XXIII. *On the Fossil Remains of the soft parts of Foraminifera, discovered in the Chalk and Flint of the South-east of England.* By Gideon Algernon Mantell, *Esq., LL.D., F.R.S., &c.*

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THE last communication I had the honour to lay before the Royal Society, related to the organic remains of the colossal extinct Reptiles, which inhabited the dry land, during that remote period when the Wealden strata were deposited. The present notice embraces the consideration of the fossil relics of beings so minute as to be invisible to the unassisted eye, that swarmed in the cretaceous ocean, and of which numerous genera and species have descended through succeeding ages, and constitute a large proportion of the inhabitants of the present seas.

In a microscopical examination of chalk and flint, undertaken for the purpose of testing the accuracy of the statement of M. Ehrenberg, that a considerable portion of the cretaceous strata is composed of minute organisms, I observed that the chambers of the shells of many *Rotaliæ* were filled with a substance, varying in appearance from a dark opaque brown, to a light transparent amber; and resembling in form, the soft bodies of existing species of Polythalamia*. I was particularly struck with the similitude between some of the fossils, and the recent *Nonionina* when deprived of its shell by immersion in diluted hydrochloric acid; and having, by the courtesy of Mr. Williamson of Manchester, procured Rotaliæ from mud dredged up in the Levant, I found among them several that contained the body of the animal partially collapsed, and of a dark brown colour, which presented an analogous appearance. I was therefore led to infer, that the substance filling the cells of the flint Rotaliæ was the remains of the soft parts of the original animalcules, in the state of *molluskite*†.

In a paper read before the Geological Society of London, and published in the Annals of Natural History for August 1845‡, I ventured to suggest this explanation of the origin of the fossils in question; but the conjecture was regarded by certain geologists as "very startling and unsatisfactory;" and as the specimens were enveloped in flint, the appearance was attributed to an infiltration into the empty

* The first flint specimen that came under my notice was discovered by my friend the Rev. J. B. Reade, F.R.S.

† *Molluskite*; a name proposed by the author, (in a paper read before the Geological Society, but not published) for the carbonaceous substance resulting from the soft bodies of testaceous mollusks that abounds in various limestones. See Medals of Creation, p. 431.

‡ Notes of a Microscopical Examination of the Chalk and Flint of the South-east of England, with remarks on the Animalculites of certain Tertiary and modern Deposits.

chambers, of mineral matter of a different colour from the surrounding matrix; a circumstance of common occurrence, not only in Ammonites, Nautili, and other chambered Cephalopoda, but also in Polythalamia, which are frequently filled with chalk, flint, and silicate of iron*. The usual appearance of the fossil Rotaliæ filled with chalk, when viewed by transmitted light, and rendered semi-transparent by Canada balsam, is shown in fig. 6.

The unequivocal organic structure, however, discernible in the substance contained in the cells of the Rotaliæ by a highly magnifying power, and of which no traces are observable in the mineral casts, and the identity of appearance in the fossils and the corrugated animal body in the Levant specimens, convinced me of the correctness of the explanation I had suggested. I therefore resolved to follow up the inquiry by an examination of Rotaliæ from chalk, in the expectation, that if the shell were dissolved by acid, indications of the body of the original might be detected in the residuum, in an unmineralized condition. After many fruitless experiments, I succeeded in procuring several examples of the soft bodies of Rotaliæ in an extraordinary state of preservation, from the grey chalk of Folkstone.

To Mr. Henry Deane of Clapham Common, an able chemist and microscopical observer, I am indebted for the most illustrative specimens; accurate figures of which, drawn by Mr. Mounsey, and M. Dinkel, are subjoined. These relics were obtained by subjecting a few grains of the cretaceous rock to the action of weak hydrochloric acid, by which means the calcareous earth, and the shells it enveloped, were removed; the residue consisted of particles of quartz, and of green silicate of iron, with which the chlorite chalk abounds, and numerous remains of the soft parts of animalcules. A small portion was then prepared in the usual manner with Canada balsam, and this was found to contain many Xanthidia, and the Rotaliæ hereafter described.

I have not had an opportunity of examining the structure of the living Rotaliæ; but from the recent observations of M. Ehrenberg, it appears that the organization of these minute animals is very simple, and has no relation whatever to that of the Cephalopoda, as was formerly conjectured. The body is inclosed within the shell, and occupies not only the outer chamber, but also all the cells *contemporaneously*; and the shell is pierced all over with minute pores like a sieve (see fig. 15), through which tentacula protrude; there are also several soft transparent feelers or *pseudopodia*, which are instruments of locomotion. The shell of the Rotalia, therefore, though presenting the general form and chambered structure of that of the Nautilus, is essentially different; for while in the shell of the latter, the animal occupies only the outer chamber, and all the internal compartments are successively-quitted empty dwellings, in the Polythalamia the body distinctly fills up *simultaneously* all the cells. When the

* In these cases, the shells were probably either empty when enveloped in the liquid chalk or flint, or speedily became so by the decomposition of the soft parts; but in the instances under examination, I conceive that the live animal was suddenly enclosed in its shell, and hermetically sealed, as it were, by the investing mineral matter, and thus the usual putrefactive process prevented.

shell is removed by weak hydrochloric acid, the soft body is exposed, and is seen to extend to the innermost chamber; and there is a connecting tube occupying the place of the siphuncle of the Nautilus, but which is the intestinal canal; for the cells of the shell contain the receptacles of the digestive sacs or stomachs, in which minute Infusoria (as Monads, Naviculæ, &c.), that have been swallowed by the animal, may sometimes be observed.

In the fossils, the appearance of the parts which I suppose to be the digestive organs, is that of a series of bladders or sacs, composed of a tough, flexible skin or integument, connected by a tube. These organs are more or less filled with a dark substance; those which are distended are always well-defined, while the empty ones are collapsed and disposed in folds, just as membranous pouches would appear under similar conditions. The sacs regularly diminish in size from the outer to the innermost cell, and vary in number from fourteen to twenty-six; being far more numerous than in the recent species. In some instances small papillæ are observable on the external surface of the integument; these are probably vestiges of the pseudopodia or tentacula.

The specimens to which I would first solicit attention are two Rotaliæ in flint (figs. 8 and 12). In the example, fig. 12, which is seen in an oblique direction, the outline and thickness of the shell and its septa are distinctly visible; as if a longitudinal section had been made through the shell, and the portion nearest the observer removed. Every compartment contains a brown granular substance, and the connecting tube is partially distended with a similar material. In this specimen, either a portion of the shell has been removed by the section of the flint so as to display the internal parts, or it has been transmuted into silex so transparent as to elude observation*. As an object of comparison with this fossil, the shell of a recent species from the Levant, seen by reflected light with a low power, is represented, fig. 15. The general contour of the shell is nearly the same in both; but in the recent example the outer surface remains, and exhibits the characteristic foramina of the genus. In the chalk Rotaliæ the perforations are for the most part obscured by the calcareous investment; but occasionally specimens both of the single and compound Polythalamia are met with, in which they are well-displayed; and in some instances the foramina are filled by a dark material, as if the bases of the tentacula were remaining in the state of molluskite†.

The fossil, fig. 8, is contained in the same atom of flint as that above described. The interior of the animalcule is here completely exposed; the sacs and the intestinal canal are as perfect as in an individual recently dead, and just taken out of the sea. The folds of the sacs that are but partially filled with the brown endochrome,

* The Polythalamia which occur in the chalk surrounding sponges inclosed in flint nodules, are frequently in a silicified state, and appear as transparent as glass, under the microscope.

† In the silicified Rotaliæ the foramina are frequently well-displayed.

resemble the duplicatures produced by the shrinking, or corrugation, of a flexible integument. The outline of the shell is but dimly visible, and can only be rendered apparent by a peculiar arrangement of the mirror of the microscope; but it is sufficiently defined to show that the sacs occupy their respective chambers. As these two specimens are contained in semi-transparent flint, the appearances described may be supposed to have originated from the soft parts having undergone silicification, the brown endochrome of the original constituting the colouring material; but this hypothesis cannot be applicable to the following examples, all of which are from the Folkstone grey chalk. These are associated with numerous particles of transparent white and green quartz; all vestiges of the shells having been destroyed by the acid. Fig. 5, is the body of a Rotalia deprived of its shell by the process previously described; it consists of fourteen sacs, in their natural position, which are filled with a dark substance, and present no folds or corrugations, as do the empty sacs in other examples. At the part corresponding with the outer compartment, a considerable space is occupied by a pale transparent material, extending in patches beyond and below, and enveloping several dark globular bodies (*a*), that resemble in shape the ova of certain Gasteropoda. That these belong to the same animal seems probable from the occurrence of similar ova (*a*, *a*, *a*,) in the fossil represented, fig. 11, which is the body of a Rotalia seen foreshortened in the horizontal plane; in this specimen four large sacs are exposed, and these exhibit in a striking manner the folded condition of the integument of which they are composed. The globular bodies (*ova*?) are twenty-one in number.

The examination of the specimens above-described will elucidate the nature of the remarkable fossil delineated in fig. 10; a specimen, to which I would especially refer in confirmation of the opinion, that the appearances described can only have resulted from the preservation of the internal parts of the animalcules in an unmineralised state, like insects in amber; at least no other interpretation occurs to me as affording so satisfactory an explanation of the phenomena under review.

In this example the entire integument of the body of a Rotalia appears to be present, the shell having been wholly removed by the acid. The membrane of the largest sacs is very much corrugated, and disposed in numerous duplications, probably from the empty state of those organs; but the general contour of the original shell is preserved, and the inner subdivisions maintain an involuted discoidal arrangement. Some granules dispersed through a mass of light-brown matter, appear in the upper part of the specimen; and on several of the sacs there are papillæ, which may be regarded as indications of the bases of pseudopodia. The drawing so faithfully represents the original, that further description is unnecessary*. On this fossil I cannot forbear to observe, that this extraordinary preservation of the soft delicate body of an animalcule invisible to the unassisted eye, through the innumerable

* The shell of this specimen was probably of the same species as that represented in fig. 6.

ages that must have elapsed since the deposition of the chalk in which it was enshrined, is a fact not less remarkable than the occurrence of the carcase of the Lena Mammoth, in the frozen soil of Siberia.

In another example (fig. 7), a series of sacs, held together by the connecting tube, is uncoiled as it were, and extended in a longitudinal direction; proving the flexible nature of the original substance.

On examining by reflected light, under the microscope, some pieces of chalk collected from the stratum which yielded the fossils above-described, minute particles of a brown colour may be observed scattered over the surface; these I have no doubt are remains of the integuments of foraminifera; for in one instance, three cells of the shell of a Rotalia lined with a similar substance, were exposed. Mutilated Rotaliæ, consisting of only four or five sacs (figs. 2, 3), and sometimes of but one (fig. 4), are common both in chalk and flint; and these invariably have a torn and collapsed appearance.

The fossil organisms termed by EHRENBERG *Xanthidia*, which have long been known in flint, and were formerly considered to be siliceous, have been shown by Mr. DEANE to occur in the chalk in a similar condition to the Rotaliæ; an unequivocal proof of the flexible nature of the original (see fig. 1).

That the correctness of the statements embodied in the preceding remarks may be verified, I submit the specimens to the Royal Society for examination under the microscope.

I will only add, that if the explanation I have suggested of the facts described be correct, and the fossils before us are the delicate soft parts of animalcules preserved in chalk and flint, in like manner as the bodies of mollusks occur as a carbonaceous substance in the Wealden freshwater limestones—this discovery, though relating to some of the minutest forms of existence, may yet prove an important element in many of the most interesting speculations of the geologist; for in strata in which no vestiges of shells, corals, or other dense organisms have been detected, the relics of countless myriads of beings may lie concealed*.

* In confirmation of these views I may state, that Dr. BAILEY, Professor of Chemistry in the United States Military Academy at West Point, whose high attainments as an accurate microscopical observer are well-known, had arrived at the same conclusions, from the examination of American specimens, before he was apprised of the result of my researches. In a recent communication, he informs me that he has obtained, from the marls of New Jersey, not only casts of the interior of the shells of *Rotaliæ* and *Textilariæ*, but also the soft bodies of the animals, in the condition of molluskite. I have detected similar specimens in marl from the same locality, sent to me by Dr. BAILEY.

Chester Square, Pimlico,
May 1846.

Description of the Plate.

PLATE XXI.

The specimens are represented as seen by transmitted light under the microscope, with the exception of figs. 13 and 15, which were viewed as opaque objects. The size of the originals is from about $\frac{1}{20}$th to $\frac{1}{200}$th of a line in linear dimensions; they are figured as seen by daylight; when viewed by the illumination of a lamp, they appear more transparent, and of a lighter colour.

Fig. 1. A Xanthidium from the grey chalk of Folkstone, presenting a torn and shrivelled appearance.

Figs. 2 and 3. Specimens of mutilated Rotaliæ from the Folkstone chalk.

Fig. 4. A single membranous empty sac of a Rotalia, very transparent.

Fig. 5. The soft parts of a Rotalia from chalk; the cells are distended with a dark substance.

a, *a*, *a*; globular bodies, probably *ova*.

Fig. 6. The usual appearance of the shells of Rotaliæ in chalk, when mounted in Canada balsam: the interior is filled with chalk, and presents no traces of the animal matter; numerous foramina are apparent. The shell of the specimen, fig. 10, was probably a larger individual of this species: from Dover.

Fig. 7. The body of a Rotalia uncoiled, the membranous sacs and their connecting tube being extended: from Folkstone chalk.

Fig. 8. A Rotalia in flint, with the internal parts preserved. All the chambers are occupied by the stomachs or digestive sacs, which are connected by the intestinal canal, and contain a brown granular substance.

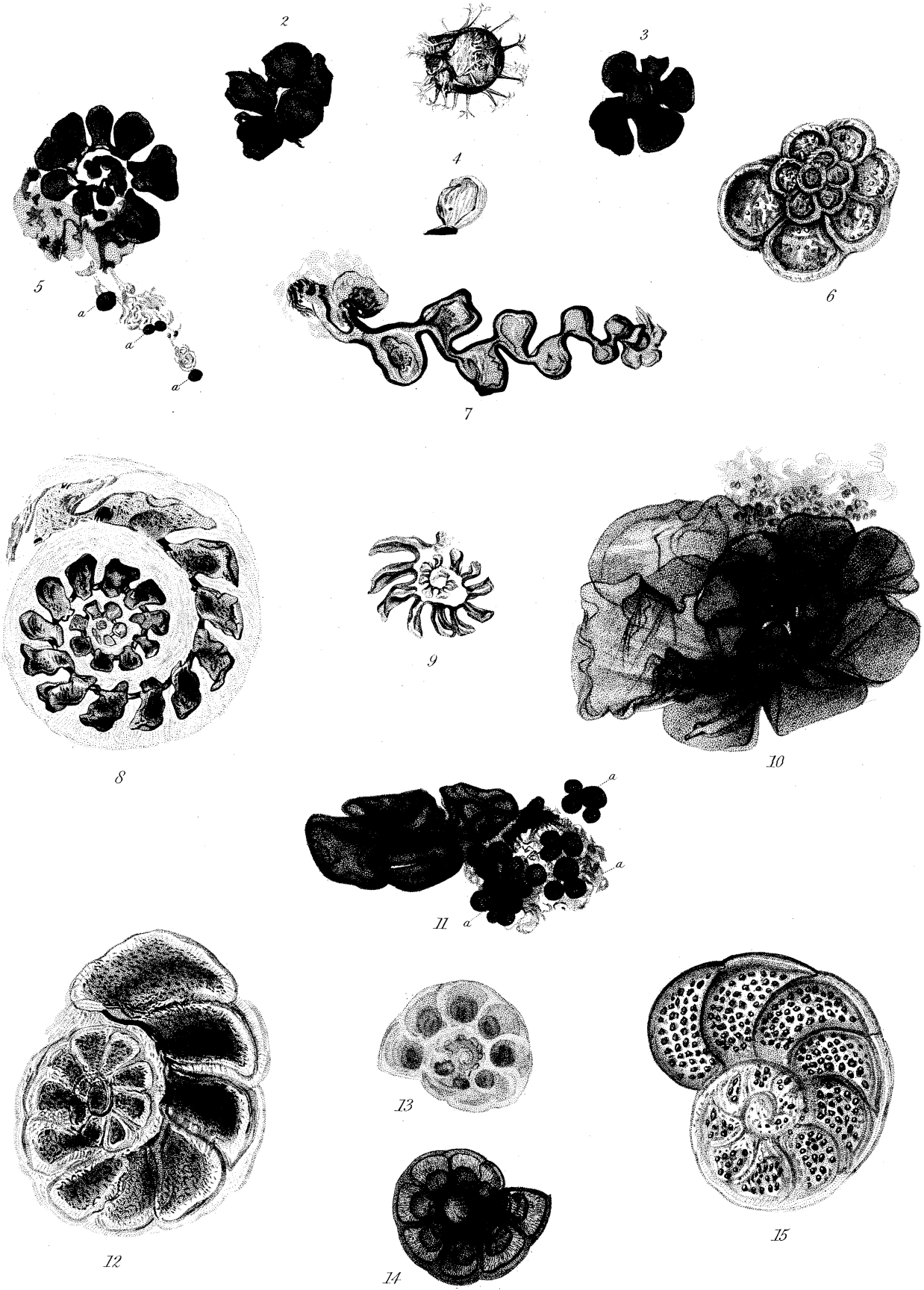
Fig. 9. The body of a Rotalia from the grey chalk of Folkstone, seen by transmitted light, and magnified 150 diameters. The shell and surrounding chalk have been removed by weak hydrochloric acid, and the specimen rendered translucent by immersion in Canada balsam; by Mr. Deane.

Fig. 10. The internal parts of a Rotalia from the chalk. The folds and duplicatures of the integument of the digestive organs are beautifully displayed; the intestinal canal is concealed by the membranous sacs; the discoidal arrangement of these organs is preserved in the inner convolutions. This specimen is in an extraordinary state of preservation: from Folkstone. The original is about $\frac{1}{20}$th of a line in diameter.

Fig. 11. Four large membranous sacs of a Rotalia seen in a fore-shortened position; the sacs are folded and collapsed. There are upwards of twenty *ova* (?) (*a*, *a*, *a*,) in connection with the anterior part of the specimen.

Fig. 12. A Rotalia in flint, with the soft parts remaining in the shell; the sacs

Fig. 1.



Fossil remains of the soft parts of Rotaliæ in Chalk and Flint.

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and intestinal tube are partially filled with a brown granular endochrome, and are very distinct.

Fig. 13. A *Rotalia*, collected by Mr. WILLIAMSON, from a recent deposit of marine sand, near Boston, Lincolnshire. In this figure the specimen is represented as seen by reflected light, with a power magnifying fifty diameters.

Fig. 14. The same object viewed by transmitted light; the body of the animal occupies the chambers of the shell, as in the recent state, and closely resembles in appearance the fossils above delineated.

Fig. 15. The shell of a recent Rotalia from the Levant.

*** Figures 9, 13 and 14, have been added to the Plate, by permission, since the communication was read before the Royal Society.