8. *The Charophyta of the Lower Headon Beds of Hordle [Hordwell] Cliffs (South Hampshire).* By CLEMENT REID, F.R.S., F.L.S., F.G.S., and JAMES GROVES, F.L.S. (Read November 22nd, 1916.)

[PLATES IV-VI.]

PREFATORY NOTE.

[The first part of this paper, written by the late Clement Reid, was communicated to the Society very shortly before his death. It may be taken as the latest expression of his views upon the position of the Lower Headon Beds of the Hordle Cliffs, arrived at by the study of these beds during the last four years of his life, when he resided at Milford-on-Sea. Except for a few verbal corrections, the paper is given as he left it.

The Charophytic remains, nearly all collected by him, had been discriminated and partly classified before his death, but the descriptions had not been written.

It will be noted that some of his statements refer to the difficulty or impossibility of comparing specimens from other areas. This is due to the fact that, when he wrote, the War was still in progress. The same cause led to delay in publication of the paper, for it was deferred in the hope of obtaining further information as to the remains occurring in the Paris Basin; but, unfortunately, this has not been found possible.—E. M. REID & J. GROVES.]

PART I.

THE correlation of limestone-deposits lying in isolated basins has always been a matter of much difficulty and uncertainty. Thus far no group of freshwater fossils has proved sufficiently widespread and characteristic for the purpose of zonal work. The mammals have a very limited geographical range, their assemblage depends so largely on the nature of the surrounding country, and their remains are usually so scarce, that they do not greatly help; besides which, in strata older than the Tertiary they almost fail us. Other vertebrates, such as fishes, would also vary greatly in adjoining areas.

The freshwater and brackish-water mollusca, which are so abundant, and would at first sight appear so useful, cannot be depended on for the comparison of distant areas. Many of the species are very local, and their variation under slightly changed conditions is so great as to give rise to much confusion. Anyone who has worked with the genera *Unio*, *Corbicula*, *Cyrena*, *Paludina*, *Melania*, *Potamides*, or *Limnæa* in the London and Paris Basins must have felt this difficulty. In the case of the non-sculptured genera, such as *Paludina*, the difficulty is increased by a tendency to vary around a certain generic type, to which the species seem to revert again and again. Indeed, in certain of the molluscan genera the specific differences are so slight as only to be recognizable in specimens better preserved than such as are commonly available.

The higher plants are usually very local, and their remains are

too rare in most strata to be of much assistance. For the correlation of far-distant deposits we need some group of fossils easily dispersed, and therefore widely spread, having many generic and specific forms of limited range in time, with specimens occurring in profusion in a determinable state. In short, for zonal work in freshwater strata we require a group somewhat equivalent to the graptolites in wide distribution and characteristic forms.

One group seems to possess all these qualities, if we can obtain sufficient material. The Charophyta are submerged aquatic plants, of which the living genera and species have generally wide ranges, and the peculiar fruits with their spirally-coiled cells offer many characters for specific determination. They usually occur in profusion in the places where they grow, and they grow nearly everywhere in pools, lakes, and brackish-water lagoons. The fruits, being commonly calcified, are found in most deposits that contain freshwater mollusca: in fact, many of the so-called 'shell-marls' would be more properly described as '*Chara* marls.'

Though for many years the fossil Charophyta have been gathered from various freshwater deposits, it was not until one of us settled in Hampshire, and began to collect more fully the plants of the Hordle Cliffs, that the idea of using Charophyta as zone-fossils took shape. A slight search showed that in these Tertiary strata there were many unknown forms, some apparently of peculiar generic types. Concurrently with this work on the Tertiary species, we undertook the examination of the Purbeck Charophyta, with the result that the various Purbeck forms seem all to belong to strange extinct genera. The Swiss Miocene and the Austrian Lower Eocene forms, only as yet slightly examined, seem also to belong to well-marked groups of limited vertical range.

These indications of the value of the group for the purposes of zonal work, combined with the discovery in a short time of so many undescribed types, has induced us to undertake the working-out of the Charophyte flora of the zone most thoroughly searched—the Lower Headon Beds. We should like to have investigated the whole of the Hampshire-Basin Eocene and Oligocene deposits, also to have established the correlation of the freshwater strata with those of the Paris Basin; but the War made it impracticable to get about in certain areas, and also made it impossible to consult the foreign museums, especially those of Paris.

In the Hordle Cliffs of the mainland of Hampshire, the strata below the superficial gravel belong certainly to the Lower Headon Series: a small outlier of the marine Middle Headon, formerly seen, having now been entirely destroyed by the encroachments of the sea. There is no possibility, therefore, that any of our specimens can have come from any but this one horizon. The Headon Beds, though placed by British geologists, following Judd, in the Oligocene, and lithologically more closely allied to the Oligocene above than to the Barton Beds below, are in reality on the same horizon as the Calcaire Grossier of the Paris Basin, and this for

some time has been recognized. As the Charophyta also, so far as they can yet be compared, lead us to the same conclusion, we shall not hesitate to speak of the Headon Beds as Upper Eocene.

The strata seen in Hordle Cliffs consist throughout of fresh-water and brackish-water deposits, more or less calcareous, laid down in wide shallow lakes and lagoons, precisely the conditions in which Charophyta best flourish. The flora, therefore, is rich and varied; and this one deposit has already yielded many more species than the whole of the British strata were known to contain. Although so many species occur, there is no reason to consider that the Lower Headon strata belong to more than a single zone. There are slight differences in the species contained in different seams; but nearly all of them have now been found in the thin seam of limestone, which (of all the beds) has been most thoroughly searched.

An excellent account of the succession of the beds in Hordle Cliffs was published by E. B. Tawney & H. Keeping in this Journal,¹ and we cannot do better than use their numbering of the beds, although in some cases botanical work might induce us to subdivide differently these variable and impermanent strata. The total thickness of the Lower Headon strata is given by them as 83½ feet, and we do not think this measurement far wrong.

It should be remembered that for Charophyta the ordinary carbonaceous plant-beds are not suitable from the point of view of preservation, for calcareous fossils usually tend to decay in the presence of much vegetable matter. Shaly beds also are bad conservators, for any crushing of the specimens makes it impossible to extract the Charophyta in a recognizable state, though we may be able to note the deposit as largely made up of these plants. Charophyta are best preserved in the soft limestone, in the shelly beds, or in sandy seams which have resisted compression.

Our search for these plants in Hordle Cliffs has been conducted systematically, and they prove to be far more generally diffused than the published accounts would suggest. As a rule, however, each seam or lenticle yields only two or three species, and, in order to avoid spending time unprofitably in washing large quantities of such material, work latterly has been concentrated on a few very prolific seams in which the Charophyte flora has proved to be exceptionally varied.

The lowest beds of the Headon deposits (Nos. 1 to 7 of Tawney & Keeping) are carbonaceous clays, not good receptacles for Charophyta. Then follows a conspicuous band of big ironstone-nodules (No. 8), which will enable the geologist to fix his position. Next follow 12½ feet of bluish and greenish clays, with seams of sand (No. 9). This is commonly known as the Mammal-Bed, for most of the larger mammalian remains have been found in it,

¹ 'On the Section at Hordwell Cliffs, from the Top of the Lower Headon to the Base of the Upper Bagshot Sands' Q. J. G. S. vol. xxxix (1883) pp. 566-74.

though of late years finds have been rare. No. 9 is also full of small lenticular seams of sand, some of which are crowded with fruits of *Chara*. Several of these little seams have been washed, and the following species have been found:—*C. Wrightii*, *C. vasiformis*, *C. helicteres*, *C. tornata*, and *C. subcylindrica*. Possibly these little sandy lenticles in the clays point to the washing-together of the comparatively heavy Characeous fruits into shallow channels during exceptional floods or storms, for the rest of Bed 9 suggests very tranquil deposition.

No. 10, the 'Basement Seed-Bed' including the 'Leaf-Bed,' is noted by Tawney & Keeping as a variable series of deposits. At the top is a carbonaceous clay with rootlets, below a lenticle of lignite varying from 9 inches in thickness on the east to 12 feet where it crops out under the gravel at Long Mead End; and under this is some green clay with ironstone slabs penetrated by small roots. Recent exposures show it to be even more variable than is stated: for in one place it is strongly current-bedded; in another it is channelled, and shows a local development of seams of grey calcareous loam, full of seeds of aquatic and terrestrial plants. These 'seed-beds' have lately been carefully searched for their plants, which include several undescribed species; but fruits of Charophyta are comparatively rare, and, as is usual in carbonaceous deposits, tend to go to pieces. The species obtained were:—*C. Wrightii*, *C. calata* var. *baccata*, *C. vasiformis*, *C. tornata*, and *C. subcylindrica*. The 'leaf-beds' on the same horizon, but more conspicuously developed farther west, are full of fragments of a pinnate-leaved palm, of a cinnamon, and of fronds of a tropical fern, *Chrysodium*; in them Charophyta do not occur in a determinable state.

Beds 11 to 13 were sampled, but yielded no *Chara*, and the same was the case with Bed 14 (the 'rolled bone-bed' of Tawney & Keeping). Above this comes Bed 15, a 7-foot mass of fine silty sands, with thin loamy seams and conspicuous bands of *Potamomya* and a few other brackish-water shells. The shells are mostly tender and fragile, and it was very difficult to preserve the *Chara*-fruits found in the sand; but, after some of the clay-partings had been washed, two species were obtained. Bed 15 is evidently a lagoon deposit of brackish-water origin; it is the principal source of the crocodile-remains.

Bed 16 is a mass of green clay, with a conspicuous band of big ironstone-nodules; at its top is a seam of lignite. We do not happen yet to have met with any of the thin seams full of *Chara*-fruits, which are usually to be found in clays of this character; and Bed 17 is so much more promising, that it was thought better to devote the time available to its more thorough investigation.

Bed 17 is a conspicuous band of soft cream-coloured limestone, varying from 3 to 7 inches in thickness, and occurring almost exactly in the middle of the Lower Headon Series. Though so

thin, it is easy to find, for it makes a distinct ledge, and is the only limestone now left in Hordle Cliffs. It crops out under the gravel at Long Mead End, and sinking eastwards must descend to the sea-level near the first steps to the beach, though talus still hides this part of its outcrop. The part of the cliff in which this limestone appears, after being for several years much obscured by talus, has lately been much better exposed. The limestone is full of *Limnæa* and *Planorbis*, and seems to be purely of freshwater origin. At its hardest it is a soft stone, and much of it is so marly as to go to pieces if dried and then placed in water. It is full of fruits of *Chara*, and has yielded a more varied Charophyte flora than any other of the Headon Beds. This is partly due to its real productiveness, partly to the much greater attention paid to it when its productiveness was discovered.

The best pieces to select for washing in this limestone are the fairly hard lumps in which the mollusca are not much distorted, for the more marly and shaly parts will not bear washing without the fossils going to pieces. Though the bed only crops out for a short distance, it is well to take a number of samples, for some of the species of *Chara*-fruits drift into little pockets or nests, and have only been found at a single spot. In addition to the fruits, fragments of stems and branchlets belonging to several species have been found. Most of the Lower Headon Charophyta occur in this bed; but its flora is not quite so exceptionally rich as would at first appear, for some of its species are of extreme rarity, and have only been found through long-continued search. Only two of the fruits that we have named, occurring fairly commonly in the limestone, have not been found in any of the other beds—the exceedingly minute *Tolypella parvula*, and *Chara polita*. With the latter fruit possibly may be associated the slender solidly-calcified stems and branchlets found in the same deposit (type A), though at present we cannot definitely associate any of the fruits with their corresponding vegetative parts.

The list of Charophyta found in the limestone is as follows:—*C. Wrightii*, *C. cæolata*, with vars. *bicincta* and *baccata*, *C. rasiiformis*, *C. polita*, *C. strobilocarpa* and var. *ellipsoidea*, *C. turbinata*, and *Tolypella parvula*; but, as several of the most peculiar forms are only represented by very few specimens, this list is probably by no means complete.

The next 14 or 15 feet of strata (Beds 18 to 27?) consist mainly of clays, not at present well seen, and therefore not thoroughly searched. They form a gentler slope above the ledge of limestone, and lead up to another white band, this one consisting of highly calcareous shelly sand, nowhere hardened into stone. This white band, only a few inches thick, is seen in the upper part of the cliff, just under the gravel, nearly opposite Hordle House; but it can best be examined where it caps the landslip at the top of the undercliff immediately below. It can be reached by descending the westernmost ladder, and then walking a short distance westwards

along the undercliff. [1 The white band is an important horizon in the Headon Beds; but, unfortunately, it is the only one as to the correlation of which with Tawney & Keeping's section we feel in doubt. If it is their 'Chara Bed' (part of No. 28), then the details now seen do not correspond with their measurements and description, and it is strange that a collector who has worked so long at these deposits, as did Keeping, should not have noticed the numerous small bones and teeth, mainly of rodents, which it contained. It is curious also that these authors should state that their Chara Bed is seen at Paddy's Gap,² but thins out westwards. The deposit that we have seen and collected from is well exposed, as already mentioned, on the west; but we think that it was sunk below the beach-level before Paddy's Gap is reached. At Paddy's Gap recent storms have entirely cleared the section, and thin lenticles crowded with fruits of *Chara* are seen in a matrix of blue or green clay; but they do not resemble or appear to be on the same horizon as our 'Rodent-Bed.' Probably the deposit is part of the series marked 4 in the Marchioness of Hastings's description,³ for in this she found the small bones.

This part of the cliff, after being obscured by talus for many years, is now gradually being cleared again by renewed encroachments of the sea; but there is still a piece, from opposite the Hotel westwards to the last steps to the beach, along which the bed's cannot be traced continuously, so that the exact details of this part of the section must remain in doubt. If we are right in thinking that the Chara Bed of Paddy's Gap is not the same as the Rodent-Bed, then it is probable that a few feet must be added to the total thickness of the series.]

From the Rodent-Bed, which is only a few inches thick, we have obtained several species of freshwater and brackish-water mollusca, a number of small mammalian bones and teeth, and several species of Charophytes. One minute subglobose fruit (*Tolypella headonensis*) is confined to this horizon, as perhaps are one or two other noticeable forms. The difference between the flora of this deposit and that of the limestone is, however, more likely to be due to the influence of varying amounts of salt, rather than to any great difference of date. The species found in the Rodent-Bed are:—*C. Wrightii*, *C. vasiformis*, *C. distorta*, *C. tornata*, *C. subcylindrica*?, *C. strobilocarpa* var. *bitruncata*, and *T. headonensis*.

At its top the Rodent-Bed is cut off abruptly by a thin seam of black clay, perhaps Bed 29. Then follows a thick mass of green clay (Bed 30?), with occasional thin lenticles of drifted *Chara*-fruits. These seem to be the beds seen at the foot of Paddy's Gap (Mineway), close to the beach-level. The species are few, only

¹ The discrepancies referred to in the part of the text enclosed between square brackets are probably due to the fallen state of the cliff, which rendered observation difficult. [E. M. R.]

² Paddy's Gap is the gap leading to the shore opposite Rookcliffe. In older records it was known as 'The Mineway.'

³ Bull. Soc. Géol. France, ser. 2, vol. ix (1852) pp. 191-203.

Chara Wrightii, *C. helicteres*, and *C. vasiformis* being seen. Other fossils, except *Paludina* and *Unio*, are not common.

A conspicuous but thin sandy band crowded with seeds of *Limnocarpus* and *Stratiotes* is very noticeable east of Paddy's Gap. It has yielded also a few fruits of *Chara*, but they are not very well preserved.

Then follow thin bands of clay and sand, with *Paludina*, *Melania turritissima*, and *Unio*; in these we have not observed any Charophyta.

Bed 31 is the sand which now rises nearly to the top of the cliff under the gravel. It was formerly followed by a band of clay, and this by a thin limestone (32)—the How Ledge Limestone; but these two beds, together about 5 feet thick, have now entirely disappeared, as has the marine Middle Headon last seen about the year 1850.

PART II.

The remains of Charophyta, which afford the material for this paper, consist of numerous detached fruits, some fragments of stems and branchlets, and a few stem-nodes with portions of the internodes of stems and the bases of the branchlets attached. There are also a few bodies which are apparently the actual stem-nodes. In no instance has a fruit been found attached to a branchlet, and, owing to the fact that in each deposit more than one type of fruit is present, it is not possible to identify any of the fruits with the vegetative parts to which they belong.

Fruits.

The fruits, the remains of which are here preserved as fossils, would appear to consist only of those which have developed a 'lime-shell,' similar to that with which we are familiar in many existing species of *Chara* and in a few of the *Tolypellæ*. This lime-shell is formed by the secretion of carbonate of lime of extremely fine grain, in the interior of the five spiral cells which constitute the wall of the oogonium. As the fruit matures the lateral walls of the spiral cells, where they are in contact one with the other, break down, and the calcareous contents of the five cells combine to form one shell which surrounds the oospore. The calcareous deposit goes on increasing, until it has almost entirely replaced the original protoplasmic contents of the cells. That the preservation of these fossil fruits is due to the presence of the lime-shell may, we think, be fairly adduced from the following considerations:—

- (1) The practical impossibility of large thin-walled cells being preserved in such a formation if merely filled with protoplasm.
- (2) The fact that no evidently young fruits are found as fossils, and that in existing species the lime-shell only occurs in mature fruits.
- (3) The invariable absence in the fossils of the coronula and stalk-cell, which organs, in existing species, do not secrete calcium carbonate.
- (4) The great diversity in the thickness of the shell in the fossils, the

thinner being concave, the thicker flat or convex on the exterior, corresponding with the various stages in the development of the lime-shell of living species. The calcareous accretion forming the latter is built up by deposits on the concave inner wall of each spiral cell; hence in earlier stages, when it is thin, the whole lime-shell presents a series of ridges with rounded concave valleys between, which latter gradually fill up, until the whole space is occupied, and the valleys have been transformed into rounded ridges, while the former ridges have become furrows.

In the case of the fossil fruits, when they break up, the spiral portions separate most readily along their edges, long detached pieces of individual spirals being frequently found, and when these are fractured it is by a clean break transversely. When a recent lime-shell breaks, this is not usually the case, a fracture taking place more commonly quite irregularly across several spirals. This difference may be due to the fact that the lateral walls of the spiral cells, in the case of the Tertiary plants, do not break down so completely before calcification, as in the recent species, and the lime-shell, in consequence, is incompletely developed along the sutures.

We have found the oospore preserved in a few cases, mostly in the gathering from the Basement-Bed. Owing to the non-preservation of the stalk-cell, there is an opening at the base of the oogonium which is referred to in the descriptions as *foramen basilare*. The walled-in space at the base of the oospore corresponding to this is styled *cohors basilaris*.

The fossil fruits are very diverse in shape, ranging from completely globular (Pl. IV, figs. 1-8) to elongated ellipsoid, elongated obovoid, and (Pl. V, figs. 4 & 5) subcylindrical. In size the diversity is also considerable, the length of those measured ranging from about 325 to 1200 μ , and the breadth from 250 to 1650 μ . In colour, also, there is great diversity; but this doubtless is, to some extent, due to the conditions under which the fruits were preserved. Some of the types of fruit resemble those of living species.

In the lime-shell of existing species we have seen no approach to the remarkable papilliform processes found in some of the fossils, to the cause and nature of which we have not at present discovered any clue. The papilliform processes occur at more or less regular intervals along the spiral cells. They were apparently first observed by Sir Charles Lyell in fruits from the Bembridge Beds, described and figured by him in Trans. Geol. Soc. ser. 2, vol. ii (1826) p. 94, pl. xiii, figs. 7 & 8, under the name *Chara tuberculata*. Subsequent authors have described other species having similar processes. Dr. Guido Stache, in his fine monograph on the fossils of certain ancient Tertiary beds in the neighbourhood of Trieste ('Die Liburnische Stufe' 1889), describes and figures six species with this characteristic, and constitutes for them a section *Kosmogyræ*, placing them under two genera, *Kosmogyra* and *Kosmogyrella*.

Among living species there are none with fruits quite like the large globose and sub-globose types figured in Pl. IV, figs. 1-10.

The features essential to the satisfactory determination of the genera are, unfortunately, lacking in the fossil fruits. The types numbered 11 & 12, however, so closely resemble the fruits of living species of *Tolypella* that we think there can be little doubt that they are correctly placed under that genus. The rest have been provisionally retained under the parental generic name *Chara*, sufficient evidence not being available to place them under other genera, although there is every probability that some do not belong to the genus *Chara* in its restricted sense. It is probable that the large globular and broadly-ellipsoid fossil fruits, with swollen tips to the spiral cells suggesting a deciduous coronula, belong to a genus akin to *Nitellopsis*.

None of the fossil fruits that we have examined shows any sign of the longitudinal flattening characteristic of the genus *Nitella*.

The following types appear to us sufficiently distinct to justify their differentiation as species. Possibly some of those now referred to varieties may also prove to be distinct, especially when we consider the similarity of the fruits of closely-allied living species.

There are, in addition, a few fruits which we have not been able to refer with certainty to any of the types described, but which either appear insufficiently distinct, or for which there is insufficient material to justify the assignment of a name to them (Pl. VI, figs. 6-8).

The presence of so great a number of more or less distinct types in this series of beds is not surprising, in view of the number of living species sometimes found growing together in the same piece of water. In Hickling Broad (East Norfolk), for instance, Canon Bullock-Webster has collected twelve species of Charophytes; while M. Émile Gadeceau in his admirable monograph on the Lac de Grandlieu (near Nantes) records no less than seventeen species from that lake.

The measurements given here are those of well-developed fruits, the smaller specimens often present being ignored. Many imperfect fruits occur, and in such cases it is almost always the apex which is wanting. The thickness of the spiral cells is stated when broken specimens in which the calcareous shell seems to have attained its full development are available.

1. CHARA WRIGHTII, Salter in Forbes, Mem. Geol. Surv. 1856, p. 160 & pl. vii, figs. 15-21. (Pl. IV, fig. 1.)

Oogonium fere globosum, latitudine quam longitudine plerumque majus, diametro c. 950-1100 μ ; cellulae spirales in statu maturitatis convexae, latissimae (c. 150-200 μ) et crassissimae (c. 75-125 μ), leves vel nodulosae, in apice, supra collum constrictum, plusminusve turgido, circ. septem convolutiones exhibentes; foramen basilare comparate parvum, cum conformatione variabili, plerumque paulo dilatatum, interdum cum ore lato. [Oospora fere globosa, diametro c. 700-775 μ , liras humiles sex-septem exhibentes; cohors basilaris diametro c. 150 μ .]

Var. *RHYTIDOCARPA* nov. Cellulæ spirales eminentias inæquales et angulatas prætendentes. (Pl. IV, fig. 3.)

Var. *MINOR* nov. Oogonium cum conformatione formæ typicæ simili sed minus, diametro c. 750–850 μ . (Pl. IV, fig. 2.)

The fruits vary in colour from light yellowish to dark purplish-brown. When fully developed the spiral cells are convex; they are often much swollen at the apex, which is often a lighter brown, and the constriction at the neck is very marked. The form of the fruit differs from that of any living Charophyte, in that the breadth is often greater than the length. It may be conjectured that the plant belonged to a genus akin to *Nitellopsis*.

If not identical with *C. medicaginula* Brongniart, as suggested by J. W. Salter (*op. cit.*), there is no doubt that *C. Wrightii* is very closely allied to that species. The size of the fruits of the former given by W. Ph. Schimper, in his 'Traité de Paléontologie Végétale' vol. i (1869) p. 221 (1100–1150 μ), is somewhat greater than that of the Hordle plant. We have not had sufficient opportunity of examining the remains from the Paris Basin to form an opinion as to their identity.

The var. *minor* of *C. Wrightii* bears about the same proportion in size to the type as the var. *minor* of *C. medicaginula*. The form *rhytidocarpa* may be merely an abnormality; but we have seen similar specimens from the Lower Headon Beds of the Isle of Wight.

In the Basement (Seed)-Bed a number of the oospores are preserved within the oogonia; but, being very thin-shelled and brittle, they are difficult to handle. We have, however, been able to get out three specimens nearly entire, and from this rather meagre material the above description is drawn. A nearly globose oospore from the Limestone-Band, filled with the matrix, probably also belongs to this species. This is shown in Pl. IV, fig. 11.

C. Wrightii is the commonest Charophyte in the Hordle Beds, sometimes occurring in great numbers. It was obtained from the Mammal-Bed, the Basement (Seed)-Bed, the Limestone-Band, the Rodent-Bed, and the Mineway.

2. *CHARA CELATA*, sp. nov. (Pl. IV, figs. 4–6.)

Oogonium fere globosum, diametro c. 950 μ ; cellulæ spirales latissimæ (c. 150–175 μ) cum ordine tuberculorum rotundato-conicorum, apice turgescens, circa septem convolutiones exhibentes; foramen basilare angustum, ore paulo dilato.

Var. *BICINCTA*. Cellulæ spirales ordine tuberculorum irregulariter duplicato. (Pl. IV, figs. 7 & 8.)

Var. *BACCATA*. Oogonium subglobosum quam idem formæ typicæ minus, diametro c. 850; tuberculi magni humiles rotundati; foramen basilare latius. (Pl. IV, figs. 9 & 10.)

In shape the fruit of this species resembles that of *C. Wrightii*, but it is less flattened at the extremities. In some cases, as in those figured, the tubercles are particularly well-marked; in the

var. *baccata*, which may be a distinct species, they are broader (quite half the breadth of the spiral cell) and almost contiguous. We found one fruit in the Mammal-Bed closely resembling that of *C. cæolata*, but having holes at regular intervals in place of tubercles (Pl. VI, fig. 9).

Obtained from the Limestone-Band, and one specimen of *C. cæolata* var. *baccata* from the Basement (Seed)-Bed.

3. *CHARA VASIFORMIS*, sp. nov. (Pl. IV, figs. 12-15.)

Oogonium obovoideum deorsum ad basem insignem pentagonum plerumque fastigatum, magnitudine variata, long. c. 750-950 μ , crass. c. 475-725 μ ; cellulæ spirales lat. c. 75-100 μ , crass. c. 50-60 μ , apice paulo dilato, cum ordine tuberculorum eminentium truncatorum, convolutiones decem-duodecim exhibentes; foramen basilarium plerumque latum infundibuliforme. [Oospora obovoidea, long. c. 650-725 μ , crass. c. 450-500 μ , liras eminentes c. novem exhibens: cohors basilaris diametro c. 125 μ .]

A well-marked fruit very variable in size, usually pale brown. Evidently allied to *C. tuberculata* Lyell, from the Bembridge Beds, but differing in its smaller size, in being more or less obovoid, rather than ellipsoid, and in having usually a more prominent vase-like base, which latter feature does not come out well in our figures. The tubercles of the other tuberculate-fruited species are either rounded or conical, whereas in *C. tuberculata* and *C. vasiformis*, when fully developed, they are abruptly truncated, the apex being flat. The probable explanation of this is that the extent of their development was limited by the cell wall. In a very small proportion of the fruits the tubercles are absent (see fig. 14). In some there are smaller irregular intermediate tubercles forming a serrated ridge along the centre of each spiral cell. We were in doubt as to the origin of the tubercles: that is, whether they were possibly merely a calcareous encrustation, or were organic. Our friend, Mr. D. J. Scourfield, a skilled microscopist and biologist, kindly made a careful examination of them, and reported as follows:—

‘The tubercles are very peculiar, but I have come to the conclusion that they are actual productions of the plant. If a piece of a spiral be examined, it will be seen that, despite much irregularity of growth along the whole course of the spiral, the more or less flat-topped projections (that is, the tubercles properly so called) are spaced at fairly constant intervals. The amount of these growths varies from nothing on some specimens to an almost continuous band on others. I suppose that this depends on the stage of development of the fruit. If a piece of one of the spirals be treated with weak acid the carbonate of lime will be seen to be gradually dissolved away, leaving an exact copy in some organic substance (? cellulose) with a rather wrinkled surface. A number of very minute crystals (? substance) are embedded in this, and also usually a number of somewhat rounded grains, probably sand-grains, as they do not dissolve in fairly strong nitric acid.’

From the Limestone-Band a few fruits were obtained, of which the apex was prolonged into a point. (See Pl. IV, fig. 15.)

In the gathering from the Basement (Seed)-Bed, in addition to a number of loose oospores, some were obtained in their enclosing oogonia, and it is upon these that the description of the oospore is based; but the measurements, etc. may not apply to those of the other beds. The uniformly salient vase-like base separates this and *Chara tuberculata* from all the other species.

Obtained from the Mammal- and Basement (Seed)-Beds, the Limestone-Band, the Rodent-Bed, and the Mineway. Next to *C. Wrightii* this is the most frequent species.

4. *CHARA DISTORTA*, sp. nov. (Pl. V, fig. 6.)

Oogonium ellipsoideo-fusiforme, long. c. 1000–1200 μ , crass. c. 875–925 μ ; cellulæ spirales latissimæ (c. 150 μ) et crassissimæ (c. 150 μ) plerumque convexæ, apice haud multo dilato, convolutiones irregulares septem–octo exhibentes; foramen basilare angustum, ore paulo dilato.

Of a dark purplish-brown, varying much in size and shape, but characterized by the usually somewhat tapered apex and base, and by the irregularly-coiled spiral cells. It is not unlike an extended form of *C. Wrightii*. So far as can be gathered from A. Watelet's description and somewhat crude illustrations of his *C. depressa*,¹ *C. distorta* resembles that species, but differs from it in the form of the apex of the spiral cells.

Obtained in fair quantity from the Rodent-Bed.

5. *CHARA HELICTERES*, Brongniart, in G. Cuvier & A. Brongniart's 'Description Géologique des Environs de Paris' 1822, p. 368 & pl. xi, fig. 8. (Pl. V, fig. 11.)

Oogonium late ellipsoideum, apice plus minusve truncatum, long. c. 1050–1200 μ , crass. 950–1050 μ ; cellulæ spirales convexæ, in apice turgidæ et plerumque ad jugum constrictæ, convolutiones regulares octo–novem exhibentes; foramen basilare latum et haud profundum, margine cum angulis acutis et plerumque prætendentibus.

The fruits are variable in shape, usually decidedly longer than broad, but sometimes almost spherical, often conspicuously flattened at the apex and occasionally tapering somewhat towards the base. The Hordle specimens are of a light brown with a smooth surface. The dimensions are smaller than those given by Schimper in his 'Traité de Paléontologie Végétale' vol. i (1869) p. 222 & pl. v, figs. 20–32. That author shows the number of convolutions of spiral cells displayed as eleven; but in Brongniart's original figure eight only are shown.

Obtained from the Mammal-Bed and Mineway.

¹ 'Description des Plantes Fossiles du Bassin de Paris' 1866, p. 55 & pl. xv.

6. *CHARA TORNATA*, sp. nov. (Pl. V, figs. 1-3.)

Oogonium ellipsoideum vel cylindrico-ellipsoideum, long. c. 550-700 μ , crass. 400-475 μ , apice paulo acuto, base truncato; cellulæ spirales convexæ, lat. et crass. c. 65 μ , ad apicem dilatæ sed complanatæ, ad basem dilatæ, convolutiones c. duodecim exhibentes; foramen basilare paulo latum et haud profundum, margine cum angulis deorsum prætendentibus. Oospora ellipsoidea apice truncato, long. c. 600-700 μ , crass. c. 350-400 μ , liras subhumiles novem-decem exhibens; cohors basilaris diametro c. 100 μ .

A distinct well-marked type, pale yellowish to dark brown. The regular rounded spiral cells give it a particularly neat appearance; the flattened (collapsed) apices cause the fruit to seem pointed at the apex, while the five obtuse points of the basal aperture, projecting downwards, produce a truncated outline below.

Plentiful in the Mammal- and Basement (Seed)-Beds, and occurring also in the Rodent-Bed. In the Basement-Bed oospores are present.

7. *CHARA SUBCYLINDRICA*, sp. nov. (Pl. V, fig. 4.)

Oogonium ellipsoideo-cylindricum, long. 475-600 μ , crass. 275-350 μ ; cellulæ spirales convexæ, lat. c. 65 μ , ad apicem paulo dilatæ, convolutiones c. duodecim exhibentes; foramen basilare latum et haud profundum, margine cum angulis deorsum prætendentibus.

Resembling the species last described, but smaller and proportionally narrower and more rounded at the extremities. A few whole specimens only were found, and these differ considerably in size. Four broken specimens, with but slightly developed lime-shell and consequently concave spiral cells, obtained from the Rodent-Bed (fig. 5), probably also belong to this species.

Mammal- and Basement (Seed)-Beds, and (?) Rodent-Bed.

8. *CHARA POLITA*, sp. nov. (Pl. V, figs. 9 & 12.)

Oogonium globoso-ellipsoideum, ad basem paulo fastigatum, long. 675-750 μ , crass. 625-675 μ ; cellulæ spirales leves lat. c. 80-100 μ , ad apicem paulo dilatæ, convolutiones octo-decem exhibentes; foramen basilare diametro c. 65 μ , ore paulo dilato.

Brown to nearly black, when fully developed smooth and shining, varying somewhat in form, but usually having the base and apex rounded. A few rather larger fruits, with the spiral cells showing one or two more convolutions, may belong to this species.

Limestone-Band, fairly numerous.

9. *CHARA STROBILOCARPA*, sp. nov. (Pl. V, figs. 7 & 8.)

Oogonium obovoideum deorsum conspicue fastigatum, apice rotundato, long. 850-1000 μ , crass. 550-600 μ ; cellulæ spirales concavæ, lat. c. 100-125 μ , ad apicem et basem dilatæ, convolutiones novem-undecim exhibentes; foramen basilare parvum, valde angulatum.

Var. ELLIPSOIDEA. *Oogonium ellipsoideum*, sursum et deorsum paulo fastigatum. (Pl. V, fig. 10.)

Var. BITRUNCATA. *Oogonium bitruncato-ellipsoideum*, nonnunquam ad basem paulo fastigatum; foramen basilare diametro medio. (Pl. V, fig. 13.)

The type varies in size and shape, the specimen figured being the largest and most distinctive. The variety *ellipsoidea* differs from it in being somewhat tapered at both ends, slightly more below than above; the variety *bitruncata*, on the other hand, has usually both ends somewhat truncate.

The type and the variety *ellipsoidea* were obtained from the Limestone-Band, only two specimens of the latter being found; the variety *bitruncata* was obtained in fair quantity from the Rodent-Bed, and a single specimen from the Basement (Seed)-Bed.

10. CHARA TURBINATA, sp. nov. (Pl. VI, fig. 1.)

Oogonium obovoideum, apice insigne complanato, ad basem truncatam fastigatum, long. c. 625–650 μ , crass. c. 400–450 μ , cellulæ spirales lat. c. 65 μ , plerumque complanatae ad apicem et basem dilatae, convolutiones novem–decem exhibentes; foramen basilare latum, margine angulis prætendentibus.

A distinct-looking type, pale yellowish-brown, usually tapering decidedly towards the base.

Limestone-Band, a few specimens only.

11. TOLYPELLA HEADONENSIS, sp. nov. (Pl. VI, figs. 2 & 3.)

Oogonium subglobosum ad basem levissime fastigatum, long. c. 450–475 μ , crass. 400–425 μ ; cellulæ spirales lat. c. 60 μ , crass. c. 40 μ , ad apicem turgidae, convolutiones novem–decem exhibentes; foramen basilare parvulum, margine prominente.

Fruits buff-coloured, with regular spiral cells, somewhat resembling in shape those of the living species *T. prolifera*, but more globose, and having the tips of the spiral cells swollen, implying a deciduous coronula. The concavity of the spiral cells in this and the following species corresponds with what is usually seen in the dried fruits of the two living British species which secrete a lime-shell.

Obtained in fair quantity from the Rodent-Bed.

12. TOLYPELLA PARVULA, sp. nov. (Pl. VI, figs. 4 & 5.)

Oogonium globoso-obovoideum ad basem subacutam paulo fastigatum, long. c. 325–375 μ , crass. c. 225–275 μ ; cellulæ spirales concavae, lat. c. 40 μ , crass. c. 30 μ , ad apicem haud aut leviter dilatae, convolutiones novem–undecim exhibentes; foramen basilare parvulum, margine prominente.

Fruits cream- or buff-coloured, differing in size and shape from

the foregoing and in having probably had a persistent coronula. They are smaller than those of any living *Tolypella*.

Obtained in fair quantity from the Limestone-Band.

Vegetative Remains. (Pl. VI.)

A large proportion of the remains of stems and branchlets appear to belong to a single type, designated as A (Pl. VI, figs. 10-12), of which the following are the characteristics:—

STEMS.—The remains of these consist of numerous short fragments. The diameter ranges from c. 250 μ to c. 400 μ , and the rows of cortical cells from about fourteen to twenty. The latter are usually of like diameter and always contiguous. There is usually considerable torsion visible in the cortex, and this is invariably dextral, as in the living *Charea*. The arrangement of the cortical system is difficult to elucidate, on account of the fragmentary character of the remains; but, from the number of rows, it may perhaps be presumed to be diplostichous, that is, having one row of secondary cortical cells to each primary row. This cannot, however, be determined, as there is no marked difference in the diameter or prominence of the rows, and no node-cells have been made out, to indicate the primary series. The cortical cells are evidently long; but their length has not been determined, as in no case has an entire cell been found. Portions have, however, been observed, measuring as much as 1250 μ . The ends of the cortical cells seem usually to taper considerably, often to a sharp point; but, whether these belong to a secondary series, or are the terminal cells of the primary series, is not apparent.

BRANCHLETS.—The remains of these are fairly numerous, but are also extremely fragmentary. They vary in thickness from about 170 to 250 μ . Like those of living species, they show little torsion. The cortex is regular, the number of cells being about fourteen to sixteen, so that the arrangement in this case may be presumed to be diplostichous, as in nearly all living species; but no trace of bract-cells has been found. Nodes are frequent, and are indicated by a unilateral swelling of the branchlet at the spot, and by the meeting of the bases of the ascending and descending cells in a more or less even circle. The length of the cortical cells of the branchlets also cannot be determined, as in no case has a complete cell been found; but that the length is evidently very irregular is indicated by the fact that the points of meeting of the apices of the ascending and descending cells do not coincide in adjoining rows.

The cortical cells of both stems and branchlets are found in a collapsed condition, presumably from desiccation, resembling those of dried specimens of recent species, and therefore appear as grooves instead of cylinders.

From the diameter of the stems and branchlets this type may be presumed to belong to a plant of about the stature of *Chara fragifera*.

The rest of the vegetative remains found, irrespective of the nodes, which will be dealt with separately, appear to belong to four types, as follows:—

TYPE B.—Short fragment of a small stem, shown in section in Pl. VI, fig. 13, about 375μ in diameter (including cortex), with eight markedly non-contiguous cortical cells, the cortex being evidently haplostichous in character, that is, having primary series only developed, so that the number of rows of cortical cells equals that of the branchlets. The cells are not collapsed.

TYPE C (Pl. VI, fig. 14).—Several short portions of a medium-sized stem about 500μ in diameter, with eight to ten cortical rows, usually non-contiguous, and for this reason, as also from the number of rows, presumably haplostichous.

TYPE D (Pl. VI, figs. 15 & 16).—A few small fragments of a large type of stem, which can only be conjectured to be about 1300μ in diameter, no complete cylindrical portion having been found. The cortical cells are very large (about 160μ in diameter), firm and thick-walled, and their number would probably be about 12. The cortex would appear to be irregular from the portions shown in fig. 15, and the cells are nodulose. There is no evidence as to whether the cortex is haplostichous or diplostichous: but perhaps the number of rows may be regarded as suggesting that it belongs to the former category. The diameter of the stem, if correctly estimated, would suggest a plant of about the stature of *Chara rudis*.

TYPE E (Pl. VI, figs. 17 & 18).—A few portions of small to medium-sized, hollow, cylindrical bodies, belonging presumably to an ecorticate Characeous plant, with small elongated bodies, resembling the spine-cells of recent species, attached and projecting at about a right angle. The nature of these latter has not been made out, and it is probable that they are foreign bodies. As they do not proceed from nodes, they cannot well be spine-cells, and as they do not communicate by a pore at the base with the internodal cell on which they occur, they evidently are not akin to the rosette-cells of *Clavator*. We hope that the discovery of more specimens of this type may result in an elucidation of its peculiarities.

The bodies shown in Pl. VI, fig. 19 are probably stem-nodes from which the branchlets have been separated. If this be the case, the number of branchlets, as indicated by the scars, would be nine to eleven. Fig. 20 shows what is apparently a less complete node of a much larger species, perhaps Type D.

The specimens already mentioned were all obtained from the Limestone-Band.

The stem-node with bases of branchlets attached (Pl. VI, fig. 21), obtained from the Rodent-Bed, belongs apparently to an ecorticate plant. The interior diameter of the stem is about 300μ , the

exterior about $450\ \mu$. The apparent thickness of the cell-wall is evidently in part due to encrustation. The branchlets are six in number, and the internal diameter is about $250\ \mu$.

The small number of the branchlets and the apparently ecorticate stem suggest the possibility that it belongs to one of the *Nitelleæ*, perhaps *Tolypella headonensis*, the fruits of which come from the same bed.

Some remains, collected by Mr. Reid from the Basement (Seed)-Bed, had not been examined during his lifetime. This gathering has proved particularly valuable, as in addition to the entire oospores present *in situ*, referred to under species 1, 3, & 6, it includes a fair quantity of the vegetative parts, among which there are several more or less complete stem-nodes with small portions of the internodes and branchlets attached. This vegetative material is unfortunately very much encrusted and extremely friable, so that it is almost impossible to make out some of the details of structure. The portions of detached stem, some of which are well preserved, all apparently belong to one of two types. Of Type 1 the internodal cell ranges from about 375 to $500\ \mu$ in diameter, and has a haplostichous cortex formed of ten contiguous or almost contiguous rows of large cells measuring about 100 to $125\ \mu$ in diameter. The cortical cells are frequently nodulose, and on some of them there are apparently clusters of three or four spine-cells. The stem therefore resembles among living species the uncommon but widely distributed *Chara canescens*. An imperfect node showing corticate branchlets probably belongs to the same species; but there is no portion of the stem-internode attached.

Type 2 has the internodal cell of about the same diameter, with a haplostichous cortex formed of about ten distinctly non-contiguous rows of small cells of less than half the diameter of those of Type 1. Most of the stem-nodes appear to belong to this type, and the branchlets apparently are uniformly ecorticate and about ten in number. There are traces of fairly large stipulodes on some of the nodes, but the encrustation prevents them from being clearly seen. In one instance there are sections of a large number of outstanding cells at the base of the branchlets. In others there appears to be only one stipulode to each branchlet. The stem-cortex of this type resembles among living species that of the rare Western European and North African *Chara imperfecta*, but that species has rudimentary stipulodes.

EXPLANATION OF PLATES IV-VI.

[All the figures are magnified 20 diameters, except figs. 9 & 21 in Pl. VI.]

PLATE IV.

- Fig. 1. *Chara Wrightii*. (See p. 183.)
2. *C. Wrightii*, var. *minor* nov.
3. *C. Wrightii*, var. *rhytidocarpa* nov.
Figs. 4-6. *Chara cæolata*, sp. nov. (See p. 184.)
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Figs. 7 & 8. *Chara cælata*, var. *bicincta* nov. (See p. 184.)

9 & 10. *C. cælata*, var. *baccata* nov.

Fig. 11. Oospore of *Chara Wrightii* (?). (See p. 184.)

Figs. 12-15. *Chara vasiformis*, sp. nov. (See p. 185.)

PLATE V.

Figs. 1-3. *Chara tornata*, sp. nov. (See p. 187.)

Fig. 4. *Chara subcylindrica*, sp. nov. (See p. 187.)

5. *C. subcylindrica* (?).

6. *Chara distorta*, sp. nov. (See p. 186.)

Figs. 7 & 8. *Chara strobilocarpa*, sp. nov. (See p. 187.)

Fig. 9. *Chara polita*, sp. nov. (See p. 187.)

10. *Chara strobilocarpa*, var. *ellipsoidea* nov. (See p. 188.)

11. *Chara helicteres* Brongniart. (See p. 186.)

12. *Chara polita*, sp. nov. (See p. 187.)

13. *Chara strobilocarpa*, var. *bitruncata* nov. (See p. 188.)

PLATE VI.

Fig. 1. *Chara turbinata*, sp. nov. (See p. 188.)

Figs. 2 & 3. *Tolypella headonensis*, sp. nov. (See p. 188.)

Fig. 4. *Tolypella parrula*, sp. nov. (See p. 188.)

5. *T. parrula* (?).

Figs. 6-8. *Chara* spp. (?).

Fig. 9. Perforated oogonium of *Chara cælata* (?) $\times 40$.

Figs. 10 & 11. Portions of branchlets, Type A. (See p. 189.)

Fig. 12. Portions of stem, Type A.

13. Section of stem, Type B. (See p. 190.)

14. Section of stem, Type C. (See p. 190.)

Figs. 15 & 16. Portions of cortex, Type D. (See p. 190.)

17 & 18. Portions of stem, Type E. (See p. 190.)

19 & 20. Stem-nodes (?). (See p. 190.)

Fig. 21. Stem-node, with portions of stem-internode, and bases of branchlets.
 $\times 27$.

DISCUSSION.

Dr. M. C. STOPES congratulated the Authors warmly upon their work, which seemed to be the kind of palæobotanical work much to be desired at present. She remarked on the exceptional nature of the Characeæ in depending so greatly on huge single cells for their external and visible morphological features, and suggested that the dearth of *Chara*-remains in the blackened and carbonaceous layers might be due to the solution of their native carbonates prior to fossilization in water with excess of carbon dioxide. She asked whether in the well-preserved fruits the carbonates were replaced by silicates to any extent, and whether the new bossed and ornamented forms of fruits could be compared at all with the skeletal or shell enlargements of certain races of animals arising some time before extinction.

Mr. J. GROVES expressed his regret at the unavoidable absence of Mr. Clement Reid. He thanked Dr. Stopes for her remarks, and in reply to her questions, he stated that he did not find any appreciable trace of silicates in the fossil fruits, which dissolved almost entirely when treated with acid; he also stated his opinion that the pronounced ornamentation of the Characeæ could not be regarded as a phase of development that preceded extinction. He thanked the Fellows for their reception of the paper.

C.R. photo.

QUART. JOURN. GEOL. SOC. VOL. LXXVII, PL. V.

C.R. photo.

CHAROPHYTA FROM THE LOWES HEADON BEDS

C.R. photo.

CHAROPHYTA FROM THE LOWER HEADON BEDS