, undivided chamber; subspherical, oval, pyriform, oblong, or fusiform; sometimes compressed laterally on two, three, or four sides. Aperture usually single; in distomatous forms the two orifices are at the opposite ends of the shell. Texture hyaline.

To the Rev. W. Howchin, of Morpeth, we are indebted for the discovery of the genus *Lagena* in beds of Carboniferous age, indeed, almost all the specimens yet obtained have been from material collected by that gentleman, and chiefly from two Northumbrian localities.

The specimens are generally more or less granular superficially, and are referrible to three tolerably distinct varieties, one of which has no superficial ornamentation, another is costato-punctate, and the third costate over its lower half with a raised, more or less conspicuous, transverse line, in which the costæ terminate, near the widest portion of the shell.

The genus *Lagena* has already been traced back by the researches of Reuss, Terquem, Blake, Wright, and others to the Cretaceous, Jurassic, and even to the Liassic age, but the examples now under consideration carry its history into a much more remote geological epoch. It is not needful in this place to enter into minute details concerning the nomenclature of the genus or its distribution; the reader, interested in such matters, may refer to the 'Monograph of the Crag Foraminifera' (pp. 28—31), where they are entered upon with some exactness, the particulars furnished representing the state and knowledge up to the date of their publication. The Carboniferous representatives of the type differ from the more recent species chiefly in their thicker and somewhat granular shells, and it is not by any means certain that they may not bear as close a relationship to the subarenaceous genus *Nodosinella* as the later species do to the hyaline type *Nodosaria*.

LAGENA PARKERIANA, *nov.* Pl. VIII, figs. 1—5.

Characters.—Shell globular, ovate, or pyriform; neck rarely much produced, aperture ectosolenian. Surface variable, more or less granular or even studded with minute irregular tubercles. Length $\frac{1}{60}$ inch (0·4 mm.).

In general contour *Lagena Parkeriana* presents a range of variation from that of *Lagena globosa*, Montagu, in its short globular modifications, to *L. lævis*, Montagu, in its pyriform or flask-shaped varieties; but it is not entosolenian like the former and seldom shows the regular tapering neck of the latter species. Its essential difference from both consists in its thick shell and granular, roughish, or even irregularly tuberculate surface.

I obtained one or two specimens of this form some years ago from the *Saccammina* bed at Elfhills, but it was not until the Rev. W. Howchin's fortunate discovery of *Lagenæ* in the Fourstones Quarry that their relationship could be stated with any degree of certainty.

The naming of a Foraminifer after my friend W. K. Parker, F.R.S., is an act that needs neither apology nor explanation.

Distribution.—In the Four-fathom Limestone (Elfhills) and in the shale overlaying the Great Limestone (Fourstones)—Northumberland. Its presence in the Scotch beds has not yet been satisfactorily established, except in a single locality, where it is associated with *L. Howchiniana*.

LAGENA HOWCHINIANA, *nov.* Pl. X, figs. 1—5.

Characters.—Shell sub-spherical, oval, or flask-shaped, often unsymmetrical; with more or less strongly marked parallel longitudinal costæ, along the top of which at regular intervals are well-defined perforations. Neck short, often irregular. Orifice wide. Length $\frac{1}{60}$ to $\frac{1}{50}$ inch. (0·4 to 0·5 mm.).

As the most striking of the Carboniferous *Lagenæ*, it is manifestly proper, for reasons I have already stated, that this species should be named after the Rev. W. Howchin. It is a well-marked form, not likely to be mistaken for any other hitherto described. The costæ do not appear to be exogenous ribs as in many similarly ornamented Foraminifera, but are formed by crenulations of the shell-wall; and the ridge of each of the crenulations is pierced by a series of small orifices placed at regular intervals. The perforations are sometimes obscured by infiltration, but their existence can nearly always be detected. The test itself is thicker than is commonly seen in the *Lagenæ*, and its surface is nearly always somewhat rough or granular. These characters, in addition to its frequent irregularity of growth, render it in so far an anomalous member of the genus. Double specimens, such as fig. 4, are occasionally found, but similar monstrosities occur in many other species, both recent and fossil.

Distribution.—Found in the Bottom Limestone at Ridsdale, and in the shale overlying the Great Limestone at Fourstones—both Northumbrian localities. Its occurrence in the Scottish Carboniferous Limestones is as yet noted in only a single position high up in the series.

LAGENA LEBOURIANA, *nov.* Pl. VIII, fig. 6.

Characters.—Shell sub-spherical or pyriform; having a surface ornamentation consisting of a few, usually four or five, regular costæ, proceeding from the base to the widest portion (about the middle) of the shell, where they are merged in a more or less distinctly raised transverse ring. Length $\frac{1}{100}$ inch (0·25 mm.).

A singular form, quite distinct from *L. semistriata* of Williamson. The costæ, commonly only four in number and equidistant, impart a somewhat quadrangular aspect to many specimens. Sometimes there is a well-marked, raised, transverse ring, similar in thickness to the costæ, round the widest portion of the test, and in these cases the ends of the costæ are united to it, thus dividing the surface of the lower half of the shell into four

or more triangular figures. Where the ring is absent or can only be partially traced, the ends of the costæ often show considerable lateral thickening, indicating the line of the abortive transverse girdle. *Lagena Lebouriana* is the smallest of the Carboniferous species of the genus, and exhibits the same slight roughening of the surface that has been remarked in its fellows. Its modifications merit fuller illustration than the single drawing which is given in Plate X, but the plate was already partly on the stone before the specimens were discovered, and room could only be made for one additional figure.

It is with much pleasure that I associate so interesting a form with the name of my friend, Mr. G. A. Lebour, F. G. S., to whose observations we owe much of our accurate knowledge of the geology of the locality in which the species was found, as also of many other portions of Northumberland.

Distribution.—In the shale overlying the Great Limestone, Fourstones Quarry, Northumberland.

Genus—Nodosarina, *Parker and Jones.*

Nodosaria, Glandulina, Lingulina, Frondicularia, Flabellina, Dentalina, Vaginulina, Rimulina, Marginulina, Cristellaria, Robulina, Planularia, &c., *auctorum.*

General Characters.—Shell hyaline, tubuliferous, either straight, arcuate, crozier-shaped, or disco-spiral; composed of several segments arranged in one series. Pseudopodial orifice terminal and single, either central or excentric. Surface smooth, or ornamented with straight raised parallel lines, either continuous or interrupted, sometimes represented by spines or granules, sometimes reduced to one or more keels.

Foraminifera pertaining to the generic type *Nodosarina* are less common in deposits of Carboniferous and Permian age than in those of almost any subsequent geological epoch, and they also exhibit a less extensive range of morphological characters; so that any lengthy exposition of the relation of the various *quasi*-generic groups above enumerated, which, with many others, have come to be included under this one generic term, would be manifestly out of place. The subject has been treated with much care in the 'Monograph of the Foraminifera of the Crag' (pp. 46 *et seq.*), and nothing that has accrued from continued observations has tended to disturb the conclusions therein laid down.[1] It is sufficient for our present purpose to say that

[1] Except, perhaps, in connection with the genus *Ellipsoidina*, which was then included with the *Nodosarinæ*. It is difficult to speak positively about so very rare a type, nor does it affect the general truth of the views in question, but I am convinced from recent observations that *Ellipsoidina* has its nearest ally in *Chilostomella*, and that *Chilostomella* is more closely related to *Polymorphina* than has been hitherto supposed.

notwithstanding the great variety, not only in minor characters but in general contour, which exists amongst the specimens included in this comprehensive genus, they form, when arranged, a complete and unbroken series. From end to end no link in the chain is wanting, there is no disconnected point at which a sharp line can be drawn to indicate a true specific, much less a true generic boundary. The characters which have been chosen and accepted by a long succession of observers as the basis of an artificial subdivision, though as good as any available under the circumstances, leave the inevitable hosts of "intermediates" unprovided for. It has been said with perfect truth "the group is one in which it is easy enough to establish generic differences when only a few strongly marked types are contrasted, whilst it becomes more and more difficult to maintain these in proportion to the number of individuals compared, until at last the difficulty amounts to an impossibility."[1] To this close connection of a long succession of slight modifications exhibited by individual specimens we owe the prodigious list of needless "specific" names which have been employed for members of the genus; a category of useless terms which I suspect has no parallel in the domain of systematic zoology.

Subgenus—Nodosaria, *Lamarck.*

Nautilus, Orthoceras, Orthocera, *auctorum.*
Nodosaria, *Lamarck, Defrance, d'Orbigny, Ehrenberg, Geinitz, Reuss, M'Coy, d'Eichwald, Richter, Parker and Jones, Williamson, Carpenter, Karrer, Brady, Stache, Schmid, &c.*

Characters.—Shell cylindrical, composed of several segments, arranged in a straight series; either smooth, or ornamented with ribs, granules, or spines; septal lines more or less depressed, making constrictions at right angles to the long axis of the shell. Pseudopodial aperture, simple, central, often pouting.

The artificial nature of the generally accepted subdivision of the *Nodosarinæ* could scarcely be more strikingly shown than in a series of Permian specimens. Take an average lot of examples just as they occur in the magnesian limestone *débris;*—they consist individually of more or less elliptical segments joined together end to end, the segments united by stoloniferous tubes; no two specimens are alike, they differ in the direction of growth, in the number of chambers, the relative size of succeeding chambers, the degree of convexity of the segments, and in many other quite non-essential particulars yielding characters of not even sub-varietal importance. Systematists begin by assigning the straight individuals to one genus, the bent ones to another. It seems absurd to say so, but it is often exceedingly difficult to determine, under which group of even so elementary

[1] Carpenter, 'Introduction,' p. 159.

a classification, many of the specimens should be placed. It is necessary, therefore, to state that the subordinate term *Nodosaria* is here used in its generally understood sense; that is, just to include the straight or approximately straight forms.

NODOSARIA RADICULA (*Linné*). Pl. X, figs. 6—16 (including varieties).

NAUTILUS RADICULA, *Linné*, 1767. Syst. Nat., ed. 12, vol. ii, p. 1164, No. 285.
— — *Montagu*, 1803. Test. Brit., p. 197, pl. vi, fig. 4.
NODOSARIA — *Lamarck*, 1822. Anim. s. Vert., vol. vii, p. 596, No. 1;—Tabl. Encycl. Méthod., pl. cccclxv, figs. 4, *a*, *b*, *c*.
— — *d'Orbigny*, 1826. Ann. Sci. Nat., vol. vii, p. 252, No. 3;—Modèle, No. 1.
— GEINITZI, *Reuss*, 1854. Jahresb. d. Wetterauer Gesellsch. vol. for 1851—1853, p. 77, fig. 12.
— — *Richter*, 1855. Zeitschr. d. deutsch. Geol. Gesellsch., vol. vii, p. 532, pl. xxvi, fig. 26.
— RADICULA, *Parker and Jones*, 1859. Ann. and Mag. Nat. Hist., ser. iii, vol. iii, p. 476;—Ibid., vol. iv, p. 344;—Ibid., 1863, vol. xii, p. 209.
— DUPLICANS (?), *Richter*, 1861. In Geinitz's Dyas, Heft i, p. 120, pl. xx, fig. 26.
— SUBACICULA (?), *Id.* Ibid., p. 121, pl. xx, fig. 27.
— GEINITZI, *Reuss*. Ibid., p. 121, pl. xx, fig. 28.
— KINGI, *Id.* Ibid., p. 121, pl. xx, fig. 29.
— KIRKBYI, *Richter*. Ibid., p. 121, pl. xx, fig. 30.
— JONESI, *Id.* Ibid., p. 121, pl. xx, fig. 31.
— RADICULA, *Parker, Jones, and Brady*, 1865. Ann. and Mat. Nat. Hist., ser. iii, vol. xvi, p. 18, pl. i, fig. 27.
— CONFERTA, *Schmid*, 1867. Neues Jahrb. für Min., Jahrg. 1867, p. 585, pl. vi, fig. 49.
— OVALIS, *Id.* Ibid., p. 588, pl. vi, figs. 50, 51.
— CITRIFORMIS, *Id.* Ibid., p. 586, pl. vi, figs. 52, 53.
— sp., *Id.* Ibid., p. 586, pl. vi, fig. 54.
— KIRKBYI, *Id.* Ibid., p. 586, pl. vi, fig. 55.
— RADICULA, *Jones and Parker*, 1860. Quart. Journ. Geol. Soc., vol. xvi, p. 453, figs. 1—5 (Triassic).
— — *Brady*, 1867. Proc. Somerset Arch. and Nat. Hist. Soc., vol. xiii, p. 106, pl. i, fig. 4 (Liassic).

Characters.—Shell cylindrical, tapering, composed of several subglobose segments united in a straight line. Surface smooth. Length, $\frac{1}{20}$ inch (1·25 mm.), more or less.

A good typical specimen of *Nodosaria radicula* has four or more segments, rarely as many as eight; the segments are sub-globular in form, regularly but only slightly increasing in size, from the earliest to the last formed, and quite symmetrically joined end to end. But, as might be expected, so very simple an organism is subject to almost as many trifling variations as there are individual specimens, and these have been abundantly made use of by systematists as the foundation of a multitude of "specific" names. Putting aside the curved forms, the result of mere lateral inequality in the setting on of the chambers, which have been supposed to constitute a distinct genus, it may be worth while just to enumerate some of the modifications of the typical, straight shell that have been thought worthy of specific separation. Thus d'Orbigny figures a specimen from the White Chalk of the Paris basin, with only three chambers, and having a band of shell-substance thickening the sutural lines, under the name *Nodosaria limbata* ('Mém. Soc. Géol. Fr.,' vol. iv, pl. 1, fig. 1). Roemer gives one of the short somewhat conical modifications, which stand as intermediate to *Nodosaria* and *Glandulina*, the chambers less globular than in the type and the sutures correspondingly less constricted, with the name *N. humilis* ('Verstein. Norddeutsch. Kreid.,' pl. 15, fig. 6). Prof. Reuss in his paper on the Chalk of Westphalia ('Sitzungsb. Akad. Wissensch. Wien,' vol. xl, pl. 1) has drawings of two excellent typical specimens, the one as *Nodosaria lepida* (fig. 2); the other, the first chamber of which is slightly mucronate, as *N. concinna* (fig. 3). The same plate has a figure of a specimen with a larger number of chambers and an excentric aperture named *Dentalina acuminata* (fig. 7), and one differing only in the oblique mouth, as *D. subrecta* (fig. 10). It is to be noticed that these latter two, named *Dentalina*, are as straight in contour as those assigned to the genus *Nodosaria*, and the segments, except the terminal one, are in every respect similar, and similarly disposed. An analogous set of figures is given by Neugeboren ('Denkschr. k. Akad. Wiss. Wien,' vol. xii, pl. 1), under the names *Glandulina elegans* (fig. 5), *Gl. Reussi* (fig. 6), *Nodosaria Beyrichi* (figs. 7—9), and *N. ambigua* (figs. 13—16). Professor Costa reproduces the common, simple form as *Nodosaria ovularis* ('Foram. Foss. Terz. Messina,' Pl. I, fig. 8, 9); and it may be found under a number of different appellations in M. Terquem's various memoirs on the Mesozoic Foraminifera of France. It would be easy to extend this list almost indefinitely, for the same little organism has been found in almost every fossiliferous marine deposit from the Permian epoch to the present time, and has at every fresh appearance been greeted with a new name, often, as already observed, with a good many. The general synonymy would form a list of great length, much too long for insertion, the references given at the head of the notice are therefore principally to names employed in memoirs upon Permian fossils, and they need but little comment. At the same time it may be well, indeed it is due to Dr. Richter and Dr. E. E. Schmid, to allude individually to the varieties figured in their papers as "species" which have been grouped together in the list of synonyms. Accurate copies of their illustrative figures will be found in Plate X.

Nodosaria Geinitzi, Reuss, 1854, and Richter, 1855, Pl. X, fig. 6,—is a typical six-chambered *N. radicula*; a better example could scarcely be found of any geological age.

Nodosaria duplicans and *N. subacicula*, Richter,—are very doubtful organisms, and in the absence of any fresh evidence from further research I am authorised by Dr. Richter to state his concurrence in the withdrawal of their names. The only new light thrown upon either is from the fractured surface of a piece of Zechstein Limestone, showing one whole segment and portions of two others, which, if appearances are not deceptive, would suggest an organism resembling *Nodosaria pyrula*, d'Orbigny. It may be, therefore, that *N. duplicans*, as figured in the 'Dyas,' represents a fossil with these characters; but I agree with Dr. Richter that the evidence of one or two broken and obscure specimens, in the matrix, is not a satisfactory foundation for the establishment of a species.

Nodosaria Kingi, Reuss,—is a slender form having the same general characters as *N. radicula*, but with a dozen segments or more instead of about half the number. The drawing, Pl. X, fig. 12, is copied from the original figure in the 'Dyas' monograph.

Nodosaria Kirkbyi, Richter,—is a smaller form and wider at the top. The figure in the 'Dyas,' copied at Pl. X, fig. 11, appears to have been drawn from a split specimen, and shows the produced neck and aperture of each segment. The primordial chamber seems to be wanting.

Nodosaria Jonesi, Richter, Pl. X, fig. 13,—is a minute, broad variety; but the figure, also apparently from a split specimen, shows neither stoloniferous tubes nor aperture. Probably the fracture has taken place considerably below the median line.

Nodosaria conferta, Schmid, Pl. X, fig. 14,—a long, irregular, many-chambered form; the earlier segments small and tapering, the remainder nearly equal in size. I have taken the liberty of reversing the figure, as it is usual to place the *Nodosariæ* with the broad chambers uppermost.

Nodosaria ovalis, Schmid, Pl. X, fig. 15,—differs from *N. radicula* in its slender contour and regularly oval segments; whilst

Nodosaria citriformis, Schmid, Pl. X, fig. 16,—is another variety of the same class, but irregular, much attenuated, and with a larger number of chambers.

The zoological value to be attached to these trifling modifications in form must be left for each observer to estimate for himself, but the larger the number of specimens examined the stronger will become the conviction that they represent little more than individual peculiarities, and that "species" on such foundation might be made *ad infinitum*. The figures however are not without their value as illustrations of the range of variation of an organism of very simple type.

Distribution.—Well-defined specimens of *Nodosaria radicula* have not to my knowledge been found in any portion of the Carboniferous Limestone Series. It is not uncommon in

the middle division of the Permian, that is, the Kupferschiefer of Germany, and also in the Zechstein proper and Middle Zechstein; but it does not appear in the Upper section of the formation in that country. In England, on the other hand, it is not found in the Lower or Middle division, but is confined to the Upper Magnesian Limestones.

Subgenus—Dentalina, *d'Orbigny*.

Nautilus, Orthoceras, Orthocera, Nodosaria, *auctorum*.
Dentalina, *d'Orbigny, Ehrenberg, Reuss, Richter, Geinitz, d'Eichwald, Parker and Jones, Williamson, Karrer, Brady, Stache, Schmid, &c.*

Characters.—Shell awl-shaped, subcylindrical, tapering, curved; composed of several chambers in a linear series; the primordial segment often very small. Septal lines either straight or oblique; usually constricted, but occasionally unmarked by any depression of the surface. Aperture terminal, often pouting and nearly always excentric.

The fact that *Dentalina* is inseparable except by purely artificial distinctions from *Vaginulina* and *Marginulina* scarcely affects the relations of the Carboniferous and Permian forms; that it only differs from *Nodosaria* as a straight line of chambers differs from one that is more or less curved, a character of the most trivial significance, is more noteworthy, inasmuch as the common representatives of the type in the Permian Limestones are two forms which differ in no respect except in the direction of the axis and the consequent greater or less obliquity of the septa. The retention of even two names (*Nodosaria radicula* and *Dentalina communis*) out of the many that have been given to the smooth Permian *Nodosarinæ*, whilst it is a step towards the simplification of a needlessly confused and complicated nomenclature, is after all a compromise only justifiable on the ground of convenience.

Dentalina communis, *d'Orbigny*. Pl. X, figs. 17, 18.

Nodosaria dentalina, *Lamarck*, 1822. Anim. s. Vert., vol. vii, p. 596, No. 2.
— (dentalina) communis, *d'Orbigny*, 1826. Ann. des Sci. Nat., vol. vii, p. 254, No. 35;—*Soldani*, Testac., vol. ii, pl. cv, fig. *O*.
— (—) — *d'Orbigny*, 1840. Mém. Soc. Géol. France, vol. iv, p. 13, pl. i, fig. 4.
Dentalina Permiana, *Jones*, 1850. In King's Monogr. Perm. Fossils, p. 17, pl. xvi, fig. 1.

DENTALINA PERMIANA, *Reuss*, 1854. Jahresb. d. Wetterauer Gesellsch., vol. for 1851—1853, p. 73.

— — *Richter*, 1855. Zeitschr. deutsch. geol. Gesellsch., vol. vii, p. 532, pl. xxvi, fig. 27.

— — *Geinitz*, 1861. Dyas, Heft i, p. 121, pl. xx, fig. 32.

— — *Schmid*, 1867. Neues Jahrbuch. für Min., Jahrg. 1867, p. 586, pl. vi, figs. 56—64.

— COMMUNIS, *Jones and Parker*, 1860. Quart. Journ. Geol. Soc., vol. xvi, p. 453, pl. xix, figs. 25, 26 (Triassic).

— — *Brady*, 1867. Proc. Somerset. Arch. and Nat. Hist. Soc., vol. xiii, p. 107, pl. i, figs. 12, 13 (Liassic).

Characters.—Shell elongate, tapering, more or less curved; consisting of numerous segments, generally somewhat ventricose. Primordial segment sometimes larger than the second, and either rounded or pointed at its free extremity. The terminal pseudopodial aperture generally excentric, sometimes produced and pouting, but more commonly a simple orifice surrounded by radiating grooves. Septal lines, straight or oblique, generally marked by constrictions. Length $\frac{1}{20}$ to $\frac{1}{6}$ inch (1·2 to 4·2 mm.).

For a more extended synonymy of *Dentalina communis* the reader may be referred to the 'Monograph of the Foraminifera of the Crag,' pp. 57—63. The minute variations observable in individual specimens of this common Foraminifer—the foundation of almost innumerable so-called "species"—are therein treated at some length, and an endeavour is made to trace the connection that subsists between the members of the various lines of differentiation. It would answer no good purpose to repeat in this place the details of the zoological history of so well-known an organism. The Permian specimens have no single character to distinguish them from those of later geological epochs nor from the living examples dredged in the shallow waters of our coast; and I can therefore find no reason for giving them another specific name. My friend Professor Rupert Jones, to whose early researches on the Permian microzoa we owe the original description of the ancient examples of this form, coincides in the view that it is better to discontinue the use of a specific name dependent on geological age rather than on zoological characters, and to revert to the earlier d'Orbignian appellation—a course which I have not hesitated to adopt.

Distribution.—The geological range of *Dentalina communis* is much the same as that of *Nodosaria radicula*. I am not aware that any satisfactory specimens have been found in rocks of the Carboniferous period, but it makes its appearance in the Kupferschiefer or lowest Zechstein of Germany, and occurs also in the Zechstein proper. In England its occurrence is recorded in the Upper Magnesian Limestone only, not in the Middle or Lower division of the Permian system. It is needless after what has been already stated to trace the species through subsequent geological formations.

DENTALINA MULTICOSTATA, *d'Orbigny*. Pl. X, fig. 19.

DENTALINA MULTICOSTATA, *d'Orbigny*, 1840. Mém. Soc. Géol. Fr., vol. iv, p. 15, pl. i, figs. 14, 15.
— KINGI, *Jones*, 1850. In King's Monog. Perm. Foss., p. 17, pl. vi, figs. 2, 3.
— — *Reuss*, 1854. Jahresb. d. Wetterauer Gesellsch., vol. for 1851—1853, p. 73.
— — *Geinitz*, 1861. Dyas, Heft i, p. 122, pl. xx, fig. 33.

Characters.—Shell elongate, arcuate, longitudinally costate; costæ numerous, delicate. Chambers subglobose; sutures straight, constricted. Length $\frac{1}{25}$ to $\frac{1}{10}$ inch (1·0 to 2·5 mm.).

D'Orbigny's figure of *Dentalina multicostata* is the first quite satisfactory representation of a finely costate, curved Nodosarian (as distinct from the thick-ribbed *D. obliqua*, Linné), with the successive chambers rapidly increasing in size and not very numerous. It is true that the *Orthoceras corniculum* of Soldani (*Dentalina cornicula* of D'Orbigny[1]) is in most respects a very similar shell and in point of order its name would take precedence, but its excessively large, smooth, globose primordial chamber gives the impression of individual monstrosity, and the figure would not therefore be satisfactory as a standard of reference for the normal form. In our notes on the Soldanian species of Foraminifera my colleagues and myself accept *D. corniculum* as a sub-varietal form on the ground of its large non-costate primordial segment. There is another striate curved Nodosarian in the 'Testaceographia' named by D'Orbigny *Nodosaria nodosa*.[2] This is a finely costate *Dentalina* like *D. multicostata*, but much more slender and elegant in outline, and with a larger number of segments all of regular elliptical shape. It would not be difficult to select many other "species" from the works of subsequent writers differing only in the most trifling particulars from *D. multicostata*, but such a review at the present moment would not serve any good purpose; it is sufficient to say that in sacrificing the name given originally to the Permian examples of this species, and associating them with D'Orbigny's Cretaceous form, I have

[1] Soldani, 'Testaceographia,' vol. i, part 2, p. 98, pl. cv, fig. k. d'Orbigny, 'Ann. Sci. Nat.,' vol. vii, p. 255, No. 47. Parker, Jones, and Brady, 'Ann. and Mag. Nat. Hist.,' ser. iv, vol. viii, p. 161, pl. ix, fig. 56. Prof. Rupert Jones calls my attention to the fact that we have unwittingly, in the paper last quoted, repeated an error made by d'Orbigny in respect to the name of this variety. Soldani's term is *Orthoceras "corniculum"* (a little horn); d'Orbigny makes it *Dentalina "cornicula"* (a little crow). There can be no doubt what was intended, and the termination originally given by Soldani must be adhered to.

[2] *Vide* 'Ann. and Mag. Nat. Hist.,' ser. iv, vol. viii, p. 158, pl. ix, fig. 55.

Prof. Rupert Jones's entire approval. Between the published figures of the specimens from Permian and Cretaceous beds respectively no difference in characters can be detected that would justify the most trivial distinction, and it is surely too late in the day to accept geological age alone, as sufficient basis for zoological species.

The figure (Pl. X, fig. 19) has been copied from the original engraving in Professor W. King's Monograph, no specimens with quite the same characters having been found in the Permian beds since Professor Jones's early researches.

Distribution.—The only recorded occurrence of Carboniferous or Permian specimens of *Dentalina multicostata* is in the Upper Magnesian Limestone of Byers Quarry, Durham.

Family, GLOBIGERINIDA, *Carpenter.*

Genus.—TEXTULARIA, *Defrance.*

POLYMORPHUM, *Soldani.*
NAUTILUS, *Soldani, Batsch.*
TEXTULARIA, *Defrance, d'Orbigny, Bronn, von Münster, Römer, Reuss, Parker and Jones, Williamson, Carpenter, Dawson, Brady, &c.*
TEXTILARIA, *Ehrenberg, Reuss, Schultze, Karrer, Gümbel, Stache, Schwager, Terquem, &c.*
CLIDOSTOMUM (?), GRAMMOSTOMUM, HETEROSTOMUM, HETEROSTOMELLA, PROROPORUS, GUTTULINA, POLYMORPHINA, RHYNCHOPLEURA (?), RHYNCHOPLECTA (?), &c. (in part), *Ehrenberg.*

General Characters.—Shell free, regular, equilateral; conical, pyriform, oblong, or cuneiform. Segments numerous, arranged in two alternate parallel series; septal orifice at the centre of the umbilical margin of each segment, close to its line of contact with the preceding opposite segment. Aperture simple or labyrinthic.

What is to be said of the Palæozoic *Textulariæ* will perhaps be best detailed in the account of the individual species. There is nothing to distinguish the Carboniferous representatives of the genus, as a group, from those of any subsequent age. They generally pertain to the rough thick-shelled forms and, as might be expected, have a tendency to labyrinthic internal structure.

The Permian species are still very obscure and, comparatively speaking, specimens are rare; material is as yet too scanty for the foundation of any very positive conclusions as to the limits of their varietal modifications.

TEXTULARIA GIBBOSA, *d'Orbigny*. Pl. X, fig. 26.

TEXTULARIA GIBBOSA, *d'Orbigny*, 1826. Ann. Sci. Nat., vol. vii, p. 262, No. 6,—Modèle, No. 28;—*Soldani*, 'Testaceographia,' vol. i, part 2, p. 119, pl. cxxxii, figs. *I*, *K*, &c.

TEXTILARIA RECURVATA (?), *Ehrenberg*, 1854. Mikrogeologie, pl. xxxvii, No. 11, fig. 17.

— LAGENOSA (?), *Id.* Ibid., fig. 15.

TEXTULARIA GIBBOSA, *Parker, Jones, and Brady*, 1865. Ann. and Mag. Nat. Hist., ser. iii, vol. xvi, p. 23, pl. ii, fig. 60.

— — *Id.*, 1871. Ibid., ser. iv, vol. viii, p. 168, pl. xi, figs. 115—119.

Characters.—Shell elongate, compressed, tapering, constricted at the sutures; depressed at the centre over the line of juxtaposition of the two series of segments; margin rounded. Chambers few in number, broad, ventricose, especially the final pair. Texture coarse. Length $\frac{1}{20}$ inch (1·25 mm.) or more.

The name *Textularia gibbosa* may be accepted with advantage for the bold coarse-shelled, somewhat compressed varieties of the genus, having inflated chambers and often more or less irregular growth. They constitute a natural group between the more delicate and regular *Textularia globulosa* of Ehrenberg, with its nearly spherical segments, and the compact *T. sagittula* of Defrance with its thin even margin. Such forms are common amongst Tertiary fossils, sometimes attaining considerable size, and large individuals occasionally have their chambers subdivided by secondary septa. The dimensions above appended to the description of *Textularia gibbosa* are those of the Carboniferous specimens; in Tertiary deposits they often attain a much larger size.

Two of the figures of Carboniferous *Textulariæ* given by Dr. Ehrenberg in the 'Mikrogeologie,' with the names *T. lagenosa* and *T. recurvata* respectively appear to possess the general characters of *T. gibbosa* though it is difficult to speak with anything like certainty from drawings based on mere transparent rock-sections.

Distribution.—In England *Textularia gibbosa* is found in both the Scar and the Yoredale Limestones; in Scotland in beds of the Lower Carboniferous Limestone Group only; it also occurs in the Calcaire de Visé of Belgium and in some of the Carboniferous deposits of Russia.

TEXTULARIA EXIMIA, *d'Eichwald.* Pl. X, figs. 27—29.

TEXTILARIA EXIMIA, *d'Eichwald*, 1860. Lethæa Rossica, vol. i, p. 355, pl. xxii, figs. 19, *a—d.*

Characters.—Test long, tapering, often curved or irregular in outline; sub-cylindrical or only slightly compressed laterally. Segments numerous, six to ten in each series, globose, distinct. Length $\frac{1}{15}$ inch (1·7 mm.).

In accepting M. d'Eichwald's name as applied to a group of Carboniferous *Textulariæ* characterized by their long tapering contour, great thickness in proportion to breadth, and distinct inflated segments, I may have recognised a needless "species," but I can find no earlier description or figures to which this set of forms can be referred with propriety. They belong to the "*agglutinans*" type, but differ in the shape of the segments and in the tendency to inequilateral growth. Professor Reuss figures a number of somewhat similar varieties from the Cretaceous strata of Bohemia, and of Westphalia, such as *Text. fœda* from the former, and *Text. bolivinoides, T. parallela, T. concinna, T. Partschi,* and *T. globifera* from the latter. These appear to differ from each other chiefly in the amount of lateral compression and in the shape of the terminal chamber, but all of them have the rounded periphery and ventricose segments.

The mere form of the chambers, and the general aspect of the shell as depending upon it are but slight grounds on which to rest zoological subdivision in so polymorphic a class of organisms as the Foraminifera, yet most of the so-called "specific" distinctions are dependent on characters of this nature, and when, as in the present case, they indicate a tolerably well-marked group, the expediency of recognising them may be accepted as a matter of convenience without insisting on sharp lines of demarcation. Without such subdivision the study of the Foraminifera would be impracticable, but it is none the less necessary that the limits of readily ascertained and fairly permanent characters should be observed, otherwise a multiplicity of names, more embarrassing than the inconveniently large groups they were designed to obviate, is the result.

M. d'Eichwald had but few specimens of fossil microzoa at his command, and his description of *Textularia eximia* has required some modification to include the finer examples which occur amongst others in our British Carboniferous beds. This appears to be the only variety of the genus which he himself obtained from the Russian limestones, though he mentions *Text. lunata*, Ehrenberg, as a species occurring among sand-grains at Witegra.

Distribution.—By far the larger number of Carboniferous *Textulariæ* have the

characters of *T. eximia*. In England it is found more or less frequently throughout the Carboniferous Limestone Series; in Scotland it occurs in the Calciferous Sandstone, and Lower Carboniferous Limestone Group, and possibly in the Upper division as well. M. d'Eichwald records its presence in the Fusulina-rocks of Russia.

TEXTULARIA JONESI, *Brady*. Pl. X, figs. 20—22.

TEXTULARIA CUNEIFORMIS,	*Jones*, 1850.	In King's Monogr. Perm. Fossils, p. 18, pl. vi, fig. 6.
—	—	*Reuss*, 1854.	Jahresb. d. Wetterauer Gesellsch., vol. for 1851—1853, p. 73.
—	—	*Richter*, 1855.	Zeitschr. d. deutsch. geol. Gesellsch., vol. vii, p. 532, pl. xxvi, fig. 23.
—	—	*Geinitz*, 1861.	Dyas, Heft 1, p. 122, pl. xx, fig. 35.
—	—	*Schmid*, 1867.	Neues Jahrb. für Min., Jahrg. 1867, p. 588.

Characters.—Test short, broad, complanate, tapering; depressed over the line of juxtaposition of the two series of segments. Segments nearly opposite, long, narrow, slightly convex. Margin thin, but little constricted at the sutures. Length $\frac{1}{50}$ inch (0·5 mm.).

The figure in King's Monograph to which Prof. T. Rupert Jones attached the name *Textularia cuneiformis* is not very intelligible, the obscurity being probably the result of distortion in the specimen or its injury in process of fossilization—at any rate Dr. Richter's drawings in Geinitz's 'Dyas' yield a more satisfactory basis for description and comment. But through the kindness of my friend Mr. J. W. Kirkby, who has sent me his only English specimen of the species (Pl. X, fig. 20), and of Dr. Richter who has supplied me with two additional drawings from fine examples in his own collection (figs. 21, 22), I am not entirely dependent on previously published materials.

The English example (fig. 20) is smaller than those of the Thuringian Zechstein; it is but little more than $\frac{1}{60}$ inch (0·44 mm.) in length, the width across the top being almost exactly the same, and it has altogether about sixteen segments. Dr. Richter's specimens are larger and have a correspondingly greater number of chambers. The singular feature of all, whether English or German, consists in the arrangement of the chambers, the two series being almost exactly opposite, instead of alternating with each other. This is so uniform a character that a doubt has more than once occurred to me

whether the specimens were actually *Textulariæ* — whether they might not belong to some unknown broad variety of one of the uniserial types, the depressed median line being in reality a fracture, the result of pressure on a very thin shell-wall. This supposition received some support from the condition in which the shells are so frequently found, that is, split horizontally. On the other hand, some of the specimens so laid open show distinct duplication of the chamber-walls where the ends meet in the centre of the test, which could not occur, at any rate with regularity, unless they belonged to two series of independent segments. The only other genus except *Textularia* to which these little fossils bear any superficial resemblance is *Frondicularia;* but even in the absence of satisfactory evidence as to the course of the stoloniferous tubes, which are obscure when not entirely obliterated, there is sufficient in the conspicuous characters of the figured specimens to render an affinity with that subtype improbable. So that, notwithstanding the shade of doubt consequent on the peculiarity alluded to, there is at present no valid reason for altering the position in which the species has heretofore been placed, that is, in the genus *Textularia.*

It has been necessary to change the trivial name, inasmuch as the term *Textularia cuneiformis* had been employed by d'Orbigny,[1] previous to the publication of Professor King's work, for another and distinct species. Under these circumstances I have followed the usual custom, which happens to coincide with my inclination, and have associated Professor Rupert Jones's name with the form under notice.

Distribution.—In the Thuringian area, *Textularia Jonesi* is by no means rare—being found in the Kupferschiefer, in the Zechstein proper, and in the Dolomite of the Middle Zechstein. In England it is a very scarce fossil; the only two localities in which I know of its having been collected are at Summerhouse, near Darlington, in the Lower, and at Byers Quarry in the Upper Magnesian Limestone.

TEXTULARIA TRITICUM, *Jones.* Pl. X, figs. 24, 25.

TEXTULARIA TRITICUM,	*Jones*, 1850.	In King's Monogr. Perm. Fossils, p. 18, pl. vi, fig. 5.
—	—	*Reuss*, 1854.	Jahresb. d. Wetterauer Gesellsch., vol. for 1851—1853, p. 73.
—	—	*Richter*, 1855.	Zeitschr. d. deutsch. geol. Gesellsch., vol. vii, p. 532, pl. xxvi, figs. 24, 25.
—	—	*Geinitz*, 1861.	Dyas, Heft 1, p. 122, pl. xx, figs. 36, 37.

[1] *Textularia cuneiformis*, d'Orbigny, 1826, 'Ann. Sci. Nat.,' vol. vii, p. 263, No. 18, 1840;—'Foram. Cuba,' p. 138, pl. i, figs. 37—39.

Characters.—"Shell conical, somewhat flattened on two of its sides; its horizontal section oval; composed of nine subglobose cells; sutures deeply sulcated. Length $\frac{1}{30}$, thickness $\frac{1}{140}$ inch," (0·85 mm.—0·18 mm.).

I have never had the good fortune to meet with this species, though I have at one time or other searched large quantities of the magnesian limestone *débris* from the locality (Byers Quarry) whence Prof. T. Rupert Jones's specimens were obtained five and twenty years ago. It is much to be regretted that the original examples have been mislaid or lost. Under the circumstances the only course left for me has been to reproduce the description and figure as given in Prof. King's Monograph.

Dr. Richter, of Saalfeld, describes and figures (*loc. cit.*) specimens which he regards as pertaining to the same species, from the Zechstein formation of Germany, thereby contributing to its better definition. His description, which does not entirely accord with that quoted above from Prof. Jones, runs as follows. "This also is one of the compressed forms like the foregoing (*T. cuneiformis*), and is always found split on the median plane. Narrow wedge-shaped, somewhat smaller than *T. cuneiformis*,[1] the relation of length to breadth is as 1·00 to 0·55. The scarcely alternating chambers are thick-walled, equal in height and length (only the latest chambers are sometimes rather shallower), concave and smooth." The length of the Zechstein specimens appear to be about $\frac{1}{25}$ inch (1·0 mm.). Through the kindness of Dr. Richter I am enabled to give a better figure of the species than that which accompanies his own description: Pl. X, fig. 25, is an accurate copy of the drawing of a Thuringian specimen in his cabinet. The chambers are rather longer in proportion to their depth than the previously published figures indicate, but the general characters accord with Dr. Richter's description above quoted. These German examples appear to be much more regularly built than that to which the name was originally applied, but beyond this fact, which is apparent from a comparison of the figures, the available materials leave little scope for comment.

Distribution.—In the Upper Magnesian Limestone, Byers Quarry, Durham; in the dark-grey Lower Zechstein Limestone of Thuringia and possibly in the Middle Zechstein also. In all localities very rare.

TEXTULARIA MULTILOCULARIS, *Reuss*. Pl. X, fig. 23.

TEXTULARIA MULTILOCULARIS, *Reuss*, 1861. In Geinitz's Dyas, Heft i, p. 122, pl. xx, fig. 38.

Dr. H. B. Geinitz in his great work on the Permian formation (*loc. cit.*) figures, on the authority of the late Professor von Reuss and from his drawings, an attenuated *Textu-*

[1] *Textularia cuneiformis* is *T. Jonesi* of the present memoir.

laria, with not less than forty chambers. No zoological description is given of the species, the dimensions of the specimens are not stated, nor is there any record of the magnifying power employed for the figures. The drawings which have been accurately copied (Pl. X, fig. 23, *a*, *b*) represent a very long, narrow, compressed shell, slightly irregular and curved in outline, and with even margin; the septa marked by fine lines without constriction or superficial depression; the segments regular and very numerous. To these particulars which are based upon Dr. von Reuss's figures I can add nothing.

Distribution.—Lower Zechstein of Gera in Thuringia.

Subgenus.—BIGENERINA, *d'Orbigny*.

BIGENERINA, *d'Orbigny, Parker and Jones, Carpenter, Seguenza, Brady, Schwager.*

General Characters.—Test free, regular, elongate; formed of numerous segments; the earlier ones arranged in two alternate parallel series; the later ones in a single straight or curved line. Aperture simple or labyrinthic. Surface, rough.

In strict zoological sense *Bigenerina* is but a subordinate group of the genus *Textularia*, characterised by a dimorphous habit of growth. The earlier chambers are arranged on the typical biserial plan, whilst the later ones are joined end to end in a single row. Such forms are more common in the recent condition than as fossils; they are generally of small size and of long attenuated contour, the Textularian segments occupying but a small part of the whole shell. A limited number of specimens pertaining to this sub-type have been found in material of Carboniferous age, and these belong to a short stout variety not hitherto described.

BIGENERINA PATULA, *nov*. Pl. VIII, figs. 10, 11, and Pl. X, figs. 30, 31.

Characters.—Test oblong, rounded, subcylindrical; somewhat compressed and tapering in the earlier portion. Biserial segments, numerous, broad, ventricose; uniserial segments few in number, rounded. Aperture, either a large single central orifice, or compound and labyrinthic. Length, $\frac{1}{20}$ inch (1·25 mm.).

This short broad variety of *Bigenerina* seldom shows more than two or three uniserial chambers and therein differs conspicuously from such forms as *Bigenerina nodosaria* and *B. digitata*, the biserial segments of which often constitute so small a proportion of the whole shell as to be recognised with difficulty. It is essentially a

Textularia of the stout thick-shelled type, like *T. gibbosa*, with the addition of a line of two or three inflated subcylindrical segments. The tendency to the labyrinthic interior structure, which characterises the larger *Textulariæ*, is strikingly seen in such specimens as Pl. X, figs. 30 and 31, and so far as it goes confirms the relationship. M. d'Orbigny in his generic description lays some stress on the regular and equilateral contour of the shell; but occasional slight asymmetry, as exhibited in fig. 30, cannot be regarded as of any morphological importance.

Distribution.—In England *Bigenerina patula* has only been found in the Saccammina-limestone of Elfhills, Northumberland; in Scotland it is equally rare, having been noticed in but one locality, belonging to the Lower Carboniferous Limestone Group. Specimens are occasionally, though rarely, met with in the friable Fusulina-limestones of Russia.

Genus.—Truncatulina, *d'Orbigny.*

Testæ hammoniformes (in part), *Soldani.*
Nautilus, *Walker and Jacob, Gmelin, Fichtel and von Moll, Maton and Rackett, Pennant, Dillwyn, Turton.*
Serpula, *Montagu.*
Polyxenes, Cibicides, *de Montfort.*
Lobatula, *Fleming, Thorpe.*
Truncatulina, *d'Orbigny, Roemer, von Hagenow, Reuss, Parker and Jones, Williamson, Seguenza, Carpenter, Dawson, Brady, Gümbel, Sars, Robertson, Parfitt, Vanden Broeck, &c.*
Rosalina (in part), *Alth, Reuss.*
Rotalina (in part), *Reuss.*
Planorbulina, *Parker and Jones, Carpenter.*

General characters.—Test parasitic, spiral; outermost convolution alone visible on the inferior[1] lateral surface; all the convolutions, including the ultimate segment, apparent on the truncate, superior (adherent) surface. Segments numerous; convex below, flat, and truncate above. Orifice single, in front of the ultimate segment, close to the carina of the preceding convolution and continued, as a fissure, along the superior connecting spiral, at the expense of the umbilical borders of the last two or three segments, but closed in by superimposed layers of shell in all the remaining ones.

It would be more strictly correct to speak of *Truncatulina* as a subgenus of

[1] D'Orbigny in his various descriptions speaks of the spiral surface of the test of the *Truncatulinæ* as the "lower" surface because it happens to be flat, and *vice versâ*. Williamson and others, having regard to homology, treat the spiral surface in all the Rotaline genera as the "superior" surface. The anomaly in *Truncatulina* is apparent rather than real, whilst uniformity in terminology is a matter of solid importance.

Planorbulina, for its modifications, by gradational variations, assume the characters of the latter type. But the name *Truncatulina* is well understood as applied to a certain set of specialised forms, and in the brief notice which is all that is needful in this place for a type so slightly represented in the Carboniferous fauna it is undesirable to complicate the terminology.

It may be well to explain also that, although the synonymy of the Rotaline types—*Truncatulina*, *Pulvinulina*, and *Calcarina*—has been given at some length, no attempt has been made to render it exhaustive. The reader interested in such matters may turn to Messrs. Jones and Parker's memoir 'On the Foraminifera of the Family Rotalinæ'[1] for much more extended references.

The Carboniferous *Truncatulinæ* offer no points calling for special notice, the most remarkable fact connected with them being their occurrence so low down in the geological series. My friend Prof. W. K. Parker, on seeing the specimens, observed that, except for alterations in appearance produced by age and by the process of fossilization, he could detect nothing in their general features to distinguish some of them from the forms now living in our seas—a remark in which I entirely concur.

TRUNCATULINA CARBONIFERA, *nov.* Pl. VI, fig. 10.

Characters.—Test oblong, depressed, rugoso-punctate, irregular; superior surface complanate; inferior, convex; margin carinate. Segments few, inflated; the later ones relatively large. Sutures more or less limbate. Diameter, $\frac{1}{60}$ inch (0·42 mm.).

A somewhat peculiar variety of *Truncatulina* differing in its carinate margin, irregular build, and inflated chambers, from any hitherto described. It is possible that the specimen represented in fig. 10 may originally have had an additional chamber; and if so, the raised line crossing the terminal segment is doubtless the remains of its shelly wall, and not, as it appears, a mere exogenous growth. The species is somewhat larger than the more regular form *Tr. Boueana;* indeed, it approaches the common *Tr. lobatula* in its dimensions.

Distribution.—In the Calcaire de Namur of Belgium, associated with *Truncatulina Boueana*, very rare.

[1] 'Quart. Journ. Geol. Soc.,' vol. xxviii, p. 103.

TRUNCATULINA BOUEANA, *d'Orbigny*. Pl. VI, fig. 11.

TRUNCATULINA BOUEANA, *d'Orbigny*, 1846. For. Foss. Vienne, p. 169, pl. ix, figs. 24—26.

Characters.—Test suborbicular, depressed, rugoso-punctate; superior surface complanato-concave; inferior, convex, slightly excavated at the umbilicus; segments nine in number, complanate, arcuate; margin somewhat limbate. Diameter $\frac{1}{80}$ inch (0·33 mm.).

The above description is a mere English rendering of d'Orbigny's words, excepting in the transposition of the terms "superior" and "inferior," on the grounds set forth in a former page. One or two minute *Truncatulinæ* from the Belgian Carboniferous beds answer so exactly to the description of *Tr. Boueana* and to the figures given in the "Vienna Basin" monograph, that, notwithstanding the difference of geological age, they must be treated as representatives of that form. They correspond even in dimensions and number of visible chambers. There is not much in the name, for after all *Truncatulina Boueana* only represents a neatly made, small sub-variety of *Tr. lobatula*, having an even margin, with the later segments slightly embracing on the superior surface; but, as the only specimens found have the characters assigned to this particular form, it seems best to retain the trivial appellation.

Distribution.—It would, I suspect, be impossible to define the distribution of this variety, as distinct from *Tr. lobatula*, in the Tertiary microzoic rocks or in the living condition. In the Carboniferous beds it is represented by a very few specimens from the Calcaire de Namur of Belgium.

Genus—PULVINULINA, *Parker and Jones.*

HAMMONIÆ, NAUTILI, *Soldani.*
NAUTILUS, *Fichtel and von Moll.*
PULVINULUS, PLACENTULA, *Lamarck.*
EPONIDES, CANCRIS, CIDAROLLUS, *de Montfort.*
CREPIDULINA (in part), ROTALITES (in part), *Defrance.*
ROTALIA (in part), *d'Orbigny, Reuss, Ehrenberg, Schwager.*
ROTALINA (in part), *d'Orbigny, Reuss, Egger, Williamson, Parker and Jones.*
PULVINULINA, *Parker and Jones, Carpenter, Reuss, Karrer, Brady, Gümbel, Sars, Vanden Broeck.*

General Characters.—Test free, spiral, typically bi-convex and trochoid, but varying from this to depressed, complanate, or even vermiculate; composed of few convolutions, all of which are visible on the superior lateral surface; the inferior surface nearly or entirely occupied by the last convolution. Segments less numerous than in the other *Rotalinæ*, varying from 7 to 26 in number. Shell very finely porous and almost destitute of canal-system; sutures often limbate, sometimes granulate; the limbation of the sutures frequently accompanied by further exogenous deposit in the form of a star radiating from the umbilicus. Margin angular or subcarinate. Aperture large, variable, often arcuate and notched, situate on the outer edge of the inferior surface of the terminal segment near the umbilicus.

Only a few small obscure specimens referrible to the genus *Pulvinulina* have been found in Carboniferous deposits. These are described under the name *Pulvinulina Broeckiana*. The genus has been long known to exist as far back as the Trias, and from that period through succeeding geological eras it is represented by a gradually increasing number of species. The type still furnishes some of our most common deep-sea Rhizopoda.

PULVINULINA BROECKIANA, *nov.* Pl. VI, fig. 12.

Characters.—Test orbicular, depressed; superior side only slightly convex; inferior more strongly so; margin carinate. Spire composed of about three convolutions. Upper surface smooth, sutures marked only by broad dark lines of clear shell-substance; inferior surface more or less granular or tuberculate, sutures marked by slight depressions. Diameter $\frac{1}{40}$ inch (0·65 mm.).

In many particulars this form, with which I have had the pleasure of associating the name of my friend M. Ernest Vanden Broeck, of Brussels, to whose kindness I owe, directly or indirectly, all the Belgian Carboniferous material I have had the opportunity of examining, closely approaches the characters of *Pulvinulina elegans*, d'Orbigny; a fact the more interesting because that species and the allied *P. cassiana* (Gümbel) are amongst the oldest of the true *Rotalinæ*, which have hitherto been satisfactorily identified. Messrs. Parker and Jones found minute specimens of the former in abundance in the alabaster pits of Chellaston, Derbyshire, in a marl probably of later Triassic age;[1] whilst Dr. Gümbel records the latter from the Trias of the Alps. The Carboniferous form is much less convex on its superior surface than *P. elegans*, and does not possess the characteristic limbation of the sutures; the tuberculate condition of its inferior surface is

[1] 'Quart. Journ. Geol. Soc.,' 1860, vol. xvi, p. 455, pl. xx, fig. 46, under the name *Rotalia elegans*.

likewise peculiar. A larger supply of material might show *P. Broeckiana* to be only a modification of the species referred to, but the few specimens hitherto found seem very distinct from it.

Distribution.—In the Calcaire de Namur of Belgium. Very rare.

Genus.—CALCARINA, *D'Orbigny.*

NAUTILUS, *Gmelin, Fichtel and Moll.*
ROTALIA, *Lamarck, d'Orbigny, Reuss.*
SIDEROLINA, *Defrance, d'Orbigny.*
CALCARINA, *d'Orbigny, Reuss, Carpenter, Parker and Jones, Brady, Gümbel, Schwager.*
ROTALINA, *d'Orbigny, Egger.*
SIDEROLITES, SIDEROLITHUS, SIDEROPORUS, SIDEROSPIRA, ASTERIATITES, *auctorum.*

General Characters. — Test free, convoluted, depressed; rarely smooth, more frequently tuberculate or rough; formed of a spire regularly coiled; convolutions all more or less visible on the superior surface, embracing on the inferior, formed of many chambers. Shell-wall produced at intervals into marginal appendages, often much elongated, simple or furcate, resembling the rowel of a spur. Interior structure remarkable for its tendency to produce supplemental growths of shell-substance forming an intermediate skeleton furnished with a well developed canal-system. Aperture, a longitudinal slit (often bridged over so as to form a line of orifices) in the terminal chamber, close to the penultimate convolution.

The genus *Calcarina* is so small and unimportant a constituent of the Carboniferous fauna that there seems no need in this place to enlarge upon its general history. It is much better known as a recent than as a fossil type. The great abundance and large size of the living specimens obtained in tropical seas, together with their striking peculiarities, whether of external form or internal structure, have invested the genus with somewhat unusual zoological interest.

CALCARINA AMBIGUA, *nov.* Pl. VI, fig. 13.

One or two small Rotaline shells which there can be little doubt pertain to the genus *Calcarina*, have been found in the *débris* of the Belgian Carboniferous Limestones. The exterior of these little fossils is so obscured by age and external agencies, that it

would not be wise to attempt to describe in concise terms their special zoological characters. They appear to represent a smaller species than any hitherto described, the diameter of the figured specimen, which is the largest, being only $\frac{1}{40}$ inch (0·65 mm.). The margin has been strongly carinate and apparently rowelled, but it is partly broken away and partly worn smooth. The less prominent parts of the surface show the remains of the hispid or tuberculate condition, which is so common a characteristic of the smaller varieties of the genus *Calcarina*.

The drawings of one of the Carboniferous specimens, Pl. VI, fig. 13, though of necessity deficient in minute characters, will serve as a record of the occurrence of the form, and render its identification easy should further research bring to light a more plentiful supply of specimens.

Distribution.—In the Calcaire de Namur, Belgium, very rare.

Family, NUMMULINIDA, *Carpenter.*

Genus.—ARCHÆDISCUS, *Brady.*

General Characters.—Shell convoluted, rounded, more or less unsymmetrical; formed of a non-septate tube coiled upon itself in a constantly varying direction. Shell-wall traversed by very numerous, parallel, minute tubuli.

The genus *Archæodiscus* was established for a number of minute discoidal fossils, structurally related to *Nummulina*, but differing in some important morphological particulars. The range of modification observable in individual specimens pertaining to the type is not great, and for the present there seems no need to recognise more than a single specific form; its detailed description and history therefore may best be given under the subordinate heading.

ARCHÆDISCUS KARRERI, *Brady.* Pl. XI, figs. 1—6.

ARCHÆDISCUS KARRERI, *Brady*, 1873. Ann. and Nat. Mag. Hist., ser. iv, vol. xii, p. 286, pl. xi;—Report Brit. Assoc., Bradford Meeting, p. 76 (abstract).

— — *Id.*, 1873. Mem. Geol. Survey Scotland; Expl. Sheet 23, p. 95, &c.

Characters.— Shell lenticular, rounded, bi-convex, somewhat unsymmetrical. Periphery determined by the last revolution of the tubular cavity. Margin angular or slightly rounded; entire except near the orifice where the shell, owing to diminished thickness, is often broken and irregular. Aperture, the open unconstricted end of the tubular cavity, rounded or crescentic, simple. Diameter, $\frac{1}{25}$ inch (1·0 mm.).

The brief notice above referred to, read before the British Association at its Bradford Meeting, and subsequently published in the Annals of Natural History (*loc. cit.*) contains an account of the structure and affinities of this interesting type as far as at present known—continued observations having resulted in little beyond the confirmation of the views therein expressed and the extension of our knowledge of its distribution.

Externally the specimens of *Archædiscus Karreri* are lenticular discs, seldom more than a twenty-fifth of an inch (1·0 mm.) in diameter, and a fiftieth of an inch (0·5 mm.) in thickness and never quite symmetrical. They often present an appearance as of laminated structure, and altogether bear a superficial resemblance to minute Nummulites.

The interior will be best understood by comparing it to a tube coiled upon itself in constantly varying directions, the periphery being determined by the last circlet of the coil. The tube, which represents the cavity occupied during life by the main body of the animal, is never subdivided into chambers either by constriction or by true septa, and it increases in size with each successive turn. The earlier portion in one section which has been measured has a transverse diameter of about $\frac{1}{600}$ of an inch (0·04 mm.), the later portion $\frac{1}{200}$ of an inch (0·13 mm.), though in most cases the difference is scarcely so great as these figures imply. The shape of the tube also varies considerably. Its transverse section at times represents about three-quarters of a circle, the truncate or flattened side facing inwards; at others it exhibits an irregularly crescentic or saddle-shaped contour, the concave surface of which embraces portions of the preceding convolutions to a greater or less extent.

The coil terminates externally on the periphery of the disc, and the majority of specimens have an appearance as though a part of the end of the tube had been broken away (as sometimes observable in *Nummulina*), owing probably to the greater delicacy and tenuity of the newly deposited shell-substance. The mouth of the tube, which forms the general aperture of the shell, appears not to have been constricted or otherwise closed in.

A shell formed in the manner described would present an irregular surface, were the walls of the tube of equal thickness throughout, but in reality the exterior is even and smooth. A transverse section of the entire fossil (Pl. XI, fig. 4) shows that this is due to a somewhat remarkable thickening of the shell-wall, especially on its lateral surfaces, most observable near the centre of the disc, and usually to a greater extent on one side

than on the other. Sometimes the deposit of shell-substance is proportionally so great that the animal has occupied but a small part of the whole test.

The minute structure of the shell is far better preserved than might be expected in so old a fossil, and it has many points of interest. The walls throughout are traversed by a multitude of very minute tubuli. In the thinner portions (best seen in the horizontal section, Pl. XI, fig. 3), these are apparently the ordinary pseudopodial foramina; in the thicker (fig. 4), though their course is more or less sinuous, they are perhaps only the prolongation of the same. Quite distinct from these, there exists a series of tubes of much larger dimensions, most readily observed near the ends of a transverse section, and clearly defined by a magnifying power of 200 diameters or more, as in fig. 5. I have been unable to make out what purpose they serve, but the presence of two distinct systems of tubulation is a noteworthy fact. A condition to some extent analogous may be found in other genera of Foraminifera, in *Orbulina* for example, but as that genus is characterized by a thin and uniform shell-wall, the two cases may have nothing in common in their structural significance.

With reference to the lamination of the shell. In the true Nummulite this is a character of importance, for it arises from the prolongation of the alæ of the saddle-shaped chambers to the umbilicus of the test, each turn of the spire forming a fresh and complete investment of the whole. In *Archæodiscus* a tendency to a similar condition exists, but developed in a much less marked degree and with no approach to uniformity. A section of the test highly magnified, as in fig. 6, shows the successive layers of shell formed by the prolongation towards the umbilicus of the crescentiform edges of the tube; but the earlier portions of the tube are nearly circular (transversely), and it is only in the later stages of growth, when it becomes concavo-convex in section, that it assumes this investing character.

Whether there is any essential distinction, either in structure or function between the thin shell-wall and the additional deposit which makes up the thicker portion—in other words, whether there is as in the Nummulite a distinct primary and secondary skeleton, is a question that must still to some extent be left open. It is, nevertheless, quite possible at times to trace the thin line of the primary wall, even when no difference in structure is observable between it and the immediately adjacent supplementary layer. In the same way, though I have not been able to identify any part of the structure as referrible to a true canal-system, there are appearances that continually suggest the possibility of its existence.

The foregoing description, though incomplete in many points, is sufficient to indicate the Nummuline affinities of *Archæodiscus*. It differs from the typical Nummulite in its less complex general structure,—a coiled non-septate tube taking the place of a spiral line of chambers, the tube, however, showing something of the same tendency as the Nummuline chambers to bifurcate laterally.

The difficulty of determining the structure and organization of so minute a fossil is

always great; but in the present case it is much increased by the infiltration with a sub-crystalline substance of the same chemical composition as the original shell. It may be recollected that the true structure of the Nummulite itself, a very large organism, comparatively speaking, was chiefly elucidated by the study of non-infiltrated specimens from the sandy Tertiary beds of Hampshire. It is needless to say that no examples in this favorable condition have been available from the compact rocks of the Carboniferous age.

From *Nummulina* the genus *Archæodiscus* is readily distinguished by features already detailed. The only Carboniferous Foraminifera with which there is much likelihood of its being confused is the very simple *Trochammina incerta*. The likeness is quite superficial, but there is considerable *primâ facie* resemblance between the small, smooth specimens of the latter species, especially in its thicker biconvex varieties, and very young examples of *Archæodiscus*.

Distribution.—When originally described this little fossil had only been found in the rich shale of Brockley in Lanarkshire that has yielded so many rarities, but further investigation has revealed its presence in other localities. It has now been collected both from the Scar Limestone and the Yoredale Rocks of England; from the Calciferous Sandstone and the Lower Carboniferous Limestone Groups of Scotland, as well as from one habitat pertaining to the Upper Limestone Group of that country. I have found no traces of it in material from foreign sources.

Genus.—AMPHISTEGINA, *d'Orbigny.*

AMPHISTEGINA, *d'Orbigny, Bronn, Reuss, Seguenza, Williamson, Carpenter, Parker, Jones, and Brady, Karrer, Bunzel.*
HETEROSTEGINA, NONIONINA, *Ehrenberg.*

General Characters.—Shell free, discoidal, inequilateral, more convex on one side than the other, consisting of a turbinoid spire, each convolution of which completely embraces the previous one. Chambers saddle-shaped; the alar prolongations on the upper side simple (as in *Nummulina*); on the lower, divided each into two portions by the constriction of the sarcode to a narrow neck;—the secondary lobes being directed backward and radially, and being intercalated, give the appearance externally of an independent whorl of chambers. Aperture on the lower side of the ultimate chamber, as in the *Rotalinæ*.

The occurrence of a well-defined example of the genus *Amphistegina* in the Carboniferous Limestone is not only remarkable as an extension of the supposed range

of the genus in geological time, but also in the increased importance it imparts to the *Nummulinida* in their relation to the Palæozoic epoch.

In the living condition *Amphistegina* is widely distributed. It is found, often in large numbers, in the Coralline and Coral Zones of tropical and subtropical seas, rarely or never in those of temperate latitudes.

It is common in microzoic deposits of the Tertiary epoch from the Eocene forward, both in Europe and America. Earlier than this it has only been recorded hitherto from a single locality. D'Orbigny,[1] in the 'Tableau Méthodique,' gives amongst the species of *Amphistegina*, one which he names *A. Fleuriausi* from the Upper Chalk of Maestricht, but without any details as to specific characters. Professor Reuss[2] identifies this with a form found by himself in the same deposit. It is quite open to question whether the fossils described and figured by Professor Reuss ought not to be referred to the allied genus *Operculina* rather than to *Amphistegina*; but on the supposition that they pertain to the latter type, they have been regarded as marking its earliest appearance, so that the discovery of a veritable member of the genus as low down in the geological series as the Carboniferous Limestone adds a long period to its life history.

AMPHISTEGINA MINUTA, *nov.* Pl. XI, fig. 7.

Characters.—Shell discoidal, lenticular, the two sides nearly equally convex. Margin entire, acute. Chambers very numerous, sinuous. Surface smooth. Diameter $\frac{1}{33}$ inch (0·77 mm.).

The unique representative of the genus *Amphistegina* found in the Carboniferous Limestone, though exhibiting in a striking manner the characters of the type, yields only slender basis for the details of specific description. It resembles d'Orbigny's 'Modèle' (No. 40) of *A. vulgaris*, but is more Nummuline in general aspect, and the segments are relatively narrower and more numerous. It seems in fact to lie, morphologically, between *A. vulgaris* and *A. Lessonii* (Modèle No. 98). The shell is, however, smaller than any fossil variety of the genus which has as yet been described. The oldest species, geologically speaking, hitherto recorded (*A. Fleuriausi*, D'Orb.) has a diameter, according to Reuss, of $\frac{1}{12}$ of an inch (2·0 mm.); D'Orbigny's three Miocene forms range from the same size to $\frac{1}{6}$ of an inch (4· mm.); and Dr. Carpenter gives from $\frac{1}{20}$ to $\frac{1}{7}$ of an inch (1·2 to 3·7 mm.) as the range of variation in the various members of the genus. The modification now under notice, in the mature condition, as far as can be told, has only a

[1] 'Ann. Sci. Nat.,' 1826, vol. vii, p. 304, No. 7.

[2] 'Sitzungsb. k. Akad. Wissensch. Wien,' vol. xliv, p. 308, pl. i, figs. 10—12.

diameter of $\frac{1}{33}$ of an inch (0·8 mm.); so that in the absence of prominent structural peculiarities, its diminutive size may be taken as a basis for its specific name.

The almost identical dimensions of the specimens of the allied types *Nummulina* and *Archædiscus* would make it appear that relatively small size is the normal character of the Carboniferous representatives of all three genera.

Distribution.—Only found hitherto in the "Foraminifera Bed" of the Upper Mountain Limestone, Leigh Woods, Bristol.

Genus.—Nummulina, *d'Orbigny.*

Nummulina, *d'Orbigny, Michelotti, Bronn, Galeotti, Buvignier, Carpenter, Williamson, Bornemann, Parker and Jones, Seguenza, Gümbel, Brady, &c.*
Nautilus, Ammonites, Helicites, Camerina, Discolithes, Phacites, Nummulites, Lenticulites, Rotalites, Lycophris, Nummularia, Egeon, Assilina, *auctorum.*

General Characters.—Shell free, spiral, equilateral or sub-equilateral, regular, rounded: typically, discoidal, lenticular. Convolutions embracing, the last enclosing those preceding it. Segments numerous, V-shaped, the later ones, in mature shells, gradually contracted at the peripheral margin so that the ultimate convolution loses itself in the penultimate. Aperture single, simple, close to the periphery of the preceding convolution.

Any general history of the genus *Nummulina* would be misplaced in a paper relating primarily to fossils of the Carboniferous period; nor is there the necessity to enter at length upon a subject which has already been exhaustively treated in many of its aspects in the well-known works of Joly and Leymerie, d'Archiac and Haime, Williamson, Carpenter, Carter, Rupert Jones and Parker, and others. Anything that could be said within the space that could properly be devoted to it here would be but an imperfect abstract of the writings of such authors. At the same time the occurrence in Palæozoic beds of undoubted examples of a type of animal life for long regarded as peculiar to the Tertiary epoch can scarcely be introduced without some notice of other recorded Prætertiary Nummulites, even though it be, in part at least, a repetition of what has already appeared.

In 1849 Rouillier and Vosinsky[1] described under the name *Nummulina antiquior* an unsymmetrical Foraminifer from the white Carboniferous limestone of the neighbourhood of Moscow. In 1861 d'Eichwald,[2] supplied with specimens, as I understand, by these

[1] 'Bulletin Soc. Imp. des Naturalistes de Moscou, vol. xxii, p. 337, tab. K, figs. 66—84.

[2] 'Lethæa Rossica,' vol. i, p. 352, pl. xxii, fig. 16.

authors, adopted their specific term, added a description of an allied symmetrical variety, and formed of the two a new genus *Orobias*, the representatives being named *O. antiquior* and *O. æqualis* respectively. The separation from the genus *Nummulina* was grounded on the non-tubulation of the shell and the absence of any indication of a canal-system. Through the courtesy of General G. von Helmersen of St. Petersburg, I have had the opportunity of studying these and other allied forms existing in large numbers in the Russian white Carboniferous limestones, and can confirm in great measure d'Eichwald's observations, though I hope at a future time to be able to show that, not only the unsymmetrical specimens described by MM. Rouillier and Vosinsky, but also M. D'Eichwald's symmetrical discoidal form, so like a Nummulite in external appearance, are in reality true *Fusulinæ*.

Turning to the Secondary epoch Buvignier[1] has described and figured an Upper Jurassic Nummulite (*N. Humbertina*) from the Astarte-marl of the north-east of France, and, though more detailed illustration would have been acceptable, there seems little reason to doubt the correctness of the diagnosis. More recently Dr. Gümbel[2] has entered the field with a well-marked member of the genus (*N. jurassica*) from the *Ammonites tenuilobatus* and *A. dentatus* zones of the Upper Jurassic formation of Franconia, instancing at the same time a fossil with similar characters from the Jurassic Beds of Mösskirch in Baden. Passing to the Cretaceous system—as early as 1847, Prof. Zeuschner[3] mentions the occurrence of Nummulites in large numbers in a dolomite of Neocomian age in the Carpathian Mountains, but without entering into any particulars. In 1867 Fraas[4] obtained from the Cretaceous formation of Palestine a number of *Nummulina*-like fossils, which he assigned to the genus under three specific names. One of these at the least, *N. Arbiensis*, Conrad, appears to be a true Nummulite, though about the other two there may be considerable doubt. The few cases which have been quoted form, perhaps, the entire record of the occurrence of specimens of the genus *Nummulina* previous to its enormous development in the early part of the Tertiary epoch, and, as will be seen, they are so few in number that, whilst they scarcely affect the general truth of previously accepted views as to its distribution, they impart a new aspect to its life-history. The structural relationship which exists between *Nummulina* and *Fusulina*, that is to say, between the great rock-building genera of the Tertiary and the Palæozoic epochs is one of extreme interest. Hitherto *Fusulina* has been regarded morphologically as little more than a Nummulite drawn out at its umbilici, and so assuming the long, fusiform, tapering contour presented by the familiar type *F. cylindrica*; but if it can be shown that oblate and even discoidal specimens, such as those already alluded to as contained in the limestone of Miatschkovo near Moscow, are true *Fusulinæ* what becomes of the zoological distinction between the two types?

[1] 'Stat. Géologie d. Dép. de la Meuse,' 1852, p. 338; 'Atlas,' p. 47, pl. xxx, figs. 32—35.

[2] 'Neues Jahrb. für Min., Jahrg. 1872, p. 241, pls. vii and viii.

[3] 'Verhandl. Russ-Kaiserl. min. Gesellschaft, St. Petersburg,' Jahrg. 1847, p. 105.

[4] 'Geol. Beobacht. am Nil, auf der Sinai-Halbinsel u. in Syrien,' 1867, s. 82—84, Taf. 1, fig. 8.

NUMMULINA PRISTINA, *Brady*. Plate XI, figs. 8—11.

NUMMULINA PRISTINA, *Brady*, 1874. Ann. and Mag. Nat. Hist., ser. iv, vol. xiii, p. 225, pl. xii.

Characters.—Shell lenticular, obscurely radiate, with angular or more commonly blunt and rounded margin. Composed of three to four convolutions gradually increasing in width, the third convolution having about fifteen chambers. Primordial chamber of medium size. Diameter $\frac{1}{30}$ inch (0·85 mm.); thickness $\frac{1}{70}$ inch (0·36 mm.).

The brief zoological description of this little Nummulite above given represents the average characters of the comparatively few specimens that have hitherto been met with. In some particulars further information may be gained by the detailed examination of individual specimens.

The dimensions above given are those of one of the larger examples. Most of the specimens are bilaterally symmetrical or nearly so, white and smooth as to surface, the uniformity being broken only by radial lines more transparent in texture than the rest of the shell. A section on the median plane reveals a spiral of three or four convolutions, the whorls of nearly equal width or only increasing slightly towards the periphery, a primordial chamber relatively rather large, the ordinary chambers few in number for a Nummulite, and bounded by curved septa.

The relation between the diameter and thickness is apparently tolerably constant, that is, about as $2\frac{1}{4}$ to 1; larger examples, however, exhibit some tendency to spread out and grow thinner at the periphery. When the surface of the test is not worn, the radiation is either very indistinct or appears in the form of uneven, slightly curved lines of somewhat darker colour, but without sensible limbation; but in weathered specimens not only are the lines more or less elevated, but the centre from which they proceed is thickened and the test becomes to some extent umbonate also.

An accidentally split specimen (Pl. XI, fig. 9) will serve the purpose of a horizontal section. It consists of three convolutions, the outermost having sixteen chambers, and the second twelve or thirteen. Another somewhat larger individual has precisely similar septation, so that, without assigning any great importance to it, the drawing may be assumed to represent a specimen with about the normal number of chambers for the adult condition.

The primordial chamber has been measured in three examples, and the diameter found to be ·004, ·003, and ·0027 of an inch (0·1, 0·08, and 0·07 mm.), being respectively from $\frac{1}{7}$ to $\frac{1}{10}$ of the entire diameter of the test.

The minute tubulation of the shell is perfectly preserved, and may be easily seen in the transverse section under a magnifying power of 100 diameters, as in Pl. XI, fig. 10.

The canal-system of the septa and marginal cord may be traced here and there, though only imperfectly. The transverse section (fig. 10) gives distinct evidence of the existence of the marginal cord, but the details of the structure are obliterated; and in the more highly magnified drawing (fig. 11) indications are not wanting of canals traversing the septa as well as the supplementary skeleton.

Such is a detailed account, as far as can be furnished from the materials available, of the finer specimens of this Carboniferous Nummulite; and in the absence of larger individuals or of fragments indicating their existence, they may fairly be supposed to be adult and fully developed examples of the species. But, in addition to these, a number of smaller individuals have been found apparently belonging to the same form, though neither so uniform in external appearance nor so unmistakably Nummuline in character. One or two are somewhat explanate in their mode of growth, and if mature may pertain to an 'Assiline' variety. Others, smaller still, not much more than a hundredth of an inch in diameter, are unsymmetrical, the convexity of the two faces being unequal and irregular. They probably represent either one of the early stages of the organism or perhaps an arrested condition of growth. Their precise relation to the better developed form must be left for future determination, in the lack of sufficient specimens to work the question fully out.

Referring to D'Archiac and Haime's Monograph,[1] the figures most closely resembling *N. pristina* are those of *N. variolaria*, Sowerby, which represent a Nummulite of somewhat larger dimensions, but remarkably similar in general external characters and septation. Thus the nearest allies, zoologically speaking, of the Carboniferous form are the small thick members of the "radiate" group, regarded by Profs. Parker and Jones as the western modifications of *N. planulata*.[2] *N. variolaria* especially is a poor and variable form whose descent may be easily traced.

It is not a little singular that in the Carboniferous precursor of the Nummulitic group we should have an organism so exactly corresponding in minutest features with its most modern representatives. This cannot be a mere coincidence. Is it not rather a curious exemplification of persistence of essential characters through innumerable ages, whilst modifications of the original, forming collateral "species," have, under favourable circumstances, exhibited an extraordinary development in size and complexity of structure and a corresponding increase in geological importance? Then, as external conditions have become less favourable, little by little, the type has reverted to its primitive state, gradually dwindling in size, and losing by degrees those minor characters which were the easily recognised evidence of higher organization, and in its later history suggesting the lingering stages which precede complete extinction.

Distribution.—I can add nothing to what was stated in the paper containing the

[1] 'Descr. des Anim. foss. du groupe Nummulitique de l'Inde,' p. 146, pl. ix, figs. 13, *a*—*g*.

[2] See Messrs. Parker and Jones on the nomenclature of the genus, 'Ann. and Mag. Nat. Hist.,' 3 ser., vol. viii, p. 231.

original notice of *Nummulina pristina* concerning its distribution. The specimens were almost all found in marly calcareous shale from three distinct bands in a limestone quarry, ("*la Carrière du Fond d'Arquet*") near Namur, Belgium, pertaining geologically to the Calcaire de Namur. Doubtful specimens have been met with in a somewhat higher bed at Flémalle, near Liége, belonging to the Calcaire de Visé group.

POSTSCRIPT.

Receptaculites as a Carboniferous Foraminifer. — Mr. Lebour has drawn my attention to the fact that Prof. Suess has determined the existence of *Receptaculites oceani*, d'Eichwald, in company with *Productus fimbriatus*, Sowerby, and *Camarophoria Suessi*, Suess, in the middle member of the Dobschau beds (Hungary), a deposit generally recognised as of Carboniferous age (*vide* Lodin, 'Ann. des Mines,' sér. 7, t. vii, p. 388).

Mr. Carter's researches on Polytrema and its allies.—Whilst the present paper has been in the printer's hands an elaborate contribution to the history of an interesting group of parasitic Foraminifera has appeared in the 'Annals of Natural History' ("On the Polytremata [Foraminifera], especially with reference to their Mythical Hybrid Nature," by H. J. Carter, F.R.S., &c., 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. xvii, p. 185, pl. xiii). The observations therein recorded concerning the cancellated structure of *Polytrema*, as distinct from the labyrinthic developments of the test in the *Lituolida*, have considerable bearing on many of the Carboniferous species, and they have the important recommendation of being based upon the examination of recent specimens of considerable size. It appears from Mr. Carter's investigations that the fact of large sand grains being occasionally built into the test of *Stacheia polytrematoides* would not necessarily separate it from the genus *Polytrema*, but rather would indicate an affinity to that type. Space permits me to do no more than direct the attention of those interested in the subject to Mr. Carter's memoir. The difficulty in the case of the Carboniferous forms most affected by these researches depends, unfortunately, chiefly on the specimens themselves, their comparatively small size, and the changes they have undergone in the process of fossilization.

§ 9. DISTRIBUTION TABLES.

General Note.—The columns of the Distribution Tables are, as far as practicable, arranged in geological order, beginning at the lowest. In that referring to England and Wales it has been needful to divide the table into geographical groups, in the absence of data for correlating the beds of areas widely separated. The particulars as to geological position are such as have been furnished by correspondents together with the material collected from each locality. In some cases this information has been given with much more detail than in others, and it is possible that strict geological order may have been disturbed by defective information in one or two instances, but not to an extent to affect the general accuracy of the arrangement.

The Number at the head of each column refers to the paragraph bearing the corresponding number in the "Geological and Geographical" section, pp. 29 to 51.

The occurrence of each species is marked by a cross (×).

As already stated, the condition in which the minute fossils of the Carboniferous beds are found is often such as to render identification difficult. When much surface-corrosion has taken place the specimens have, as a rule, been thrown aside, but when it is present to an extent only sufficient to throw doubt on the determination of the exact species the occurrence is marked in the tables by a note of interrogation (?). In some columns referring to rocks either of subcrystalline texture (like the Calcaire de Namur in the Belgian Table), or containing iron-compounds the oxidation of which disintegrates calcareous shells, such entries are not unfrequent.

Table I. CARBONIFEROUS.—ENGLAND AND WALES.

		Northern Counties																				Midland Counties and North Wales						Bristol District						
		Ridsdale.	Skellygate, Ridsdale.	Colster Clough.	Kendal Limestone.	Gaythorn.	Fallowfields.	Harlaw Hill.	Brinkburn.	Forest Burn.	Elfhills Quarry.	Hallington.	Newbrough.	Quarries near Haydon Bridge.	Middlehope Burn.	Alston.	Newton-on-the-Moor.	Newton-on-the-Moor.	Langley.	Bollyhope.	Green Leighton.	Fourstones Quarry.	Ingoe.	Belsay.	Coquetdale.	Hurst, Swaledale.	Downholme, Swaledale.	Gressington Lead Mine.	Keld Head.	Gaping Gill, Clapham Cave.	Wyebourne.	Bakewell.	North Staffordshire.	Llan-y-Mynick.	Steeraway Mine.	Bangor.	Great Crme's Head.	Gt. Quarry, nr. "Longispinosa" Bed.	Bridge Valley Road.	Leigh Woods, Foraminifera Bed.	Leigh Woods, between Foram. Beds.	Opposite Point, Leigh Woods.	No. 2 Foraminifera Bed.	Backwell.
	No....	1	2	3	24	25	4	5	6	7	8	9	10	11	20	22	12	13	14	21	15	16	17	18	19	26	27	28	29	30	23	31	32	33	34	35	36	37	38	39	40	41	42	43
1	Saccammina Carteri, *Brady*	...	...	...	...	×	...	×	×	×	...	×	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	Lituola nautiloidea, *Lamarck*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	Haplophragmium rectum, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	Climacammina antiqua, *Brady*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...
5	Trochammina incerta (*d'Orbigny*)	×	×	×	...	...	×	...	...	...	×	...	...	...	...	×	×	×	...	...	...	×	×	×	×	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	— centrifuga, *Brady*	×	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	×	...	...	...	×	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	— anceps, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	— annularis, *nov.*	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	— gordialis, *Jones & Parker*	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	— filum (*Schmid*)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	Valvulina palæotrochus (*Ehrenb.*)	...	×	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	×	...	×	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...
12	— — *var.* compressa	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	— Youngi, *Brady*	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	— — *var.* coutraria	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	— decurrens, *Brady*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	×	×	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	— plicata, *Brady*	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	— rudis, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	Endothyra Bowmani, *Phillips*	...	×	×	×	...	×	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
19	— ammonoides, *Brady*	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	?	...	...	...	...	...	...	...	...	...
20	— globulus (*d'Eichwald*)	...	×	×	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	— crassa, *Brady*	...	×	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	— radiata, *Brady*	...	...	×	?	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	— macella, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	— ornata, *Brady*	...	×	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...
25	— — *var.* tenuis	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	— obliqua, *Brady*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	Nodosinella cylindrica, *nov.*	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...
28	— digitata, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	? ×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	— concinna, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	— lingulinoides, *nov.*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	Stacheia marginulinoides, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32	— fusiformis, *nov.*	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33	— pupoides, *nov.*	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34	— acervalis, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35	— congesta, *nov.*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	— polytremoides, *nov.*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37	Lagena Parkeriana, *nov.*	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38	— Howchiniana, *nov.*	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39	— Lebouriana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40	Textularia gibbosa, *d'Orbigny*	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	×	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
41	— eximia, *d'Eichwald*	...	×	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	×	...	...	...	...	...	...	...	...	×	×	...	...	×	×	...	...	...	...	...	...	...	...
42	Bigenerina patula, *nov.*	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
43	Archædiscus Karreri, *Brady*	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	...	...	...	...	...	...	...	...
44	Amphistegina minuta, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Ironstone Shale . . . . .
Bottom Limestone . . . .
Local Limestone, weathered
Horizon doubtful . . . .
Local Limestone, weathered
Scar.

Four-fathom Limestone . .
Roof of top coal . . . . .
Great Limestone . . . . .
Shale overlying Gt. Limest.
Little Limestone . . . . .
Top Limestone, Coquet . .
Yoredale, without more definite horizon . . . .
Yoredale.

Exact horizons not determined . . . . . .
Scar.

Middle Mountain Limestone
Upper Mountain Limestone
Up. Carboniferous Limestone Beds, (?) Yoredales.

Table II. CARBONIFEROUS.—SCOTLAND.

		Donkins' Quarry, Ecclefechan.	Boushawburnhead Quarry, ditto.	Cauldronlee Quarry, ditto.	Craigenglen, Campsie.	Abden, on shore E. of Kinghorn.	Glenwhapple Burn, Craigenglen.	Millburn, Campsie.	Braidwood.	Fulwood Old Quarry.	No. 16 Mine, Addiewell.	Baad's Mill, Harwood Burn.	Crichton Quarry, near Pathhead.	Middleton Quarry, Borthwick.		Fulwood Old Quarry.	Headsmuir Quarry, Fiddler's Burn.	South Shiells Farm Quarry.	Ponfeigh Burn.	Poniel Water at Brockley.	Whitfield Old Quarry.	Whitebanks Old Quarry.	Hillhead Quarry, nr. Cockmuir Bridge.	Invertiel Quarry, near Kirkcaldy.	Cowdens Quarry, N.W. of Dunfermline.	Braidwood.	Trearne and Dockra, near Beith.	Seafield.	On shore E. of Seafield Tower, Fife.	Galabraes Quarry, near Bathgate.	Sunnyside, Bathgate.
	No....	123	124	125	49	152	48	51	87	86	58	62	59	60	61	88	89	90	91	92	120	52	63	153	154	103	118	44	155	53	54
1	Saccammina Carteri, *Brady*......	×	...	...	...	...	...	...	×	...	×	×	×	×	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...
2	Lituola Bennieana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	Climacammina antiqua, *Brady*...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	...	...	...
4	Trochammina incerta (*d'Orbigny*	...	...	...	×	×	...	...	...	...	...	...	...	...	...	×	×	×	...	×	...	×	...	×	×	×	...	...	×	...	...
5	— centrifuga, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
6	— anceps, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	...	...
7	— annularis, *nov.* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	— gordialis, *P. & J.*.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...
9	— pusilla (*Geinitz*)...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...
10	— Robertsoni, *nov*....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	Valvulina palæotrochus, *Ehrenb.*	×	×	×	...	×	...	...	×	×	...	?	...	...	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
12	— — *var.* compressa	...	...	...	...	...	...	...	×	×	...	...	...	...	×	...	...	×	...	×	...	...	...	×	...	×	...	...	×	×	...
13	— Youngi, *Brady*.........	...	?	...	...	×	...	×	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	×	×	...	...	...	...	...	...
14	— — *var.* contraria	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...
15	— decurrens, *Brady*......	...	×	...	...	×	...	...	×	...	...	...	...	...	×	...	...	×	...	×	×	...	...	...	...	×	...	...	...	×	...
16	— plicata, *Brady*.........	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	...	...
17	— rudis, *nov*................	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	Endothyra Bowmani, *Phillips*...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	...	...	...
19	— ammonoides, *Brady* .	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...
20	— globulus(*d'Eichwald*)	...	×	?	...	×	...	...	×	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	×	?	...
21	— crassa, *Brady*	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	...	...	...	×	...	...	...
22	— radiata, *Brady*	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	×	...	×	...	...	...	...	...	...	...	...	...	...	...
23	— macella, *Brady*	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
24	— ornata, *Brady*.........	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...
25	— — *var.* tenuis ...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	— obliqua, *Brady*	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	— subtilissima, *nov.* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
28	Nodosinella concinna, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...
29	Stacheia marginulinoides, *nov*....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×	...	...	...	...	...	...
30	— fusiformis, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×	...	...	...	...	...	...
31	— pupoides, *nov*.............	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	×	...	...	...	×	...	...
32	— acervalis, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
33	— congesta, *nov.*	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...
34	— polytremoides, *nov*.......	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
35	Lagena Parkeriana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	— Howchiniana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37	Textularia gibbosa, *d'Orbigny*...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...
38	— eximia, *d'Eichwald* .	×	...	×	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	×	...	...	...
39	Bigenerina patula, *nov*............	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	...	...	...	...	...	...	...	...	...	...
40	Archædiscus Karreri, *Brady* ...	×	...	...	×	×	×	...	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	×	...	...	...	...	...
		Local Limestone (weathered)	Shale above Local Limestone		Shale below Main or Hurlet Limestone	Shale below No. 1 Limestone of Midlothian Series = Main or Hurlet Limestone	Ditto	Ditto (?)	Main Limestone		Addiewell Limestone (= Main Limestone)	Addiewell or Hurlet Limestone (ditto)	No. 1 Limestone, Midlothian (= ditto ?)		Shale between beds of No. 1 Limestone	Shales over Main Limestone					Shale above No. 1 Limestone			Ditto, Midlothian Series.	Shale above Linn Limestone (?= No. 1 Limestone of Midlothian Series)	Second Calmy Limestone (Carluke)	Exact position not determined	Shale below No. 2 Limestone (Midlothian)	Shale above Seafield Tower Sandstone	Shale below Bathgate Limestone (= No. 2 Limestone of Midlothian ?)	Bathgate Limestone (ditto)
		Cement Stone Group.			Lower Carboniferous Limestone Group.																										
		Lower Carboniferous or Calciferous Sandstone Series.			Carboniferous Limestone Series.																										
		CARBONIFEROUS.																													

		Fullarton Quarry.			Magazine Lime Works, near Pathhead.	Brunston Colliery.	Kidlaw, near Gifford.	Dunbar.	Mount Lothian Quarry.		Currielee, near Gorebridge.	Bents' Quarry, near Carlops.	Cousland Quarry, near Dalkeith.	Blinkbonny Quarry.	Carlops Quarry.	Brunston Colliery.	Salton Lime Works.	East Salton Quarry.	Murrayfield Pit.	Burlage Quarry.	East Barns Quarry.	Spilmersford Quarry, near Salton Hall.	Lampland Quarry, near Pathhead.	Glenniston Quarry.	Sunnybank Quarry.	Charleston Quarry.	Roscobie Quarry, near Dumfermline.	Corrieburn, near Kilsyth.	Hillhead Farm Quarry.	Head of Mouse Water.	Hairmyres.
	No....	64	65	66	67	68	78	79	69	70	71	121	73	74	122	72	80	81	55	82	83	156	157	45	46	47	158	50	93	94	101
1	Saccammina Carteri, *Brady*......	×	...	×	×	×	×	×	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	Lituola Bennieana, *nov*............	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	Climacammina antiqua, *Brady*.	...	...	...	...	...	...	...	...	×	...	?	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	Trochammina incerta (*d'Orbigny*)	...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	×	×	×	×	×	×	×	×	×	×	...	...	...	×
5	— centrifuga, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	— anceps, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×	...	...	...	...	...	...	...
7	— annularis, *nov.* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	— gordialis, *P. & J.*	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	— pusilla (*Geinitz*)...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	— Robertsoni, *nov*....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	Valvulina palæotrochus, *Ehrenb.*	...	×	...	...	...	...	...	×	×	...	×	×	...	×	×	×	×	...	...	...		...	...	...	×	×	×	×	...	×
12	— — *var.* compressa	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	×	×	...	...	...	...
13	— Youngi, *Brady*.........	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...
14	— — *var.* contraria	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...
15	— decurrens, *Brady*......	...	×	...	...	...	...	...	...	...	...	...	×	×	×	...	...	×	...	...	..	...	...	...	...	...	...	...	...	...	...
16	— plicata, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×
17	— rudis, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	Endothyra Bowmani, *Phillips*...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×
19	— ammonoides, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	— globulus (*d'Eichwald*)	...	×	...	...	...	...	...	...	×	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×
21	— crassa, *Brady*	...	...	...	...	...	...	...	...	?	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	— radiata, *Brady*	...	×	...	...	...	...	...	×	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
23	— macella, *Brady*	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	— ornata, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	— — *var.* tenuis...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?
26	— obliqua, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	— subtilissima, *nov*......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	Nodosinella concinna, *nov*.........	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	Stacheia marginulinoides, *nov*....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	— fusiformis, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
31	— pupoidea, *nov*.............	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	×
32	— acervalis, *Brady*.........	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
33	— congesta, *nov.*...........	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34	— polytremoides, *nov*.......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
35	Lagena Parkeriana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	— Howchiniana, *nov*.........	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37	Textularia gibbosa, *d'Orbigny* ...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38	— eximia, *d'Eichwald* ...	...	×	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39	Bigenerina patula, *nov*............	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40	Archædiscus Karreri, *Brady* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
		No. 2 Limestone (Midlothian Series)	Ditto (lower layer of shale *in situ*)	Ditto (upper layer of shale *in situ*)	Ditto				Ditto (shale between the beds)		Ditto	Ditto (shale between the beds)	Shale above No. 2 Limestone (Midlothian Series)											Shale above No. 1 or No. 2 Limestone			Shale above No. 2 Limestone (Midlothian Series)	Shale connected with No. 2 Limestone	Shale over Hosie Limestone (= No. 2 Limestone of Midlothian Series?)		Shale over Birkfield Calmy Limestone

Lower Carboniferous Limestone Group.

Carboniferous Limestone Series.

CARBONIFEROUS.

		Mouse Water, opposite Lambcatch.	Capelrig and Brankumball Old Quarries.			Old Quarry on Calderside Ground.	Auchentibber, Broomhouse, & Newfield Q	Boghead Farm Quarry.	Old Quarry, Limekilns House.	Climpy Quarry.	Auchenbeg Old Quarry.	Orchard, near Pollackshaws.	Burn behind Gillfoot House.	Belstonburn.	Prestongrange, near Prestonpans.	Dykeneuk Old Quarry.	Whitehouse Old Quarry.	Woodhill Old Quarry.	Barmulloch Old Quarry.	Robroyston House Old Quarry.	Westerhouse Old Quarry.	Gair Old Quarry.	Limekilnburn Quarry.	Craigburn, above Turnpike Rd. Douglas.	Kennox Water, above Kennox House, do.	Old Q. on County Boundary, nr. Climpy.	Levenseat Limestone Pit.	Levenseat Quarry.	Meikle Earnock.	Kinneil Mill, Avon River.	Garple Burn, near Muirkirk.
	No. ...	102	95	96	96	97	98	99	100	104	105	85	115	116	84	56	75	109	110	111	106	107	108	112	113	114	76	77	117	57	119
1	Saccammina Carteri, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...
2	Lituola Bennieana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...
3	Climacammina antiqua, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
4	Trochammina incerta (*d'Orbigny*)	...	×	×	×	×	×	×	×	...	...	×	×	×	...	...	×	...	×	...	×	×	×	...	...	...	...	...	×	...	×
5	— centrifuga, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...	×	×	×	...	...	...	...	...	...	...	...
6	— anceps, *nov.*	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	— annularis, *nov.*	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	— gordialis, *P. & J.*	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	— pusilla (*Geinitz*)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
10	— Robertsoni, *nov.*	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	×	...	×	×	...	...	...	...	...	...	...	...	...
11	Valvulina palæotrochus, *Ehrenb.*	×	×	...	...	...	...	...	×	×	...	×	...	×	...	×	×	...	×	×	×	×	...	...	...	×	×	×	×	...	×
12	— — *var.* compressa	...	...	...	...	...	...	...	...	...	×	...	...	×	...	...	×	...	...	...	...	×	...	...	...	...	...	...	...	...	...
13	— Youngi, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	— — *var.* contraria	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	— decurrens, *Brady*	...	×	...	...	...	...	...	...	...	×	...	×	×	...	×	...	×	×	...	×	×	...	...	...	...	...	×	...	...	...
16	— plicata, *Brady*	...	×	...	×	×	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
17	— rudis, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	Endothyra Bowmani, *Phillips*	...	×	×	...	×	...	...	...	×	...	...	...	×	×	...	×	...	...	...	...	×	...	...	×	...	...	...	...	×	×
19	— ammonoides, *Brady*	...	×	...	...	×	...	×	...	...	...	×	×	×	...	...	×	...	×	...	×	×	...	...	...	...	...	...	×	?	×
20	— globulus (*d'Eichwald*)	...	×	×	?	×	×	...	...	...	...	...	×	×	×	...	×	...	...	...	×	×	...	...	×	...	...	...	...	×	...
21	— crassa, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	— radiata, *Brady*	...	...	...	...	...	...	...	...	×	...	×	×	×	×	...	×	...	×	...	×	×	...	...	×	...	...	...	...	...	×
23	— macella, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	— ornata, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	— — *var.* tenuis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
26	— obliqua, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	— subtilissima, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	Nodosinella concinna, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	Stacheia marginulinoides, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	— fusiformis, *nov.*	...	×	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	— pupoides, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
32	— acervalis, *Brady*	...	?	?	?	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
33	— congesta, *nov.*	×	×	...	...	...	...	...	...	...	...	...	...	×	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34	— polytremoides, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
35	Lagena Parkeriana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	— Howchiniana, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
37	Textularia gibbosa, *d'Orbigny*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
38	— eximia, *d'Eichwald*	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
39	Bigenerina patula, *nov.*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
40	Archædiscus Karreri, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
		Shales of the Kinshaw Limestone Series (?)	Coralline band over No. 1 Limestone (Calderwood Series)	Shales over No. 1 Limestone of the Calderwood Series (East Kilbride)					Shale over No. 3 Limestone (Calderwood Series)	Cowglen or Index Limestone	Shales over the Seven-foot Limestone (Lesmahagow)	Gillfoot or Belstonburn Limestone	Shale over Belston Burn Limestone	Exact horizon uncertain	Shale above No. 5 Limestone (Midlothian Series) = Gair Limestone	Shale above Dykeneuk Limestone (ditto)	Shale above Gair Limestone										Levenseat Limestone	Ditto (shale bands between the beds)	Shale over Upper Limestones, of doubtful position		
		Lower Carbon. Limestone Gr.								Upper Carboniferous Limestone Group.																					
		Carboniferous Limestone Series.																													
		CARBONIFEROUS.																													

Table III. CARBONIFEROUS.—IRELAND.

	Castle Espie.	Bundoran.
No....	126	127
Valvulina palæotrochus (*Ehrb.*)	×	×
— *var.* compressa	×	
decurrens, *Brady*	×	
Endothyra Bowmani, *Phillips*	...	×
macella, *Brady*	×	
ornata, *Brady*	×	
— *var.* tenuis	×	
obliqua, *Brady*	×	
Nodosinella lingulinoides, *nov.*	×	

Table IV. CARBONIFEROUS.—BELGIUM.

	Carrière du Fond d'Arquet.	Do. 2me couche inférieure.	Flémalle, près Liége.	Calcaire de Visé.
No....	128	129	130	131
Saccammina Carteri, *Brady*	...	...	...	×
Lituola Bennieana, *nov.*	...	...	×	
Trochammina gordialis, *Jones and Parker*	...	...	×	
Valvulina palæotrochus (*Ehrenb.*)	...	×	...	×
bulloides, *nov.*	×			
Endothyra globulus (*d'Eichwald*)	×	×	×	
crassa, *Brady*	...	...	...	×
radiata, *Brady*	?			
subtilissima, *nov.*	...	?		
Nodosinella digitata, *nov.*	?			
lingulinoides, *nov.*	?			
Textularia gibbosa, *d'Orbigny*	...	...	...	×
Truncatulina carbonifera, *nov.*	...	×		
Boueana, *d'Orbigny*	...	×		
Pulvinulina Broeckiana, *nov.*	...	×		
Calcarina ambigua, *nov.*	...	×		
Nummulina pristina, *nov.*	×	×		

Table V. CARBONIFEROUS.—RUSSIA AND THE CAUCASUS.

	Mätschkovo.	Ostaschkovo.	Zærew Kurgan.	Witegra.	Toula.	Sloboda.	Caucasus.
No....	132	133	134	135	136	137	138
Lituola Bennieana, *nov.*	×						
Climacammina antiqua, *Brady*	...	...	?				
Trochammina incerta (*d'Orbigny*)	...	...	...	...	...	...	×
Valvulina palæotrochus (*Ehrenb.*)	×	×	×	×	×	...	?
bulloides, *nov.*	×						
rudis, *nov.*	?						
Endothyra Bowmani, *Phillips*	...	...	...	...	...	...	×
globulus (*d'Eichwald*)	...	...	...	...	...	×	
Textularia gibbosa, *d'Orbigny*	...	...	...	...	×	×	
eximia, *d'Eichwald*	...	...	×				
Bigenerina patula, *nov.*	...	...	×				
*Cristellaria mysteriosa, *Ehrenb.*	...	...	...	...	×		
*Rotalia antiqua, *Ehrenberg*	...	...	...	...	×		
†Nonionina rotula, *d'Eichwald*	...	...	...	...	...	×	

* *Fide* Ehrenberg. † *Fide* d'Eichwald.

Table VI. CARBONIFEROUS.—NORTH AMERICA.

	Southern Iowa.	Mouth of Platte River.	Southern Indiana.	Windsor, Nova Scotia.
No....	139	140	141	142
Valvulina palæotrochus (*Ehrb.*)	×	×		
decurrens, *Brady*	×	×		
plicata, *Brady*	×			
bulloides, *nov.*	×	?		
rudis, *nov.*	×			
Endothyra Bowmani, *Phillips*	...	...	×	
Nodosinella priscilla, *Dawson*	...	...	...	×
Calcarina ambigua, *nov.*	?			

TABLE VII. PERMIAN.—ENGLAND, IRELAND, GERMANY.

	Thuringia.	Durham.	Yorkshire.	Thuringia.	Selters in Wetterau.	Durham.	Thuringia.	Durham.	Co. Tyrone, Ireland.
No....	148	143	144	149	150	145	151	146	147
Trochammina incerta (*d'Orbigny*)	...	×	...	...	×	×			
gordialis, *Jones & Parker*	...	...	...	...	...	×			
pusilla (*Geinitz*)	×	×	×	×	...	×	×	...	×
milioloides, *P., J., & K.*	...	...	×	...	...	×			
filum (*Schmid*)	...	...	...	...	×				
Nodosinella digitata, *nov.*	...	...	...	...	...	×			
Nodosaria radicula (*Linné*)	×	...	...	×	...	..	×	×	
Subvarietal forms — *Dr. Richter*: N. Kingi	×	...	...	×					
Subvarietal forms — *Dr. Richter*: N. Kirkbyi	×	...	...	×	×				
Subvarietal forms — *Dr. Richter*: N. Jonesi	×	...	...	×					
Subvarietal forms — *Dr. Schmid*: N. conferta	...	...	...	...	×				
Subvarietal forms — *Dr. Schmid*: N. ovalis	...	...	...	...	×				
Subvarietal forms — *Dr. Schmid*: N. citriformis	...	...	...	...	×				
Dentalina communis, *d'Orbigny*	×	...	...	×	×	...	...	×	
multicostata, *d'Orbigny*	...	...	...	...	...	...	...	×	
Textularia triticum, *Jones*	×	...	...	×	...	...	×	×	
Jonesi, *Brady*	×	×	...	×	...	...	×	×	
multilocularis, *Reuss*	×	...	...	×					
	Kupferschiefer	Lower Magnesian Limestone		Zechstein proper		Middle Magnesian Limestone	Dolomite	Upper Magnesian Limestone	
	Lower.					Middle.		Upper.	
	Permian.								

TABLE VIII. GENERAL SUMMARY OF DISTRIBUTION OF CARBONIFEROUS AND PERMIAN FORAMINIFERA.

	Carboniferous.													Permian.					
	England and Wales.		Scotland.			Ireland.	Belgium.		Russia, &c.		North America.			England.			Ireland.	Germany.	
SACCAMMINA, *Sars.*																			
Carteri, *Brady*	×	×	×	×	×	...	...	×											
LITUOLA, *Lamarck.*																			
nautiloidea, *Lamarck*	×																		
Beunicana, *nov.*	...	...	...	×	?	...	×	...	×										
HAPLOPHRAGMIUM, *Reuss.*																			
rectum, *Brady*	...	×																	
CLIMACAMMINA, *Brady.*																			
antiqua, *Brady*	×	×	...	×	×	...	...	...	?										
TROCHAMMINA, *Parker & Jones.*																			
incerta (*d'Orbigny*)	×	×	...	×	×	...	...	...	...	×	...	...	...	×	×	...	...	...	×
centrifuga, *Brady*	×	×	...	×	×														
anceps, *nov.*	...	×	...	×															
annularis, *nov.*	...	×	...	×															
gordialis, *Jones & Parker*	...	×	...	×	...	...	×	...	...	...	...	...	...	...	×				
pusilla (*Geinitz*)	...	...	...	×	×	...	...	...	...	...	...	...	...	...	×	...	×	×	×
milioloides, *P., J., & K.*	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×				
Robertsoni, *nov.*	...	...	...	...	×														
filum (*Schmid*)	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	
VALVULINA, *d'Orbigny.*																			
palæotrochus (*Ehrenb.*)	×	×	×	×	×	×	×	×	×	?	...	×							
—— *var.* compressa	×	×	...	×	×	×													
Youngi, *Brady*	×	...	?	×															
—— *var.* contraria	...	×	...	×															
decurrens, *Brady*	×	×	×	×	×	×	...	...	...	...	...	×							
plicata, *Brady*	×	×	...	×	×	...	...	...	...	...	...	×							
bulloides, *nov.*	...	...	...	...	...	...	×	...	×	...	...	×							
rudis, *nov.*	...	×	...	×	...	...	...	...	?	...	...	×							
ENDOTHYRA, *Phillips.*																			
Bowmani, *Phillips*	×	×	...	×	×	×	...	...	...	×	×								
ammonoides, *Brady*	×	×	...	×	×														
globulus (*d'Eichwald*)	×	×	×	×	×	...	×	...	×										
crassa, *Brady*	×	...	...	×	...	...	...	×	×										
radiata, *Brady*	×	×	...	×	×	...	?												
macella, *Brady*	...	×	...	×	...	×													
ornata, *Brady*	×	×	...	...		×													
—— *var.* tenuis	×	×	×	...	×	×													
obliqua, *Brady*	×	×	×	...	...	×													
subtilissima, *nov.*	...	...	...	×	...	...	?												
NODOSINELLA, *gen. nov.*																			
digitata, *nov.*	...	×	...	...	...	...	?	...	...	...	...	...	...	...	×				
cylindrica, *nov.*	×	×																	
priscilla (*Dawson*)	...	...	...	...	...	...	...	...	...	...	...	...	×						
concinna, *nov.*	...	×	...	...	×														
lingulinoides, *nov.*	×	×	...	...	...	×	?												
	Lower Limestones (Scar)	Upper Limestones (Yoredales)	Calciferous Sandstone Series	Lower Carboniferous Limestone	Upper Carboniferous Limestone	Lower Limestones	Upper Limestones (Calcaire de Namur)	Upper Limestones (Calcaire de Visé)	Fusulina Limestones	Fusulina Limestones (Caucasus)	Subcarboniferous (United States)	Upper Coal Measures (United States)	Nova Scotia	Lower Magnesian Limestone	Middle Magnesian Limestone	Upper Magnesian Limestone		Kupferschiefer	Zechstein proper	Middle Zechstein (Dolomite)

TABLE VIII (*continued*).

	Carboniferous.														Permian.					
	England and Wales.		Scotland.			Ireland.	Belgium.		Russia, &c.		North America.				England.			Ireland.	Germany.		
	Lower Limestones (Scar)	Upper Limestones (Yoredales)	Calciferous Sandstone Series	Lower Carboniferous Limestone	Upper Carboniferous Limestone	Lower Limestones	Upper Limestones (Calcaire de Namur)	Upper Limestones Calcaire de Visé)	Fusilina Limestones	Fusilina Limestones (Caucasus)	Subcarboniferous (United States)	Upper Coal Measures (United States)	Nova Scotia		Lower Magnesian Limestone	Middle Magnesian Limestone	Upper Magnesian Limestone	Upper Magnesian Limestone	Kupferschiefer	Zechstein proper	Middle Zechstein (Dolomite)
STACHEIA, *gen. nov.*																					
marginulinoides, *nov.*	...	×	...	×	×																
fusiformis, *nov.*	×	×	...	×																	
pupoides, *nov.*	×	×	...	×																	
acervalis, *Brady*	...	×	...	×	×																
congesta, *nov.*	×	×	...	×	×																
polytrematoides, *nov.*	×	×	...	×	×																
LAGENA, *Walker & Jacob.*																					
Parkeriana, *nov.*	...	×	...	...	×																
Howchiniana, *nov.*	×	×	...	...	×																
Lebouriana, *nov.*	...	×																			
NODOSARIA, *Lamarck.*																					
radicula (*Linné*)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	×
DENTALINA, *d'Orbigny.*																					
communis, *d'Orbigny*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	
multicostata, *d'Orbigny*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...			
TEXTULARIA, *Defrance.*																					
gibbosa, *d'Orbigny*	×	×	...	×	...	...	...	×	×												
eximia, *d'Eichwald*	×	×	×	×	?	...	...	...	×												
Jonesi, *Brady*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...			
triticum, *Jones*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...			
multilocularis, *Reuss*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	×	×
BIGENERINA, *d'Orbigny.*																					
patula, *nov.*	...	×	...	×	...	...	...	...	×												
TRUNCATULINA, *d'Orbigny.*																					
carbonifera, *nov.*	...	...	...	...	...	...	×														
Boueana, *d'Orbigny*	...	...	...	...	...	...	×														
PULVINULINA, *Parker & Jones.*																					
Broeckiana, *nov.*	...	...	...	...	...	...	×														
CALCARINA, *d'Orbigny.*																					
ambigua, *nov.*	...	...	...	...	...	...	×	...	...	...	...	?									
ARCHÆDISCUS, *Brady.*																					
Karreri, *Brady*	×	×	×	×	×																
AMPHISTEGINA, *d'Orbigny.*																					
minuta, *nov.*	...	×																			
NUMMULINA, *d'Orbigny.*																					
pristina, *Brady*	...	...	...	...	...	...	×														

INDEX.

*** *The Synonyms are printed in Italics.*

PLATE I.

Figs. 1—7. SACCAMMINA CARTERI, *Brady*. (Page 57.)

Fig. 1. A piece of Saccammina-limestone from Elfhills, Northumberland, natural size. The upper portion of the figure shows a weathered surface, the lower a fresh fracture. The white spots on the latter indicate the tufts of crystals which often occupy the interior of the chambers.

Figs. 2, 3. Detached segments. Natural size.

Fig. 4. Polished section of fossil Molluscan Shell found by Mr. F. M. Balfour on the coast about two miles and a half east of Dunbar. The interior contains a string of segments of *Saccammina* lying *in sitû*. Natural size.

Fig. 5. A broken segment, showing the labyrinthic structure of the inner surface of the test, and the crystalline calcareous mass occupying the interior. Magnified 15 diameters.

Fig. 6. Tangential section of the test exhibiting the arenaceous structure, both of the compact exterior and of the looser labyrinthic portions. × 70 diam.

Fig. 7. One of the scars, formed of a series of concentric rings, frequently seen on the exterior of the segments. × 30 diam.

Figs. 8—11. LITUOLA BENNIEANA, *nov.* (Page 64.)

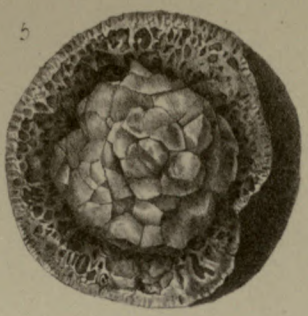
Figs. 8, 9. Lateral and periphero-lateral aspects. The small dark spots having somewhat the appearance of perforations are embedded sand-grains of nearly uniform size. The irregular depressions on the face of the large terminal chamber, in fig. 9, probably represent the position and form of the pores constituting the general orifice. × 20 diam.

Fig. 10. Cast of the interior of a smaller specimen. × 30 diam.

Fig. 11. Transparent section of a small portion of the test, highly magnified, illustrating the composite, arenaceous structure of the wall, and the labyrinthic interior. × 100 diam.

Plate 1.


1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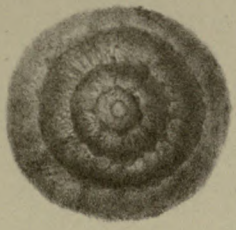
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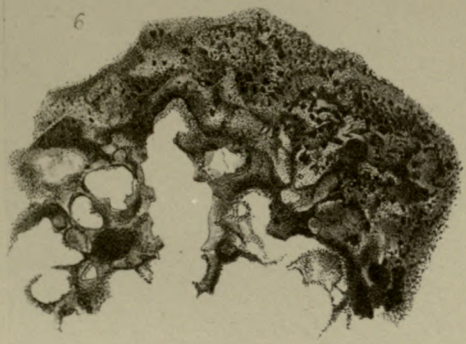
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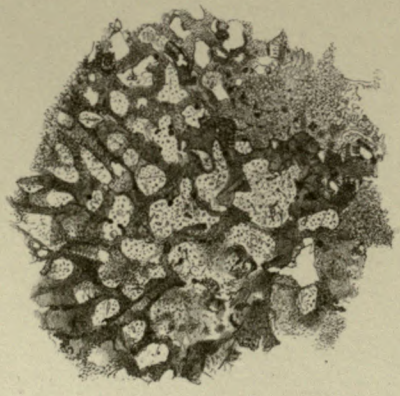
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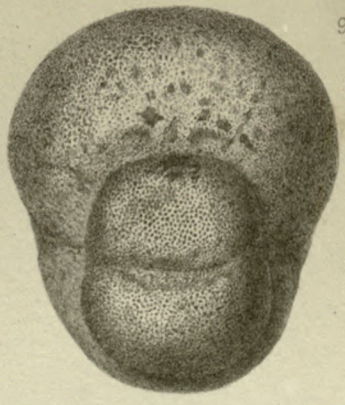
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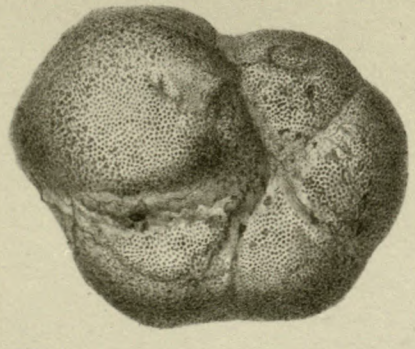
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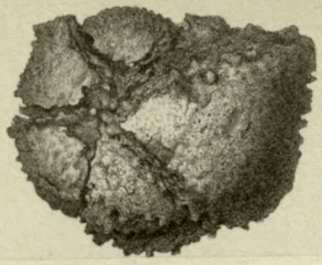
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HB Brady and A T Hollick. del.

Hollick lith Hanhart imp

CARBONIFEROUS FORAMINIFERA.

PLATE II.

Figs. 1—9. CLIMACAMMINA ANTIQUA, *Brady*. (Page 68.)

Figs. 1—5. Specimens illustrating general external characters, septation, apertures, &c. Magnified 30 diameters.

Figs. 6, 7. Casts of terminal chambers of small cylindrical specimens with their general apertures. × 30 diam.

Fig. 8. Transparent longitudinal section, showing apertures, septa, and general structure. × 30 diam.

Fig. 9. Portion of the same section, more highly magnified, to show the arenaceous structure of the test and the partial filling of the chambers with cancellated labyrinthic ingrowths. × 200 diam.

Figs. 10—14. TROCHAMMINA INCERTA (*d'Orbigny*). (Page 71.)

Figs. 10, *a*, *b*. Lateral and periphero-lateral aspects. × 60 diam.

Figs. 11, *a*, *b*. „ „ × 50 diam.

Figs. 12, 13. Lateral aspect. × 50 diam.

Fig. 14. Transparent section of test highly magnified, showing its very finely sub-arenaceous structure. × 200 diam.

Figs. 15—20. TROCHAMMINA CENTRIFUGA, *Brady*. (Page 74.)

Figs. 15—18. Lateral aspect, illustrating range of variation in general external features. × 70 diam.

Fig. 19. Periphero-lateral aspect. × 70 diam.

Fig. 20. Transparent horizontal section, showing the simple tubular character of the test and the absence of any true septa. × 70 diam.

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CARBONIFEROUS FORAMINIFERA.

PLATE III.

Figs. 1—3. TROCHAMMINA GORDIALIS, *Jones and Parker*. (Page 77.)
Figs. 1, 2. From Carboniferous specimens. Magnified 100 diameters.
Fig. 3. „ „ × 50 diam.

Figs. 4, 5. TROCHAMMINA PUSILLA (*Geinitz*). (Page 78.)
Fig. 4. From a Carboniferous specimen. × 50 diam.
Fig. 5. From a Permian specimen, after Kirkby. × 20 diam.

Figs. 6, 7. TROCHAMMINA ROBERTSONI, *nov.* (Page 80.)
From Carboniferous specimens. × 100 diam.

Fig. 8. TROCHAMMINA ANCEPS, *nov.* (Page 76.)
a Lateral, *b* periphero-lateral aspect. From a Carboniferous specimen. × 70 diam.

Figs. 9, 10. TROCHAMMINA ANNULARIS, *nov.* (Page 76.)
Carboniferous specimens. × 100 diam.

Figs. 11—15. TROCHAMMINA MILIOLOIDES, *Jones, Parker, and Kirkby*. (Page 79.)
Figs. 11—13, lateral, 14, 15 periphero-lateral aspects. From Permian specimens; after Kirkby. × 20 diam.

Fig. 16. TROCHAMMINA FILUM (*Schmid*). (Page 81.)
Copied from Dr. Schmid's figure from a Zechstein (Permian) specimen. Magnifying power not stated.

Figs. 17, 18. VALVULINA DECURRENS, *Brady*. (Page 87.)
Fig. 17. *a* superior lateral, *b* periphero-lateral aspect.
Fig. 18. Superior aspect of a weathered and corroded specimen; the septa obliterated on the exposed surface. × 50 diam.

Figs. 19, 20. VALVULINA RUDIS, *nov.* (Page 90.)
Fig. 19. *a* superior, *b* peripheral, *c* inferior aspect. × 50 diam.
Fig. 20. Horizontal section, showing the subdivision of the interior into small, irregular, angular chamberlets. × 50 diam.

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CARBONIFEROUS and PERMIAN FORAMINIFERA

PLATE IV.

Figs. 1—4. VALVULINA PALÆOTROCHUS (*Ehrenberg*). (Page 83.)

Fig. 1, *a* superior, *b* peripheral, *c* inferior aspect. Magnified 45 diameters.

Fig. 2. Adherent specimen. × 45 diam.

Fig. 3. Transparent perpendicular section. × 40 diam.

Fig. 4. Horizontal section near the middle of the test. × 40 diam.

Fig. 5. VALVULINA PALÆOTROCHUS, var. COMPRESSA, *Brady*. (Page 85.)

a periphero-lateral, *b* inferior aspect. × 40 diam.

Figs. 6, 8, 9. VALVULINA YOUNGI, *Brady*. (Page 86.)

Fig. 6. *a* periphero-lateral, *b* superior aspect. × 45 diam.

Fig. 8. Perpendicular section, showing subdivision into chamberlets. × 40 diam.

Fig. 9. Horizontal section near the middle of the test. × 40 diam.

Fig. 7. VALVULINA YOUNGI, *var.* CONTRARIA, *Brady*. (Page 87.)

Fig. 7. *a* periphero-lateral, *b* inferior aspect. × 40 diam.

Figs. 10, 11. VALVULINA PLICATA, *Brady*. (Page 88.)

Fig. 10. *a* superior, *b* inferior, *c* peripheral aspect. × 70 diam.

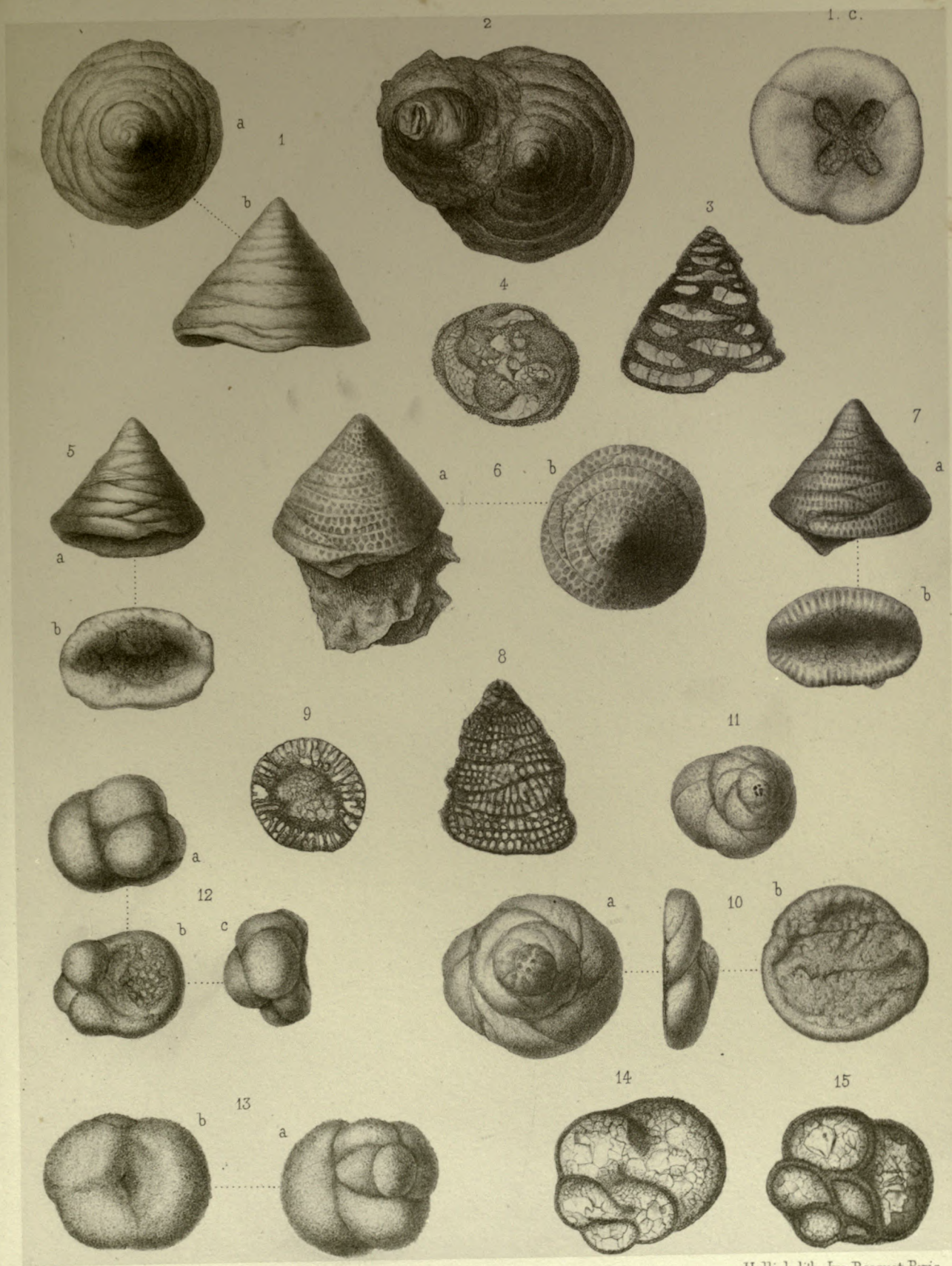
Fig. 11. Young specimen. × 70 diam.

Figs. 12—15. VALVULINA BULLOIDES, *nov.* (Page 89.)

Fig. 12. *a* superior, *b* inferior, *c* peripheral aspect. Specimen from the Upper Coal-measures of Iowa, U.S.A. × 50 diam.

Fig. 13. *a* superior, *b* inferior aspect. Specimens from the Calcaire de Namur, Belgium. × 100 diam.

Figs. 14, 15. Horizontal sections of American specimens. × 100 diam.



H.B.Brady and A.T.Hollick del.

Hollick lith. Imp.Becquet.Paris.

CARBONIFEROUS FORAMINIFERA.

PLATE V.

Figs. 1—4. ENDOTHYRA BOWMANI, *Phillips*. (Page 92.)

Figs. 1, 2 *a* lateral, 2 *b* periphero-lateral aspect. English Carboniferous specimens. Magnified 50 diameters.

Fig. 3. Subcarboniferous specimen from Southern Indiana. × 30 diam.

Fig. 4. Horizontal section. × 50 diam.

Figs. 5, 6. ENDOTHYRA AMMONOIDES, *Brady*. (Page 94.)

Fig. 5. *a* lateral, *b* periphero-lateral aspect. × 60 diam.

Fig. 6. Portion of horizontal section, from a photograph. × 100 diam.

Figs. 7—9. ENDOTHYRA GLOBULUS (*d'Eichwald*). (Page 95.)

Fig. 7. *a* lateral, *b* periphero-lateral aspect. × 50 diam.

Fig. 8. Young specimen. × 50 diam.

Fig. 9. Cast of interior of a large specimen. × 50 diam.

Figs. 10—12. ENDOTHYRA RADIATA, *Brady*. (Page 97.)

Figs. 10, 11 *a*, 12. Lateral aspect. 11 *b*. Periphero-lateral aspect. × 50 diam.

Figs. 13, 14. ENDOTHYRA MACELLA, *Brady*. (Page 98.)

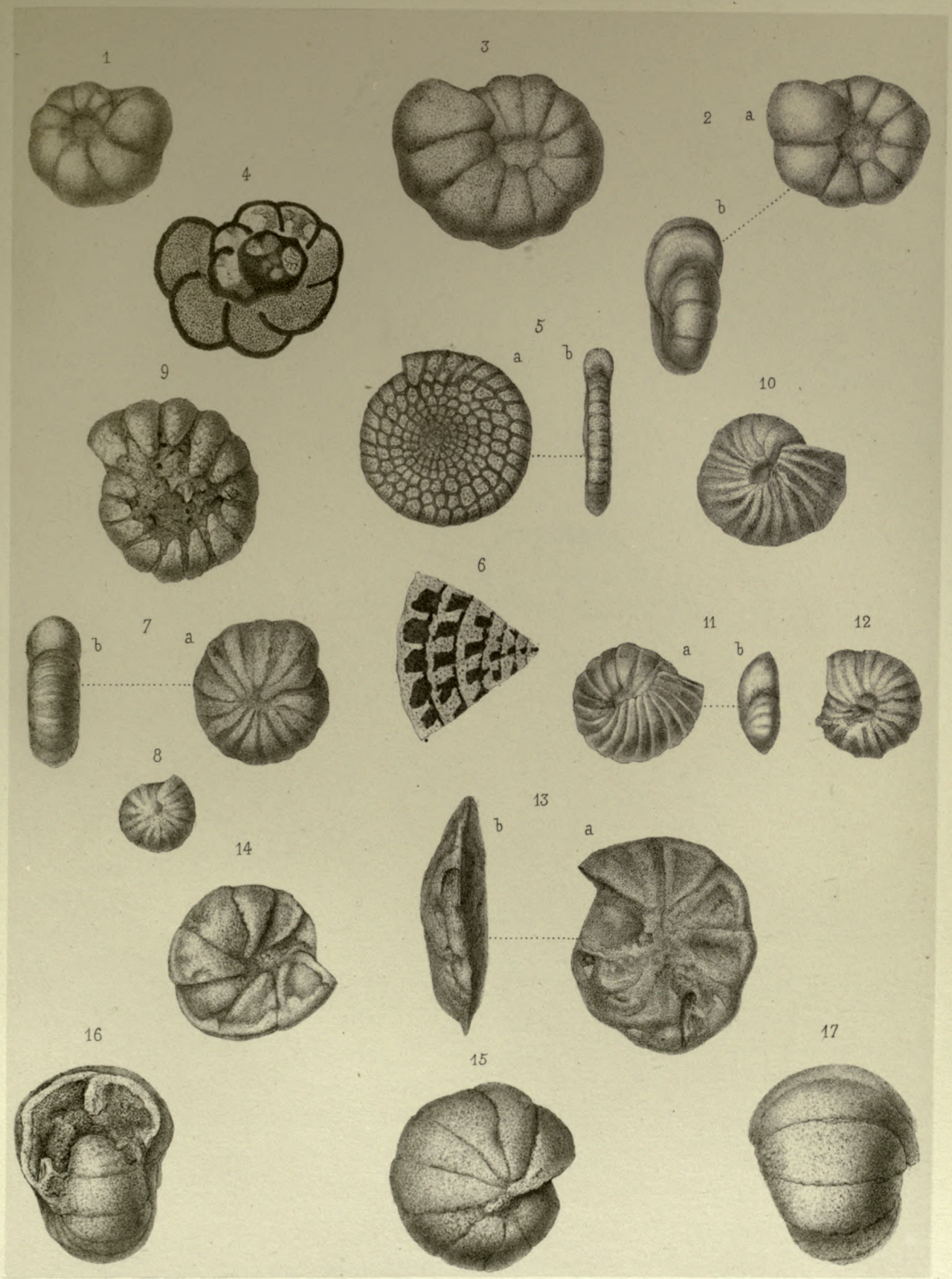
Fig. 13. *a* lateral, *b* periphero-lateral aspect. × 30 diam.

Fig. 14. Smaller specimen. × 50 diam.

Figs. 15—17. ENDOTHYRA CRASSA, *Brady*. (Page 97.)

Fig. 15. Lateral aspect.

Figs. 16, 17. Anterior and posterior peripheral aspects. The three drawings of this species are from different specimens. × 30 diam.



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CARBONIFEROUS FORAMINIFERA.

PLATE VI.

Figs. 1—4. ENDOTHYRA ORNATA, *Brady*. (Page 99.)

Fig. 1. *a* lateral, *b* periphero-lateral aspect. Magnified 50 diameters.

Fig. 2. Young specimen. × 50 diam.

Fig. 3. Horizontal section of a portion of a mature specimen. × 50 diam.

Fig. 4. Somewhat anomalous specimen probably of the same form. × 50 diam.

Figs. 5, 6. ENDOTHYRA OBLIQUA, *Brady*. (Page 100.)

Fig. 5. *a* anterior lateral, *b* periphero-lateral aspect. × 30 diam.

Fig. 6. Posterior lateral aspect. × 30 diam.

Figs. 7, 8. ENDOTHYRA ORNATA, var. TENUIS, *nov*. (Page 100.)

Fig. 7. *a* lateral, *b* periphero-lateral aspect. × 50 diam.

Fig. 8. Small irregular specimen. × 50 diam.

Fig. 9. ENDOTHYRA SUBTILISSIMA, *nov*. (Page 101.)

a lateral, *b* periphero-lateral aspect. × 70 diam.

Fig. 10. TRUNCATULINA CARBONIFERA, *nov*. (Page 138.)

a inferior lateral surface, *b* superior ditto. × 90 diam.

Fig. 11. TRUNCATULINA BOUEANA, *d'Orbigny*. (Page 139.)

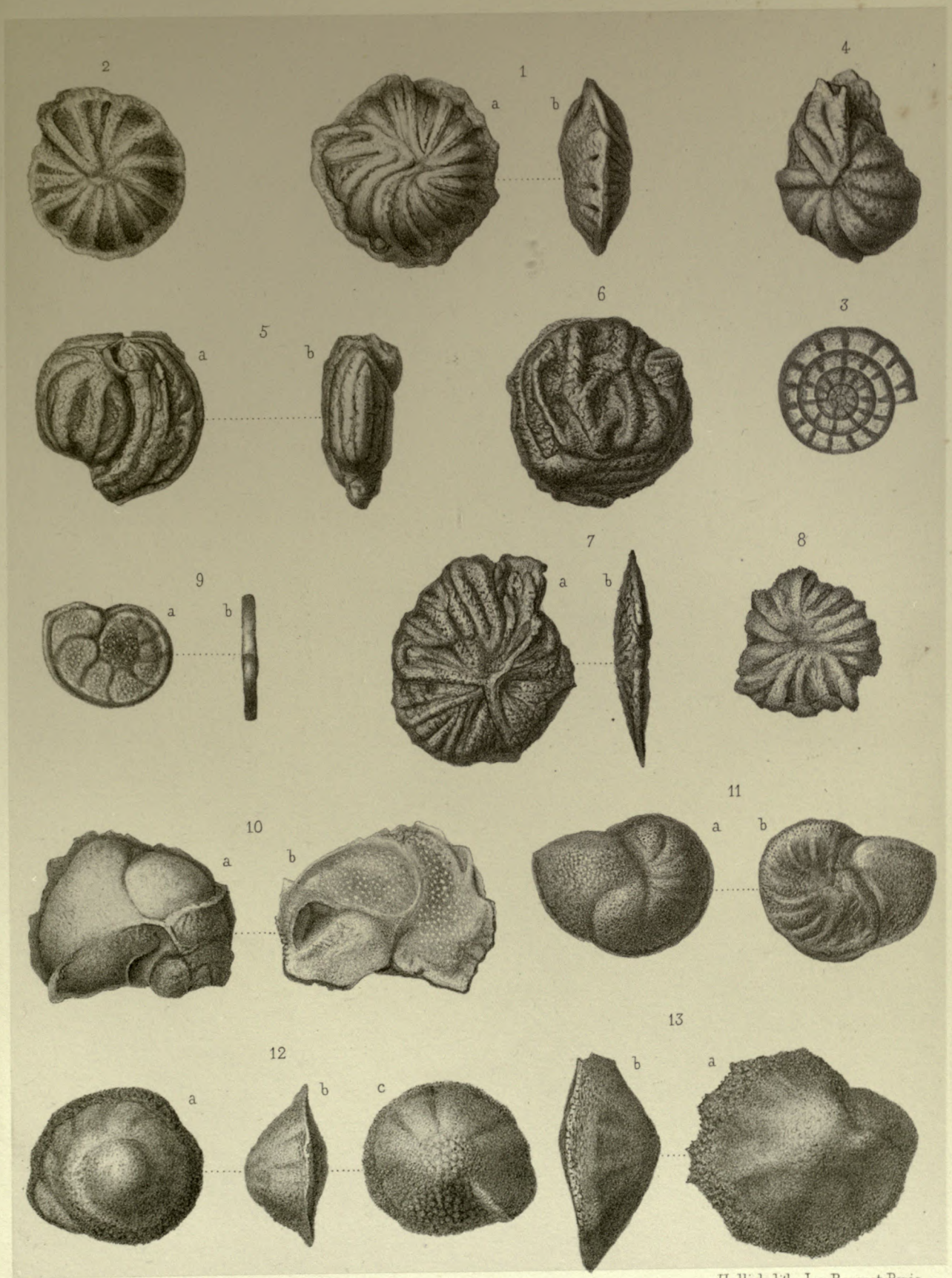
a inferior lateral surface, *b* superior ditto. × 100 diam.

Fig. 12. PULVINULINA BROECKIANA, *nov*. (Page 140.)

a superior lateral, *b* periphero-lateral, *c* inferior lateral aspect. × 50 diam.

Fig. 13. CALCARINA AMBIGUA, *nov*. (Page 141.)

a lateral, *b* periphero-lateral aspect. × 70 diam.



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CARBONIFEROUS FORAMINIFERA.

PLATE VII.

Figs. 1—3. NODOSINELLA DIGITATA, *nov.* (Page 103.)
Various Permian specimens—*a* lateral aspect, *b* end view. Magnified 30 diameters.

Figs. 4—7. NODOSINELLA CYLINDRICA, *nov.* (Page 104.)
Figs. 4—6. Various Carboniferous specimens. × 35 diam.
Fig. 7. Larger specimen partially broken, showing the labyrinthic structure of the test. × 30 diam.

Figs. 8, 9. NODOSINELLA PRISCILLA (*Dawson*). (Page 105.)
Figs. 8, 9. Copied from Dr. Dawson's figures of Canadian Carboniferous specimens, slightly enlarged. × 10 diam.
Fig. 10. Doubtful Permian specimen, perhaps more nearly allied to *N. digitata*. × 30 diam.

Figs. 11—15, NODOSINELLA CONCINNA, *nov.* (Page 106.)
Various forms from the Yoredale Rocks of Swaledale. × 50 diam.

Figs. 24, 25. NODOSINELLA LINGULINOIDES, *nov.* (Page 106.)
Lateral aspect. Carboniferous specimens. × 35 diam.

Figs. 16—21. STACHEIA MARGINULINOIDES, *nov.* (Page 112.)
a represents the lateral aspect, *b* the superior end-view in all the figures. Figs. 16—18, 20, 21. × 50 diam.—Fig. 19. × 35 diam. All Carboniferous specimens. The terminal segment of fig. 18 is entirely closed in, and the specimen presents no aperture at the superior end.
Fig. 21. Longitudinal section, showing the subdivision of the chambers.

Figs. 22, 23. Straight, compressed specimens, probably of the same species. × 50 diam. (Page 106.)

Plate VII.

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CARBONIFEROUS and PERMIAN FORAMINIFERA.

PLATE VIII.

Figs. 1—5. LAGENA PARKERIANA, *nov.* (Page 120.)

Figs. 1—4. Lateral aspect of various forms.

Fig. 5. End-view showing aperture. Magnified 50 diameters.

Fig. 6. LAGENA LEBOURIANA, *nov.* × 50 diam. (Page 121.)

Fig. 7. LITUOLA NAUTILOIDEA, *Lamarck.* (Page 63.)

a lateral aspect, *b* end-view showing the compound aperture. × 20 diam.

Figs. 8, 9. HAPLOPHRAGMIUM RECTUM, *Brady.* (Page 66.)

Fig. 8. *a* lateral aspect, *b* end-view showing the aperture. × 100 diam.

Fig. 9. Broken specimen. × 70 diam.

Figs. 10, 11. BIGENERINA PATULA, *nov.* (Page 136.)

Fig. 10. Lateral aspect. × 35 diam.

Fig. 11. Longitudinal section. × 30 diam. (See also Plate X, figs. 30, 31.)

Figs. 12—16. STACHEIA FUSIFORMIS, *nov.* (Page 114.)

Figs. 12, 13. Lateral aspect; fig. 14 end-view. × 50 diam.

Fig. 15. Longitudinal section. × 50 diam.

Fig. 16. A portion of the same further enlarged to show more clearly the subdivision of the interior. × 100 diam.

Figs. 17—27. STACHEIA PUPOIDES, *nov.* (Page 115.)

Fig. 17. A compressed variety apparently without central columnar support. × 35 diam.

Fig. 18. Longitudinal section of the same form. × 35 diam.

Fig. 19. A portion of the same further enlarged to show more clearly the interior structure. × 100 diam.

Figs. 20, 21, 23, 24, 25. Lateral aspects of various specimens of the typical form. × 50 diam.

Fig. 22. Adherent specimen. × 35 diam.

Figs. 26, 27. Longitudinal sections. × 50 diam.

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Hollick lith. Imp. Becquet, Paris.

CARBONIFEROUS FORAMINIFERA.

PLATE IX.

Figs. 1—5. STACHEIA CONGESTA, *nov.* (Pages 117, 110.)

Figs. 1—4. Lateral aspect, showing the general external characters.

Fig. 5. Transparent longitudinal section.

From Carboniferous specimens. All magnified 50 diameters.

Figs. 6—8. STACHEIA ACERVALIS, *Brady.* (Pages 116, 110.)

Carboniferous. × 40 diam.

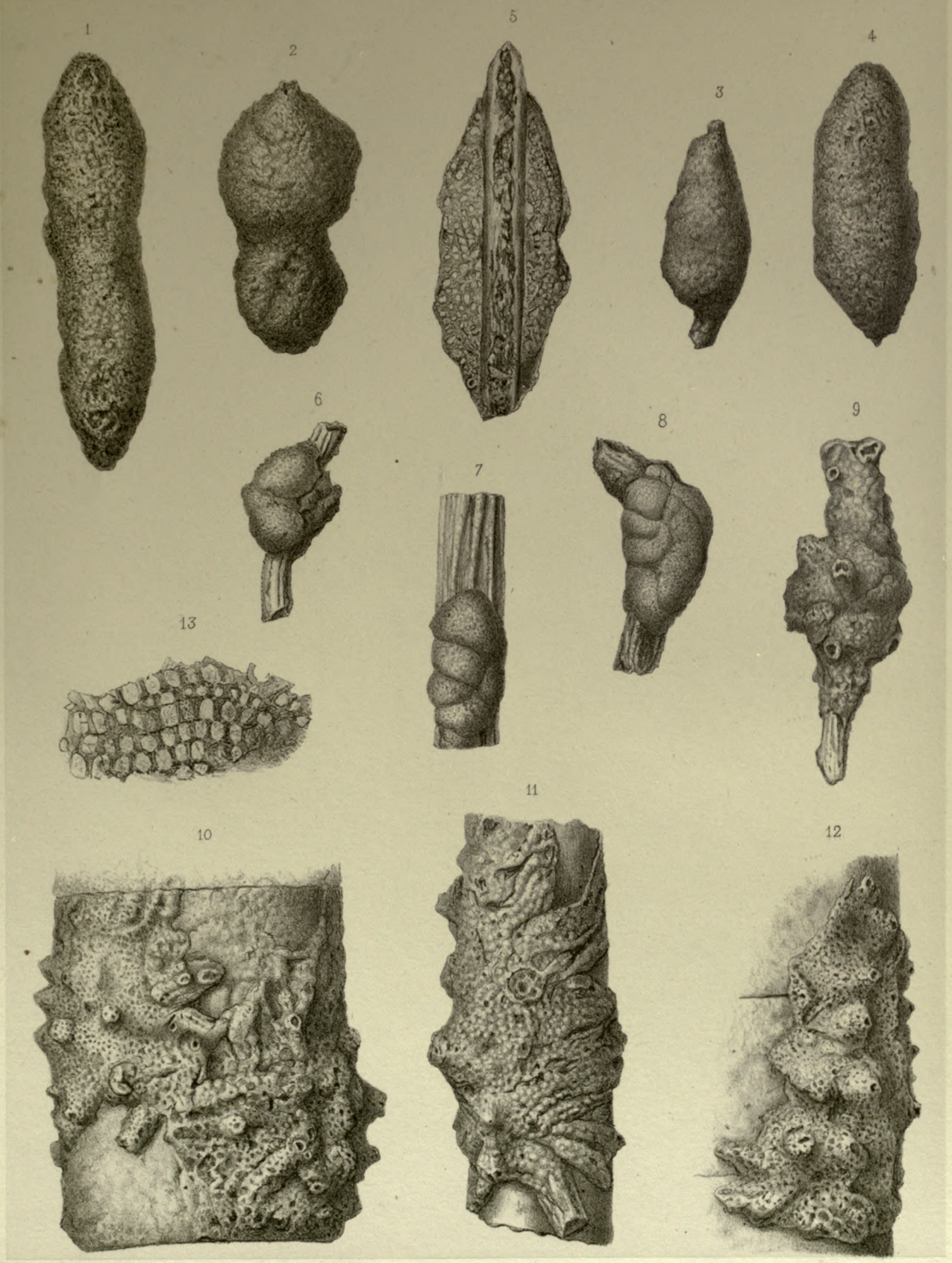
Figs. 9—13. STACHEIA POLYTREMATOIDES, *nov.* (Pages 118, 110.)

Fig. 9. Specimen growing round a fragment of a Polyzoon. × 30 diam.

Figs. 10—12. Specimens growing on the surface of Encrinites. × 20 diam.

Fig. 13. Transverse section showing the general structure and the arrangement of the chambers. × 70 diam.

Plate IX.



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CARBONIFEROUS FORAMINIFERA.

PLATE X.

Figs. 1—5. LAGENA HOWCHINIANA, *nov.* (Page 121.)

Figs. 1—3. Lateral aspect. Magnified 50 diameters.

Fig. 4. Double specimen. × 50 diam.

Fig. 5. Vertical section. × 50 diam.—All Carboniferous.

Figs. 6—16. NODOSARIA RADICULA (*Linné*), and its Permian varieties. (Page 124.)

Fig. 6. Typical form, after Reuss (*N. Geinitzi*, Rss.).

Figs. 7, 8. Typical form in matrix of weathered Magnesian Limestone. × 50 diam.

Fig. 9. Transparent longitudinal section of the same. × 50 diam.

Fig. 10. *Nodosaria Kirkbyi*, Richter, from an original drawing by Dr. R. Richter.

Fig. 11. — — copied from Geinitz's "Dyas." × 15 diam.

Fig. 12. — *Kingi*, Reuss, ditto. × 10 diam.

Fig. 13. — *Jonesi*, Richter, ditto. × 20 diam.

Fig. 14. — *conferta*, Schmid, copied from Dr. Schmid's figure.

Fig. 15. — *ovalis*, Schmid, ditto.

Fig. 16. — *citriformis*, Schmid, ditto.

Figs. 17, 18. DENTALINA COMMUNIS, *d'Orbigny*. (Page 127.)

Fig. 17. From Prof. T. Rupert Jones's figure in King's Monograph. × 30 diam.

Fig. 18. Specimen in the matrix after Dr. Schmid.

Permian and Zechstein specimens.

Figs. 19. DENTALINA MULTICOSTATA, *d'Orbigny*. (Page 129.)

After Jones, in King's Monograph. Permian. × 30 diam.

Figs. 20—22. TEXTULARIA JONESI, *Brady*. (Page 133.)

Fig. 20. Specimen from the Permian at Summerhouse, Durham. × 50 diam.

Figs. 21, 22. From original drawings by Dr. R. Richter, from Middle Zechstein specimens. × 25 diam.

The Permian *Textulariæ*, whether English or German, are very commonly found partially or entirely split horizontally, so showing the interior.

Fig. 23. TEXTULARIA MULTILOCULARIS, *Reuss*. (Page 135.)

Zechstein specimen; copied from Prof. Reuss's figure in Geinitz's "Dyas."

Figs. 24, 25. TEXTULARIA TRITICUM, *Jones*. (Page 134.)

Fig. 24. After Jones in King's Monograph. × 25 diam.

Fig. 25. From an original drawing by Dr. R. Geinitz. × 25 diam.

Permian and Zechstein specimens.

Fig. 26. TEXTULARIA GIBBOSA, *d'Orbigny*. (Page 131.)

a. Lateral aspect, *b*. Superior end-view. Carboniferous specimen. × 30 diam.

Figs. 27—29. TEXTULARIA EXIMIA, *d'Eichwald*. (Page 132.)

Fig. 27*b*. Superior end-view.—All Carboniferous specimens. × 30 diam.

Figs. 30, 31. BIGENERINA PATULA, *nov.* (Page 136.)

Fig. 30. Lateral aspect. × 30 diam.

Fig. 31. Broken specimen showing labyrinthic interior structure. × 30 diam.

Carboniferous specimens (see also Pl. VIII, figs. 10, 11).

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CARBONIFEROUS and PERMIAN FORAMINIFERA.

PLATE XI.

Figs. 1—6. ARCHÆDISCUS KARRERI, *Brady*. (Page 142.)

Figs. 1 *a*, 2. Lateral aspect. Magnified 38 diameters.

Fig. 1 *b*. Periphero-lateral aspect. × 38 diam.

Fig. 3*. Horizontal section. That the shell-wall has no appreciable thickening on the median plane is shown by the outer circlets. × 38 diam.

Fig. 4. Transverse section, showing the thickening of the walls, especially near the centre, and their extensive tubulation. × 38 diam.

Fig. 5. Lower portion of same section further enlarged, with indications of two distinct sorts of tubuli, and of a primary shell-wall, distinct from the supplementary thickening. × 230 diam.

Fig. 6. Part of a transverse section, showing the successive layers formed by the prolongation of the crescentiform edges of the tubulated shelly investment over the lateral surfaces of the test. × 230 diam.

Fig. 7. AMPHISTEGINA MINUTA, *nov.* (Page 146.)

a lateral, *b* periphero-lateral aspect. × 50 diam.

Figs. 8—11. NUMMULINA PRISTINA, *Brady*. (Page 149.)

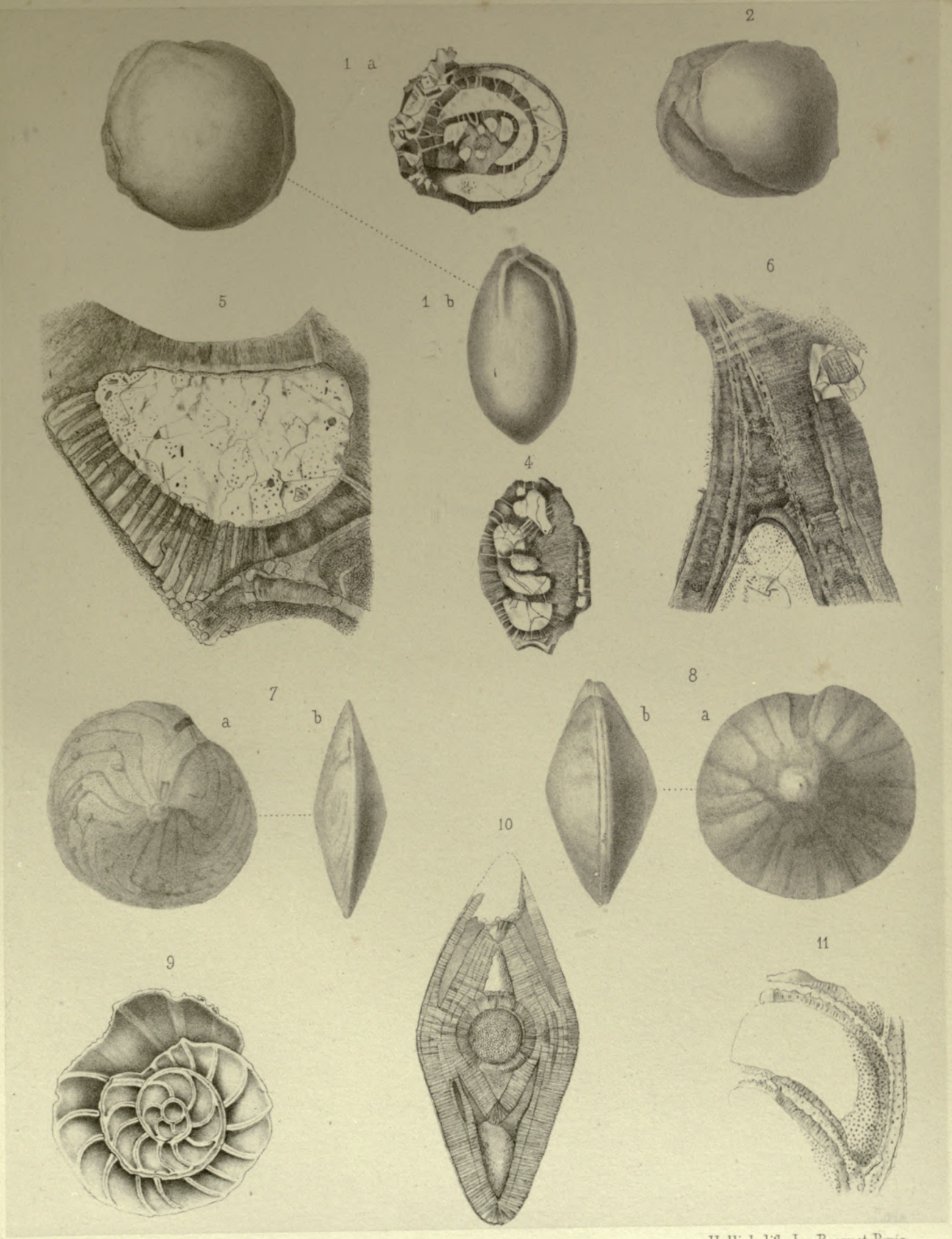
Fig. 8 *a* lateral, *b* periphero-lateral aspect. × 50 diam.

Fig. 9. Specimen split on the median plane, showing interior arrangement and septation. × 50 diam.

Fig. 10. Transverse section, showing the somewhat large primordial chamber, the investing character of the alar lobes of the chambers of the spire, and the resulting lamination of the test; also the general tubulation of the shell, and at the lower extremity some indication of the marginal cord. × 100 diam.

Fig. 11. Small portion of a horizontal section more highly magnified, demonstrating the existence of a canal-system in the septa and peripheral region. × 200 diam.

* In the lettering of the Plate the 3 has been accidentally omitted; the centre figure on the top row is the one alluded to.



H.B.Brady and A.T.Hollick del.

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CARBONIFEROUS FORAMINIFERA.

PLATE XII.

Microscopic Appearances of Transparent Sections of Carboniferous and Permian Rocks.

Fig. 1. Carboniferous Limestone, Bakewell, Derbyshire, with *Archæodiscus Karreri*, *Textularia*, sp., and *Valvulina*, sp. Magnified 10 diameters.

Fig. 2. Carboniferous Limestone, North Staffordshire, abounding in *Endothyræ*, chiefly *E. Bowmani*. × 10 diam.

Fig. 3. Carboniferous Limestone, Clifton, Bristol. An oolitic or concretional limestone, largely composed of minute, radiated and laminated, calcareous spheroids, sometimes nucleated, in rare cases Foraminifera forming the nuclei. The spheroids are often more closely packed, but it would require larger space to show fully the oolitic character of the rock. The Foraminifera are only represented in the drawing by a single specimen of *Textularia* and a few *Endothyræ*. × 10 diam.

Fig. 4. Carboniferous Limestone, Clifton, Bristol. Amorphous or subcrystalline rock, with *Valvulina palæotrochus*, *V. decurrens*, and *Archæodiscus Karreri*. × 10 diam.

Fig. 5. Carboniferous Limestone, Bangor. A subcrystalline rock, with *Endothyra Bowmani*, *E. ammonoides*, and *Textularia*, sp. × 10 diam.

Fig. 6. Saccammina-limestone (Carboniferous). A dark-coloured rock crowded with segments of *Saccammina Carteri*. × 5 diam.

Fig. 7. Upper Magnesian Limestone (Permian), Byers Quarry, Durham. An opaque, very finely sandy rock, with sections of *Dentalina communis* and *Trochammina incerta*. × 20 diam.

Fig. 8. Dark Permian Limestone ('Dunkler Kalkzechstein mit Productus horridus'), Moderwitz, Saxe Weimar. A compact black marble with sections of *Trochammina pusilla* and *Nodosaria radicula*. × 10 diam.

Note.—Figs. 1, 2, and 5 are from specimens kindly lent by Mr. H. C. Sorby, F.R.S. Figs. 3 and 4 are from sections furnished by Mr. W. W. Stoddart, F.G.S., and fig. 6 from one in the collection of Mr. J. Young, F.G.S.

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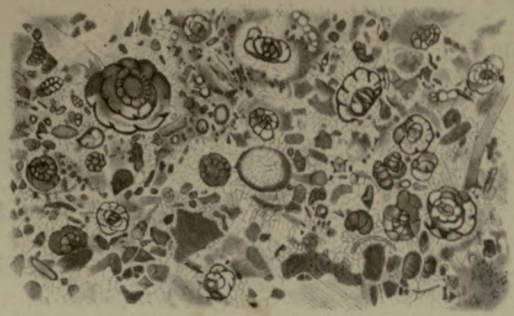

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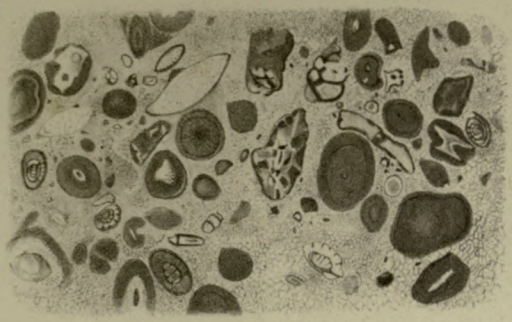

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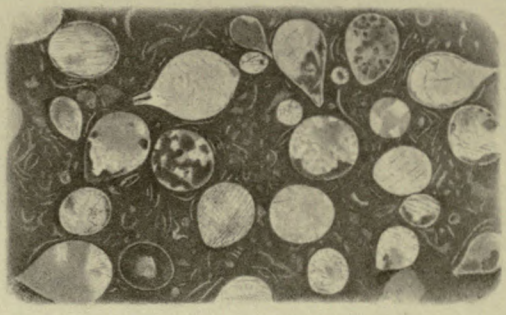

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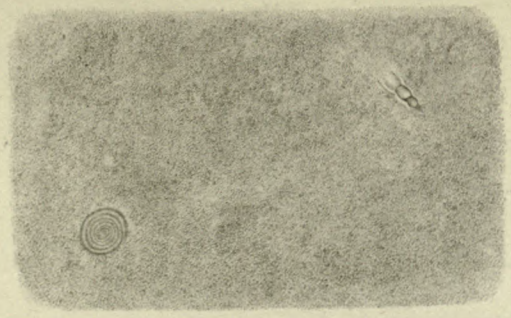

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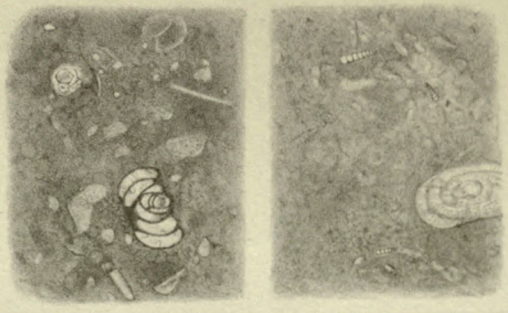

A.T. Hollick del. et lith.

Imp. Becquet, Paris.

SECTIONS of CARBONIFEROUS and PERMIAN FORAMINIFEROUS ROCKS.