CALCAREOUS ALGAE NEW TO THE BRITISH CARBONIFEROUS

by GRAHAM F. ELLIOTT

ABSTRACT. The first British records of two Lower Carboniferous algal taxa known from the U.S.S.R. and elsewhere are given: *Ungdarella deceanglorum* sp. nov., representing the Ungdarellaceae, an extinct red algal family; and *Exvotarisella maponi* gen. et. sp. nov., representing the tribe Bereselleae of the family Dasycladaceae (green algae). *U. deceanglorum* is from the Visean of Wales, probably lower D_2 Zone: *E. maponi* comes from the D_2 Zone of Northumberland. *Exvotarisella* is considered to be structurally the most advanced genus of the Bereselleae.

DURING an examination of that part of the Garwood collection of fossil algae in the British Museum (Natural History) two interesting occurrences were noted of algae described from Russia and well known from elsewhere, but not until now from Britain. The genera represented are *Ungdarella*, referable to the Rhodophyceae or red algae but not to any living family of this class, and a new genus of the dasycladacean tribe Bereselleae (Chlorophyceae or green algae). Both occur in this country in the Lower Carboniferous, Visean, D_2 Zone, and are now described below.

RHODOPHYCEAE

Family UNGDARELLACEAE Maslov 1956

Genus UNGDARELLA Maslov 1950

Remarks. This genus was described by Maslov (1950) from the Russian Upper Carboniferous and subsequently recognized in Iraq, Turkey, Austria, Spain, the north-west African Sahara, and the U.S.A. with a total range of Lower Carboniferous (Visean) to Upper Permian (Toomey and Johnson 1968). It is a calcified branching twig-like form, compared by Maslov and others in internal structure with two living non-calcified red algae, *Ahnfeldtia* and *Cystoclonium*, though not identical with either nor referable to the families Phylloporaceae and Rhodophyllidaceae to which they belong.

Ungdarella deceanglorum sp. nov.

Plate 81, figs. 1–5

Diagnosis. Small slender species of *Ungdarella*, with almost completely uncalcified medullary zone, and with less conspicuous cortical cell-detail than in other species.

Description. Calcified cylindrical branching thallus, twig-shaped, branches near-circular in cross-section and slightly irregular, length about 3 mm. or more (2·86 mm. seen), diameter often 0·26 mm. (0·14–0·39 mm. seen). Branching at irregular intervals, the angle of divergence ranging from 45 to 110°. Internally the thallus shows a thick calcified cortical zone surrounding an uncalcified central medullary zone: this latter is almost always a third or a little less of the outer diameter. Thus in specimens of the common diameter of

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0·26 mm. the medullary zone is 0·078 mm. diameter, surrounded by a cortical zone 0·091 mm. thick. This medullary zone is filled with clear calcite, or with strings and groups of dolomite crystals. In other species of *Ungdarella* this zone is occupied by calcified medullary cells, arranged in single or several axial strings, though not as heavily calcified as the cells of the outer, cortical zone. In two sections only of the British species it was possible from the arrangement of the dolomite crystals, colour of the calcite, etc., to measure single presumed medullary cells: they were 0·045–0·050 mm. long by 0·020 mm. wide, and 0·039 mm. long by 0·026 mm. wide. Both were central in position, and it is uncertain whether the remainder of the uncalcified medullary space was occupied by parallel strings of similar cells, or whether it formed the place of origin of the divergent cortical cells before they became calcified. This uncalcified medullary zone distinguishes *U. deceanglorum* from other species of the genus, whose authors were able to measure and describe medullary cells when sufficient material was available (cf. *U. uralica*, Pl. 83, fig. 6).

The cortical cells are well calcified and form the whole thickness of the outer zone. They show as close-packed parallel single strings or files of cells, inclined at an acute angle of 10–15° to the long axis of the branch, so that they traverse a considerable length before reaching the exterior. A slight irregularity is occasioned by sporadic division, the new cell-strings continuing close-packed with the others. The individual cells are about 0·016 mm. long and 0·013–0·014 mm. wide, squarish in cross-section but in sections taken adjacent to and below the sites of thallus-branching the proportions alter: examples are 0·013 mm. long by 0·020 mm. wide, and 0·010 mm. long by 0·013 mm. wide. The main lateral cell-walls are much more conspicuous than the transverse septa in vertical section. In oblique transverse sections the steep inclination of the cell-strings occasions a curious appearance, one side of the section showing a concentric structure and the other an irregularly radial one.

U. deceanglorum has the characteristic thin-section appearance of other species of the genus: a bleached wood or watered silk effect. The cell-details of *Ungdarella* are not conspicuous as in the Solenoporaceae or Corallinaceae, and in *U. deceanglorum* this negative character is especially marked.

Holotype. The specimen figured in Plate 81, fig. 1 from the Lower Carboniferous, White Limestone Division, probably Lower D_2: Bron-heulog Quarry, Trefor Rocks, 1½ miles east of Llangollen, Denbighshire, Wales. (Wedd 1927, pp. 109, 129, 148.) Brit. Mus. (Nat. Hist.), Department of Palaeontology, reg. no. V55400.

EXPLANATION OF PLATE 81

Figs. 1–5. *Ungdarella deceanglorum* sp. nov. Lower Carboniferous. White Limestone Division, probably lower D_2; Bron-heulog Quarry, Trefor Rocks, Llangollen, Denbighshire, Wales. All from reg. no. V55400. 1, Holotype, longitudinal section showing branching of thallus, fine oblique divergent files of cortical cells, and medullary zone replaced by light transparent calcite or dark dolomite crystals. Other, random cuts in section; ×30. 2, Longitudinal section of another branching specimen; ×30. 3, Longitudinal and transverse sections, the former showing files of cortical cells, and medullary zone replaced by transparent calcite with central string of dolomite crystals suggesting original single string of large medullary cells; ×40. 4, Two transverse sections, slightly oblique; the larger showing clearly the radial appearance of cortical cell-structure on one side of the section and concentric appearance on the other, typical of such sections; ×40. 5, Another longitudinal section showing layered appearance of cortical cells, and medullary zone replaced in different areas by light transparent calcite or areas of dark dolomite crystals; ×40.

Paratypes. The specimens figured in Plate 81, figs. 3, 4; from the same thin-section as the holotype.

Other material. Numerous other random sections.

Remarks. Toomey and Johnson (1968) gave detailed comparison-tables for structures and measurements of all described *Ungdarella* spp. up to date. *U. deceanglorum* is a smaller, more slender species, with smaller cortical cells, than both the type *U. uralica* Maslov, and the other Visean species *U. maslovi* Chanton. The non-calcified medullary zone of the British species is characteristic. The species throws no light on the disputed basal attachment in this genus (Toomey and Johnson 1968, p. 560), and no reproductive structures have been recognized.

Of the two living non-calcified red algae with which *Ungdarella* has been compared, *Ahnfeldtia* shows irregularly concentric rings of secondary thickenings, considered to be in part associated with successive dichotomies (Fritsch 1945, p. 495). In *U. deceanglorum* the apparent concentricity arises from the angle of cut across the normal cortical cells. *Cystoclonium* shows near-vertical medullary cells, but those of the cortex are much more irregular and directed outwards at a much greater angle from the branch-axis than in *U. deceanglorum*. Although these comparisons are valid, and *Ungdarella* probably was a red alga, the relationship is not necessarily close.

Associated in the type thin-section are small foraminifera, brachiopod, and echinoderm debris, and the dasycladacean alga *Koninckopora inflata* (de Kon.) Wood.

The specific name commemorates the old British tribe of Deceangli, whose territory in Roman times lay in what is now Flintshire and part of Denbighshire.

CHLOROPHYCEAE-BERESELLEAE

The Bereselleae are a tribe of tiny dasycladacean algae of Carboniferous age, the genera mostly described from the U.S.S.R., and reviewed by Kulik (1964), and later recognized from rocks of the same age in Turkey and in the north-west African Sahara.

The British examples now recorded were first noted in a Garwood Collection thin-section labelled 'Oxford Limestone, Bean Bed, base D_2; Northumberland'. This is a well-known band at the base of the Lower Carboniferous Middle Limestone Group in the Northumberland Province: the limestone contains small partly pyritic organic nodules with *Girvanella*, first recognized and studied by Garwood. Search in the collection produced a limestone specimen labelled similarly to the thin-section, but further annotated by Garwood. From this it appears that the limestone came from one of two old exposures of the Oxford Limestone at Wisplaw. This locality is four miles north-north-east of Alnwick, Northumberland; the old exposures are mentioned in Carruthers (1930, p. 46). The Oxford from which the limestone takes its name is a tiny locality four miles south of Berwick-on-Tweed. Further thin-sections cut from the limestone were closely similar to the original section, and showed more Bereselleae.

Subsequent discoveries, summarized and discussed in a recent study of the Lower Limestone Group of the Otterburn, North Tyne area of Northumberland by Frost (1969), have shown that the Oxford Limestone does not mark the base of the D_2 Zone, which occurs considerably below this (Frost 1969, pp. 299–301, fig. 6). The Oxford limestone is therefore not basal D_2 as Garwood considered, but well within this zone. The nodules with *Girvanella* are determined by Frost as *Osagia* (Twenhofel 1919), a

form-genus applied to some Palaeozoic nodular associations of small algal filaments and encrusting nubeculariform foraminifera (cf. Johnson 1946, 1947).

CHLOROPHYCEAE

Family DASYCLADACEAE Kützing 1843 orth. mut. Hauck 1884

Tribus BERESELLEAE Maslov and Kulik 1956

Genus EXVOTARISELLA gen. nov.

Diagnosis. Large atypical member of the Bereselleae showing primary, secondary, and tertiary branches as in the subgenus *Trinodella* but with thick primary and secondary branches (unlike *Trinodella* where all branches are uniformly thin), and with tertiary branches much longer than primary and secondary branches (in *Trinodella* the primary branches are longer than the secondary and tertiary branches). Lower Carboniferous, D_2: Northumberland, England. Type-species: *E. maponi* sp. nov.

Exvotarisella maponi sp. nov.

Plate 82, figs. 1–5, Plate 83, figs. 1–5

Description. Calcareous hollow dasyclad cylinder, straight or gently curved, of up to 5 mm. or more length (5·096 mm. seen broken), with diameters of 0·26–0·45 mm. external and 0·104–0·195 mm. internal (d/D 40–47%). Verticils of horizontally directed lateral branch-systems, each estimated to contain 14–20 primary branches. The verticils are set 0·039–0·065 mm. apart along the stem-cell cavity; between them the stem-cell cavity constricts slightly, to give a regular internal annulation. In general the detailed dimensions are more or less proportional to external size, but relatively long, slim specimens occur noticeably. Primary branches of about 0·026 mm. diameter at the stem-cell, extending outwards for 0·026 mm. before bifurcating. Secondary branches diverging at about 45°, with diameter of 0·013 mm. and length of 0·026 mm.; tertiary branchlets about 0·005 or 0·006 mm. diameter, but 0·052–0·078 mm. long. Each primary probably divides into four secondaries, and each secondary probably into four tertiaries: possibly with some variation in this character.

Holotype. The specimen figured in Plate 82, fig. 2; from the Lower Carboniferous, Northumberland Middle Limestone Group, Oxford Limestone, D_2 Zone: Wisplaw, Alnwick, Northumberland. Brit. Mus. (Nat. Hist.), Dept. Palaeont., reg. no. V55393.

EXPLANATION OF PLATE 82

Figs. 1–5. *Exvotarisella maponi* gen. et. sp. nov. Oxford Limestone, Bean Bed; Lower Carboniferous, D_2 Zone. Wisplaw, Alnwick, Northumberland. 1, Longitudinal section of slightly curved and sinuous large example, ordinary preservation, ×30; reg. no. V55398. 2, Holotype, slightly oblique transverse section, pyritic preservation, showing pyrite-filled branch-structure with primary, secondary, and tertiary branching, ×60; V55393. 3, Paratype; oblique-transverse section, pyritic preservation, showing internal annulation and pyrite-filled primary, secondary, and tertiary branches, ×60; V55399. 4, Longitudinal section of slightly sinuous individual, ordinary preservation, ×40; V55391. 5, Slightly oblique transverse section, pyritic preservation, individual with long, slim, atypical branches (cf. *Dvinella* or *Trinodella*), ×60; V55396.

Paratype. The specimen figured in Plate 82, fig. 3; same locality and horizon as holotype. Brit. Mus. (Nat. Hist.) Dept. Palaeont., reg. no. V55399.

Other material. Very numerous sections in seventeen thin-sections prepared from the same sample.

Remarks. Although the general appearance of members of the Bereselleae is characteristic, distinction between the component genera is often difficult. This is due to the extreme fineness and close grouping of the lateral branches, so that the exact nature of the preservation is very important.

Of the five genera or subgenera of the Bereselleae described hitherto, *Beresella*, *Samarella*, and *Goksuella* show various groupings of single lateral branches (primaries): in *Dvinella* these primaries divide once into several secondaries, and in *Trinodella* these

TEXT-FIG. 1. Diagrammatic two-dimensional representation of branching in *Dvinella*, *Trinodella*, and *Exvotarisella* (left to right). There are at least four branches at each point of division in the actual three-dimensional specimens, and the relative branch-lengths vary between different species of *Dvinella* and similarly between species of *Trinodella*.

in turn divide into tertiaries (Maslov and Kulik 1956, Güvenc 1966). *Goksuella* is set apart by a branching thallus; in all the others the thallus is a single, straight or curved, rod-like structure.

In the Northumberland fossils preservation is usually poor for elucidation of detail; in thin-section the areas of branch-structure, representing consecutive verticils, appear as grey truncate cones, amorphous or with the branch-structures indistinct. Calcite crystals may be continuous from the stem-cell filling into the replacement calcite of the walls, so that the boundary is only traceable by a faint colour-change. Some of the branches have the appearance of division, but this could be due to bunched primaries.

There exists a minority of specimens showing partial pyritic preservation, usually found in the vicinity of the organic partly pyritic nodules with *Girvanella* and encrusting organisms. Here again, preservation has been capricious, and in most cases the pyrites fills the stem-cell, or encrusts the outer surface of the tubular dasyclad, but does not penetrate into the branch-systems. It is only with the very small minority of specimens showing pyritic branch-infilling that the diagnostic reference may be made. These show primaries branching into secondaries with great clearness, but care has to be taken to distinguish between true tertiary branching and the regions of apparent overlap between bunched secondaries (cf. *Dvinella*, Khvorova 1949). Thus the tertiary branching characteristic of *Trinodella* and *Exvotarisella* can be definitely seen only on very few specimens, which appear to be favourably orientated sections of those showing secondary branching

as in *Dvinella*. The earlier portions (lower thallus) of individuals of *Trinodella* and *Exvotarisella* may by analogy with other dasyclads be expected to show simpler, *Dvinella* structure only, as mentioned below (p. 449).

The position is, then, that definite Bereselleae are not uncommon in the Oxford Limestone of Wisplaw. The minority of individuals which are preserved to show fine detail are all recognizable as the new genus or may be supposed to be so. None of the others show equal clarity of detail to be definitely referable to other genera. It would seem reasonable, therefore, to suppose that all are referable to the one genus and species, though there are one or two doubtful individuals. The types chosen show fine detail and in this respect are not typical of the majority of the specimens: the branch-dimensions given above under 'Description' are based on the former. It is true that in Saharan Carboniferous rocks examined by me more than one genus of Bereselleae occurs in the same section, but in these Bereselleae are so abundant as to make up an appreciable portion of the rock-volume. In the Northumberland rock they form a minor element only.

Exvotarisella maponi is easily distinguishable from another tiny English Carboniferous dasyclad, *Nanopora anglica* (Wood 1964), which shows simple straight primaries set almost equidistantly, and not bunched.

Exvotarisella differs from the three species of *Trinodella* tabulated by Kulik (1964), by its large size, thickened primary and secondary branches, and in the differing relative proportional lengths of primary, secondary, and tertiary branches and branchlets, though this last character differs between the species of *Trinodella*. The branch-thickening is important: in most Bereselleae the branches are of uniform thickness, usually about 0·002 or 0·005 mm. diameter, whether single, or dividing once as in *Dvinella* or twice as in *Trinodella*. Only in *Dvinella gracilis* Kulik are the secondaries of lesser diameter than the primaries. *Trinodella* is less common than *Dvinella* and is placed by the Russians as a subgenus of the latter. In an interesting correlation between the structure of the Bereselleae and their ecology (based on the nature of the sediments in which the fossils occur) Kulik (1964) supposed that the coarser sediments in which *Dvinella* and *Trinodella* are preserved indicate shallow, disturbed-water environments. In these the tendency to formation of a more massive calcareous dasycladacean envelope with fewer verticils led to a compensatory mechanism for assimilation by division of the lateral branches. From this point of view, their branching is simply a variant of the densely clumped, thin, single branches of the more simple genera, which flourished in deeper quieter waters.

EXPLANATION OF PLATE 83

Figs. 1–5. *Exvotarisella maponi* gen. et. sp. nov.; Oxford Limestone, Bean Bed, Lower Carboniferous, D_2 Zone, Wisplaw, Alnwick, Northumberland. 1, Thin-section of rock showing several examples of *Exvotarisella*, normal preservation, ×30; reg. no. V55395. 2, Transverse section of example showing incomplete pyritic penetration of branch-system, ×60; V55395. 3, Transverse section, slightly distorted individual, with good pyritic penetration of part of the branch-system, ×60; V55396. 4, Longitudinal section, showing pyrite-filled stem-cell with very little pyritic penetration of the branches, ×40; V55394. 5, Longitudinal section, curved individual, normal preservation apart from pyritic filling of part of the stem-cell adjacent to pyritized organic nodule (portion seen top right), ×30; V55397.

Fig. 6. *Ungdarella uralica* Maslov; Longitudinal section of fragment to show coarse cell-structure and well-calcified medullary cells (for comparison with *U. deceanglorum*), ×40; Zinnar Formation, Permian (Artinskian-Kungarian), Ora, Mosul Liwa, northern Iraq.

In *Exvotarisella*, however, the thickening of short primaries and secondaries followed by sprays of longer tertiaries, and the larger size of the thallus, shows a trend known in many other genera and part of the main stream of dasyclad evolution, leading to transfer of the sporangial bodies from stem-cell to side-branches (Pia 1920, Rezak 1959, Elliott 1968). From this point of view *Exvotarisella* is the most advanced genus of the Bereselleae, and if it did not share in the general extinction of its tribe, it is the one most likely to have evolved into something else.

Trinocladus of the Cretaceous and Palaeocene (Pia 1936, Elliott 1968) is a genus in which swollen primaries and secondaries are followed by tertiary branchlets. It is known that this full branch-development occurred in the later-formed portions only of the plant, the older earlier portions showing simpler branch-structure only. It seems very likely that this occurred in *Exvotarisella* also.

The English genus and species are dedicated to Mapon, the Celtic Apollo, once worshipped in the region of Hadrian's Wall, Northumberland, and elsewhere.

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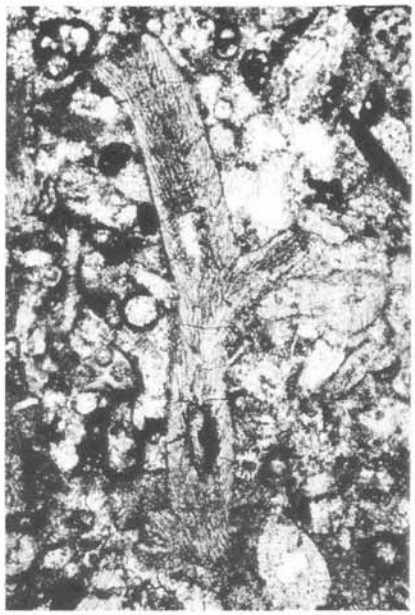

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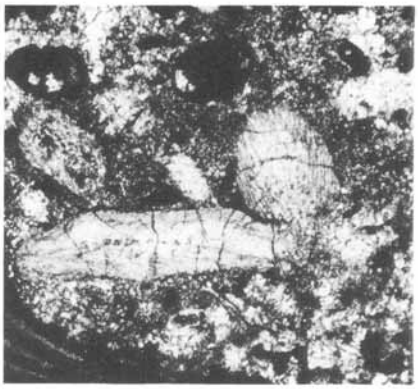

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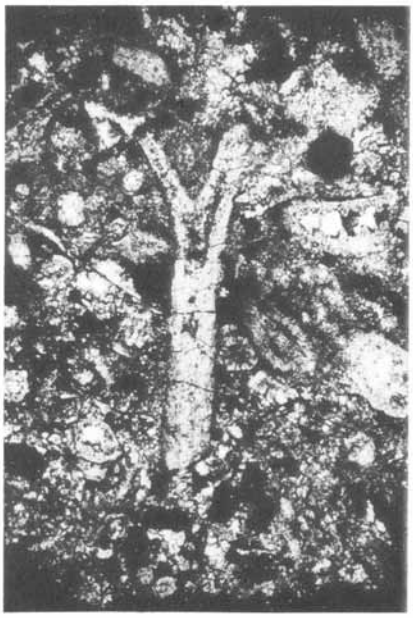

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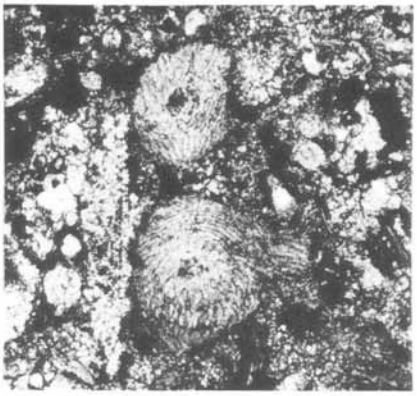

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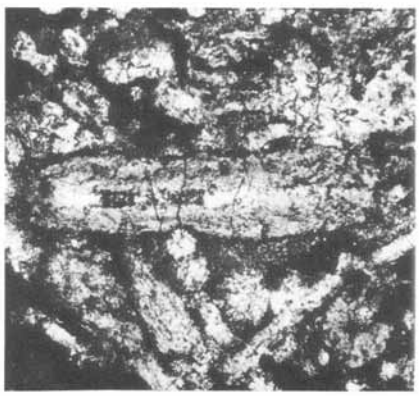

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ELLIOTT, Carboniferous Rhodophyceae (Algae)

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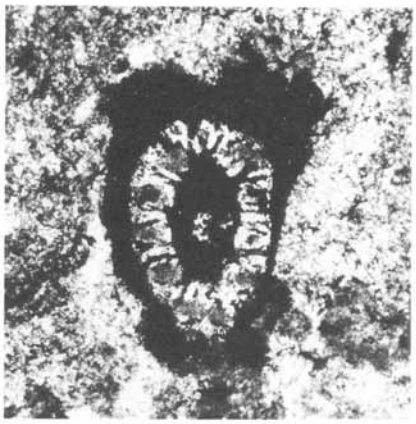

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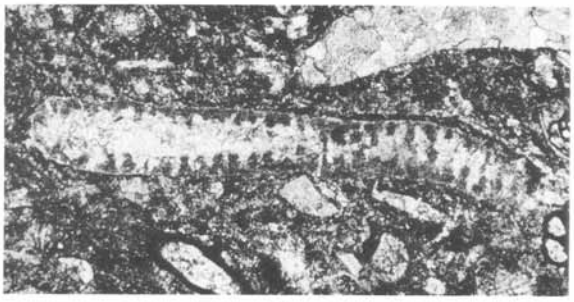

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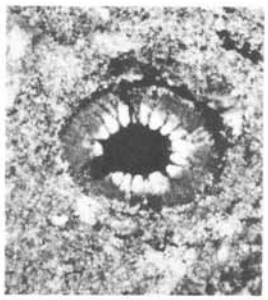

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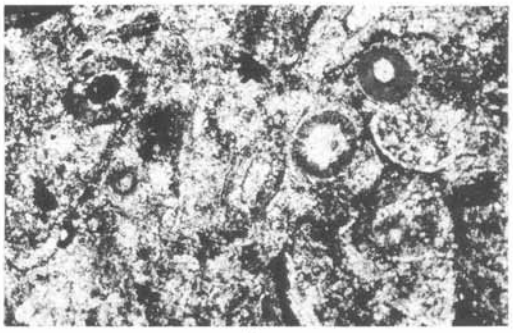
ELLIOTT, Carboniferous Chlorophyceae (Algae)



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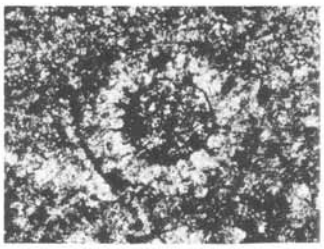

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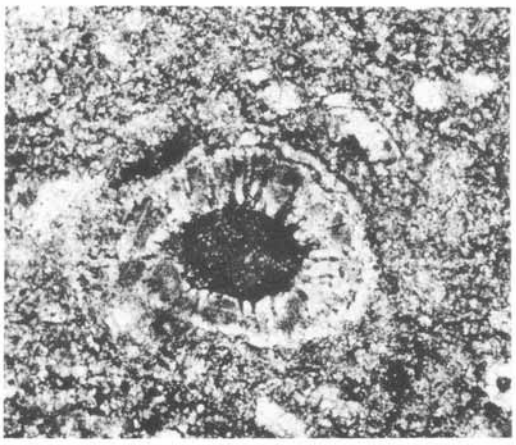

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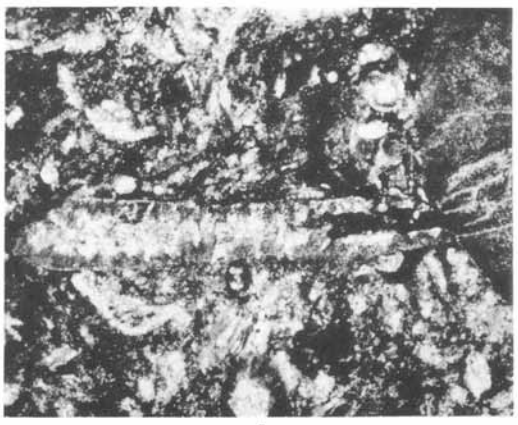

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ELLIOTT, Carboniferous Chlorophyceae (Algae)