

TRANSPORTED ALGAE AS INDICATORS OF DIFFERENT MARINE HABITATS IN THE ENGLISH MIDDLE JURASSIC

by G. F. ELLIOTT

ABSTRACT. A microflora of red, green, and blue-green algae is recorded from the Middle Jurassic Great Oolite (Bathonian) White Limestone Division, near Cirencester, Gloucestershire. New genera described are *Apophoretella* (Myxophyceae) and *Dobunniella* (Chlorophyceae, Dasycladaceae). The fossils are not found where they grew: their probable original environments are discussed, and these suggest conditions like those of the present-day Great Bahama Bank.

QUARRIES in what is now known as the White Limestone Division of the Middle Jurassic Great Oolite (Bathonian) at Daglingworth (or Dagham) Downs, east of Ermine Street to the north of Cirencester, are recorded from the beginning of the nineteenth century or earlier. The present large excavations there of Messrs. W. H. Iles and Sons (Stratton) Ltd. (Nat. Grid SP 001 061), are a rapidly extending complex which includes sections earlier described by Richardson (1930, 1933), Channon (1950), and Torrens (1967); the last gave a detailed section including much deeper levels than seen by the earlier workers.

The algae now described occur in the upper beds, of which the section seen (May 1974) was:

3. Subsurface bed at top of quarry; rubbly limestone, the pieces often showing discoloration within 0.90 mm
2. Bedded intrasparites: numerous irregular sparry seams and lenses of coarser material, including small oncolites, occasionally in regular alternation a few centimetres apart. Also occasional irregular occurrences of seams of pseudoolites with much calcareous debris of invertebrates. Macrofossils seen: *Epithyris* sp., *Protocardia* sp., *Lucina bellona* Morris and Lycett, and *Cossmannia (Eumerinea) eudesii* (Morris and Lycett). Junction with bed below obscured by talus 3.50 m
1. Pavement of waterworn limestone surface with rounded cavities and attached flat oyster-valves: 'Dagham Stone', forming the floor of the Upper Quarry workings.

Bed 1 above is Bed 6 of Torrens (1967, p. 87). Bed 2, as exposed above the talus, is Torrens's Bed 8. The dasycladacean algae now described occurred *in situ* about the middle of this bed, though the best specimens came from a loose block. The other algae came from the lower half of this bed.

The only previous record of an alga here is of *Solenopora* (Richardson 1930, 1933).

There are some ammonite records, notably of the Middle Bathonian *Morrisiceras comma* S. Buckman, from the *Lucina*-beds of Richardson (1911, 1933) in this part of Gloucestershire. These beds, terminating above at a stratigraphic break, underlie the levels exposed at Daglingworth, and it seems likely that the latter are Upper Bathonian in age (Torrens, *in litt.*, and Torrens 1967).

Myxophyceae (Blue-green algae). The Myxophyceae are frequently represented in the fossil state by calcareous crusts, nodules, and stromatolites; the associated algae originating these, if preserved, are not usually generically determinable by comparison with Recent genera. In thin-section, however, certain characteristic and consistent types of myxophyte growth are recognizable. Those recognized in the present work are given generic rank and compared with Recent taxa, but it is not claimed that the fossil genera are other than mutually distinguishable lithified myxophyte thread-structures. By reason of the nature and usual preservation of these primitive algae, the exact correspondence legitimately to be inferred between fossil and living analogues is less exact than in many other organisms, and no attempt is made to fit the fossils into the sub-ordinal classification of the living microflora.

Branching of threads, formed of serial cells, in living myxophyceae is by means of 'false-branching', where the new thread, initiated at the side of the old, continues more or less along the original line of growth. Small separate adjacent rounded cells known as heterocysts occur. These phenomena are very rarely clearly to be seen in fossils, though this has been claimed under exceptional circumstances of preservation (e.g. Elliott 1964). In the present Jurassic material little of this kind is clearly visible.

Genus ZONOTRICHITES Bornemann, emend. Elliott

Type species. *Z. lissaviensis* Bornemann, Triassic.

Diagnosis. Calcified radiate growths of slightly wavy threads, threads spaced apart, branching, and subparallel after commencement of new members, with repeated branching giving an obscure zoned effect. Thread-diameter of 0.020–0.030 mm, growths or crusts up to several centimetres across.

Bornemann's material was from the freshwater Triassic of Silesia; he referred his genus to the Recent family Rivulariaceae (Bornemann 1887). From his illustration, the thread-diameter appears to be about 0.030 mm. Algal material from the marine Upper Triassic of Oman, Arabia, with thread-diameter of 0.025 mm, was referred to *Z. lissaviensis* (Elliott 1964); the comments on preservation in this latter paper are applicable to fossil myxophyceae in general. Living myxophyceae as a group are tolerant of freshwater, brackish, marine, and supersaline environments, and are frequently abundant in the different belts of the littoral.

Zonotrichites sp.

Plate 48, fig. 3

Description. A growth of about 1.6 mm diameter showing a radiate or fan-like

EXPLANATION OF PLATE 48

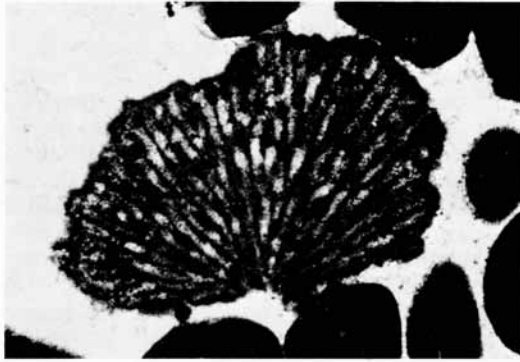
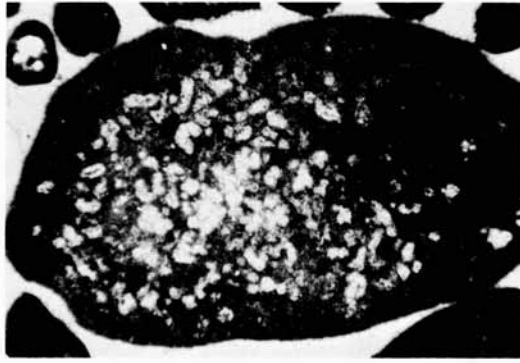
Fig. 1. *Pycnoporidium* cf. *lissicum* Elliott. Random section of rounded piece of growth, $\times 24$. V.57650.

Fig. 2. *Pseudocodium convolvens* Praturlon. Tangential section, $\times 30$. V.57651.

Fig. 3. *Zonotrichites* sp. Vertical section, $\times 40$. V.57651.

Figs. 4, 5. *Dobuniella coriniensis* gen. et sp. nov., syntypes nos. V.57652, V.57653. Transverse section of a large individual, and oblique-transverse of a smaller, $\times 40$.

All specimens from Great Oolite, Upper White Limestone (Middle Jurassic, Bathonian); Daglingworth, Cirencester, Glos.



ELLIOTT, Jurassic Algae

arrangement of dividing divergent threads of about 0.020 mm (0.018–0.023 mm) diameter. The preservation does not show the cellular structure of the threads, nor heterocysts. Initiation of new threads at the side of earlier ones (?false-branching) can be distinguished; at the points of initiation the older threads are about 0.036 mm apart, and about three such branchings can be seen in a length of 0.90 mm.

This growth is referable to *Zonotrichites* as defined above, but is insufficient for reference to a species.

Genus APOPHORETELLA gen. nov.

Type species. *A. dobunnorum* sp. nov.; Middle Jurassic of England and Italy.

Diagnosis. Calcified radiate growths of flexuous wavy branching threads, threads spaced apart and parallel, with branching tending to occur simultaneously in adjacent threads, so giving a banded appearance in section. Thread-diameter 0.010 mm or less.

Remarks. This alga shows longer, thinner, closer, and more gracefully flexuous threads than *Zonotrichites*, from which it is easily distinguishable.

The distinction between various types of fossil algae, red, green and blue-green, showing more or less radiate threads, or tubules, is not always easy. Thread-diameter is important. The visibility of cell-division within the thread, and whether the threads or tubules are touching or fused, as opposed to separate, is also diagnostic under conditions of good preservation. In *Solenopora* and its allies the partitions separating cells are usually visible, the cell rows are closely packed, curved-radiate outwards in growth, and appear as calcite-filled tubules, representing a former rigid growth. In the Myxophyceae, more variously preserved, the threads are usually separate, often dark in colour, serial cells are not normally visible, and there is a characteristic irregularity suggesting original flexibility.

Doubtful species are known. *Solenopora texana* from the Permian (Johnson 1951) is described with 'No cross partitions visible' (of cell-rows) and 'Cells rather widely spaced with thick coating of algal dust between'; this is not a solenoporoid character. The author compares it to a *Lithothamnium*, whose cells are usually characteristically different from those of *Solenopora*. I have not examined specimens of this; Johnson's illustrations suggest similarity to the Mesozoic myxophyte *Marinella* (Pfender 1939), but not to *Apophoretella*.

The new generic name is from Apophoreta, the morsels of the Roman dinner which convention permitted a guest to take away.

Apophoretella dobunnorum sp. nov.

Plate 49, fig. 3

Holotype. The specimen figured in Plate 49, fig. 3 (thin-section); Middle Jurassic (Bathonian), Great Oolite, Upper White Limestone, Daglingworth Quarry, Gloucester Road, N. of Cirencester, Glos. Reg. No. Brit. Mus. (Nat. Hist.) Dept. Palaeontology, V.57656.

Diagnosis. Characters as given for the genus.

Description. The growth is about 2.6 mm in maximum diameter. In section it shows fine parallel threads radiating from a basal centre seen to one side of the section. Due

to poor preservation it is difficult to decide on exact thread-diameters, but they are much less (0.010 mm or less) than in *Zonotrichites*. The threads are long, sinuous, and parallel, the interstices being a little more than thread-diameter. Branching tends to occur simultaneously in adjacent threads, so giving a banded effect to the growth. Heterocysts are not distinguishable.

In comparison with *Zonotrichites* this alga shows longer, thinner, closer, and more gracefully flexuous threads, and is easily distinguishable.

The 'radially-orientated *Schizothrix*-like organic tubes' of Hudson (1970, fig. 8A), from the Scottish Middle Jurassic, are similar to the threads of *Apophoretella*.

The trivial name commemorates the Dobunni, the British tribe in whose former territory the fossil is found. Daglingworth Quarry is near Bagendon, the site of their pre-Roman tribal centre.

Altered Myxophyte Threads

Plate 50, fig. 5

Hudson (1970, fig. 8C, caption B) has also figured 'fine algal tubes, comparable to *Schizothrix*' from the Scottish Middle Jurassic, comparing his material with an illustration of Monty (1967, pl. 11, fig. 2). Monty's figure shows 'Filaments of *Scytonema* and *Schizothrix* . . . reduced to small black streaks within or between crystals of the new mosaic' and is to illustrate the 'formation of crusty flakes built by *Schizothrix*', a post-mortem change in the top intertidal zone and mangrove fringes of the present-day Bahamas. This indication of a Bahaman-type littoral was considered significant in Hudson's study of certain algal beds in the Scottish Great Estuarine Series.

A very similar piece is now figured from Daglingworth; its significance is considered below.

Oncolite

Plate 50, fig. 3

Oncolites are calcareous nodules formed by consecutive growths, predominantly algal, around a nucleus. Typical oncolites, while often irregular in form and very variable, are more or less rounded, and must have been water-moved during growth. A summary account of certain Recent intertidal and subtidal forms and their environments from Florida and the Bahamas was given by Ginsburg (1960).

The Daglingworth example now figured is about 7 mm across, and in section shows many concentric layers of probable myxophyte origin with included detritus. The outer margins are undamaged apart from post-mortem pressure-solution against adjacent ooliths.

These fossils are probably the origin of the record of 'many little "pellets", regular and irregular, of pure white limestone' (Richardson 1933), from the oldest part of the quarry.

CHLOROPHYCEAE (Green Algae)
 Order SIPHONOCLEDALES (Blackman & Tansley) Oltmanns, 1904
 Family SIPHONOCLEDALEAE Schmitz, 1879
 Genus PYCNOPORIDIUM Yabe and Toyama, 1928
Pycnoporidium cf. *liasicum* Elliott, 1965

Plate 48, fig. 1

Description. Rounded remains of a *Pycnoporidium* sp. occur, but are not well preserved. *P. lobatum* Yabe and Toyama is abundant in the Tethyan Upper Jurassic and Lower Cretaceous, and *P. cf. lobatum* was determined from the Scottish Middle Jurassic (Hudson 1970). From the dimensions of the internal structures of the present specimens, it appears closest to the very similar but larger *P. liasicum* described from the Lower Jurassic of Greece (Elliott 1965).

Order SIPHONALES Blackman & Tansley, 1902
 Family CODIACEAE Kützing orth. mut. Hauck, 1884
 Genus ARABICODIUM Elliott, 1957
Arabicodium sp.

Plate 49, fig. 4

Description. A broken segment, with length (incomplete) of 1.95 mm and diameter of 1.04 mm. The medullary zone of irregular longitudinal threads is missing and replaced by clear calcite, but typical subcortical zones of fine irregular tangled and outwardly directed threads (the area of original plant calcification) are distinguishable.

Arabicodium is common as a facies-fossil in the Upper Jurassic and Lower Cretaceous of the Middle East and elsewhere. In England, a small piece of codiacid probably referable to this genus has been seen by me in the Kemble Beds (Great Oolite) elsewhere in the Cirencester area (Elliott 1973). The relegation of *Arabicodium* (and of *Boueina*) to subgenera of *Halimeda* (Elliott 1965) is not now considered correct.

Order DASYCLADALES Pascher, 1931

Records of dasycladacean algae (family Dasycladaceae) from the limestones of the English Jurassic are extremely rare by comparison with those from equivalent rocks in alpine Europe and Asia. One English example is *Stichoporella stutterdi* (Carruthers) Edwards. This was collected from the Stonesfield Slate and elsewhere in the nineteenth century, and recognized as dasycladacean by Edwards (1928). What

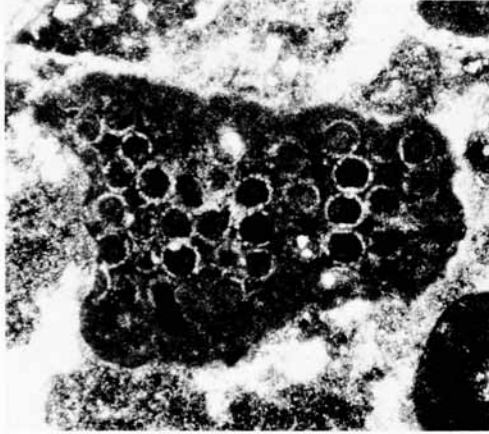
EXPLANATION OF PLATE 49

Figs. 1, 2. *Dobuniella coriniensis* gen. et sp. nov.; syntypes nos. V.57654, V.57655. Tangential and vertical sections, $\times 55$ and $\times 35$ respectively.

Fig. 3. *Apophoretella dobunorum* gen. et sp. nov.; holotype no. V.57656. Vertical section, $\times 40$.

Fig. 4. *Arabicodium* sp. Vertical section of broken segment, $\times 40$, V.57657.

All specimens from Great Oolite, Upper White Limestone (Middle Jurassic, Bathonian); Daglingworth, Cirencester, Glos.



ELLIOTT, Jurassic Algae

is surmised of the conditions of deposition of English marine carbonate Middle Jurassic rocks, and of their estimated palaeolatitude, suggests that their original littoral would have included suitable areas for dasycladacean growth, by comparison with the present-day occurrences of living members of the family. It is possible that for some reason opportunities for the migration of these plants to what is now the English area were limited. Alternatively, it may be that the dasycladaceans of the Jurassic had not achieved temperature tolerances equal to those shown by present-day representatives, which occur as far north as the Mediterranean. Thus the present addition of two more English records is of special interest. As they are not usually conspicuous fossils after the Triassic, it is possible that others remain to be discovered.

Family DASYCLADACEAE Kützing orth. mut. Hauck, 1884
 Tribe THYRSOPORELLEAE Pia, 1927
 Genus DOBUNNIELLA gen. nov.

Type species. *Dobunniella coriniensis* sp. nov. Middle Jurassic of England.

Diagnosis. Cylindrical calcareous dasycladacean tube showing verticils of branches somewhat like those of *Thyrsoporella*; each branch with a very wide primary, two swollen secondaries, and four swollen tertiaries.

Remarks. *Dobunniella* shows the thickened, swollen, presumed cladospore branches characteristic of the Thyrsoporelleae. In this character it is more like *Thyrsoporella* itself and the related *Belzungia*, both Palaeocene-Eocene, than like *Trinocladus* of the Cretaceous and Palaeocene. The branch-system is, however, much more simple than that of the genera quoted. Massieux (1966) gives the branch-plan of *Thyrsoporella* as 1:2:8:32, and that of *Belzungia* as 1:2:4:8:16:32. *Dobunniella* shows only 1:2:4. A further difference is that unlike the Tertiary genera, the branches of *Dobunniella* are not horizontal (i.e. not at right angles to the long axis of the stem-cell) but are inclined distally. The extent to which the thick and crowded tertiaries protruded outside the zone of calcification in life, and whether possibly they were there further divided or not, is not known, but *Dobunniella* seems to be a primitive genus of its tribe.

There are two other Jurassic records of alleged Thyrsoporelleae, and one Triassic record. *Thyrsoporella* n. sp. was recorded from the Lower Lias of Yugoslavia (Nikler and Sokač 1968, p. 171, pl. 2, fig. 5). *Thyrsoporella* (?) *hatigamoriensis* was described and figured from the Upper Jurassic of Japan (Yabe and Toyama 1949, p. 42, fig. 2).

EXPLANATION OF PLATE 50

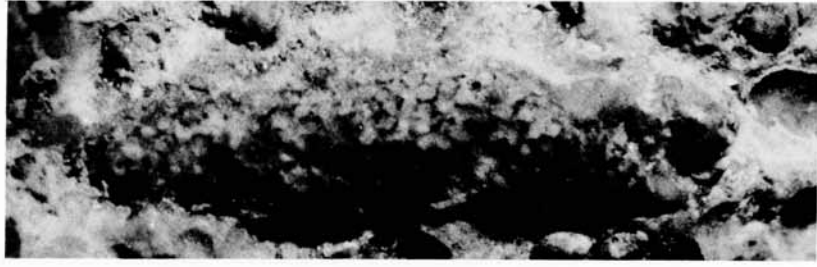
Fig. 1. *Dobunniella coriniensis* gen. et sp. nov.; syntype no. V.57658. Outer surface of solid specimen in matrix, $\times 30$.

Figs. 2, 4. *Cylindroporella* cf. *arabica* Elliott. Oblique-longitudinal and oblique-transverse sections, $\times 100$. V.57659, V.57661.

Fig. 3. Oncolite, section $\times 12$. V.57660.

Fig. 5. Intrasparite peloid showing altered myxophyte threads, $\times 300$. V.57661.

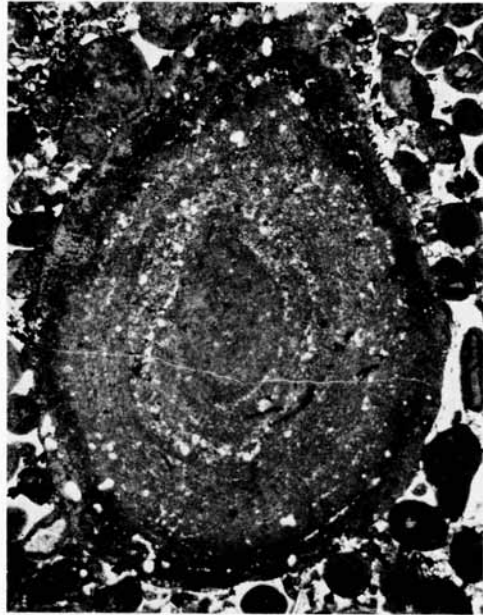
All specimens from Great Oolite, Upper White Limestone (Middle Jurassic, Bathonian); Daglingworth, Cirencester, Glos.



1



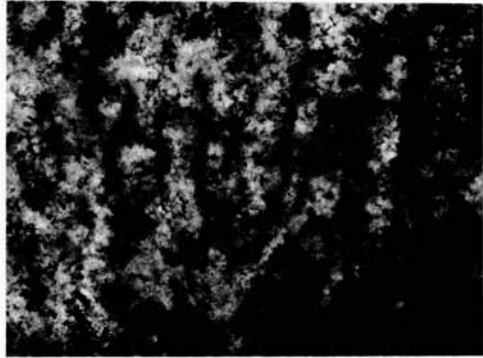
2



3



4



5

ELLIOTT, Jurassic Algae

Neither of the figures permits a critical comparison with *Dobunniella*, though a reference to 'branching of the fourth branches from the third ones' in the Japanese account, and the regular banded appearance of branchlets in tangential section, show that this species is certainly not referable to *Dobunniella*. Like *Dobunniella*, it seems from the authors' account to have been poorly calcified near the stem-cell; also, its branchlets seem to have been fewer than in Eocene *Thyrsoporella*. However, *Placklesia multipora* Bilgütay, from the Upper Triassic of Austria (Bilgütay 1968) is earliest of all and shows thickened branches dividing to branchlets of the fifth degree (1:2:8:32:128) very clearly, being thus much more advanced in this character than *Dobunniella*. Another member of the Thyrsoporellae, *Dissocladella*, whose species are mostly Cretaceous-Eocene, is known also by an older Mesozoic species (?Upper Triassic-?Upper Liassic of Greece): *D. cretica* (Ott 1965). It seems that, although best known from the Cretaceous-Eocene, the Thyrsoporellae existed from the Triassic onwards.

The name of the new genus commemorates the Dobunni, the tribe inhabiting the Cotswold area in Roman times.

Dobunniella coriniensis sp. nov.

Plate 48, figs. 4, 5; Plate 49, figs. 1, 2; Plate 50, fig. 1, text-fig. 1

Syntypes. The specimens figured in Plate 48, figs. 4, 5; Plate 49, figs. 1, 2; Plate 50, fig. 1; Nos. V.57652, V.57653, V.57654, V.57655, V.57658; from the Middle Jurassic (Bathonian), Great Oolite, Upper White Limestone, Daglingworth Quarry, Gloucester Road, Cirencester, Glos.

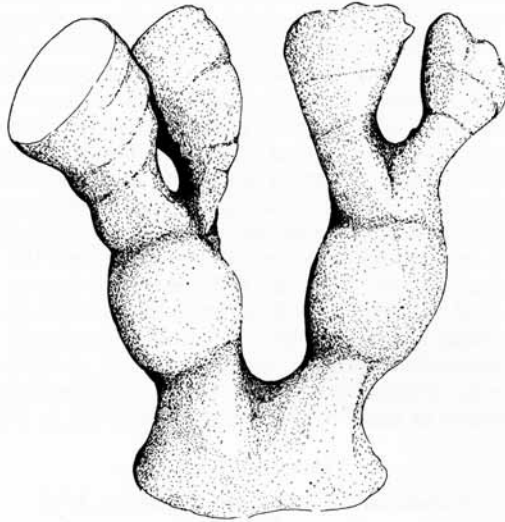
Diagnosis. *Dobunniella* of estimated 8 mm length or more, external diameter up to 1.7 mm, d/D ratio 36-41%; inner calcification weak.

Description. The species is represented by numerous broken pieces of the tubular calcareous encrustation of the plant. The longest fragment seen measured 6.5 mm; the actual plant would be longer, giving an original 'length' (height) of 8.0 mm or more. A normal external diameter is about 1.25 mm; two such specimens (1.25, 1.24 mm) have internal diameters of 0.45 mm giving a d/D ratio of 36%. Specimens of smaller external diameters 0.86 and 0.96 mm give d/D ratios of 41% and 40% respectively. However, a diameter of 1.7 mm has been measured on a large but ill-preserved specimen.

Consecutive verticils are set about 0.22 mm apart. Each verticil usually contains six branches, the inner portions set at an angle of 40-45° distally from the horizontal. These branches are thick and swollen, so that the intervening primary plant calcification is much less than in many dasycladaceans. The calcification appears to have been weak immediately adjacent to the stem-cell. Where a clear delimitation of the junction of a primary branch with the stem-cell is to be seen, with the complete calcified interstice between this and the next primary visible, the measurements usually indicate six branches per verticil. The larger example mentioned, however, contained eight.

In transverse section each branch is seen to begin with a wide and short primary, diameter 0.180 mm. This quickly divides into two divergent secondaries, waisted (diameter 0.063 mm) on leaving the primary but swelling out to diameters of 0.108 mm. Each secondary then divides into two tertiaries, also waisted (0.054 mm diameter) and then expanding to a flared termination of 0.108 mm or more at the outer surface.

These tertiaries, as thick as the secondaries, are accommodated within the wall-thickness (text-fig. 1) by irregular orientation vertically or at an angle to the plane of the secondaries, so that the full terminal thickness of the tertiaries is at the outer surface in all cases. Because of this, sections give a more confused appearance than, say, in *Thyrsoporella* itself. Occasionally a secondary appears to produce only one, or three, tertiaries, but this is probably due to the section cutting adjacent tertiaries from separate consecutive verticils. The appearance of a tertiary divided into adpressed



TEXT-FIG. 1. Reconstruction of a single living radial branch, freed from the aragonitic surround, in a verticil of a full-grown *Dobunniella coriniensis* Elliott. The drawing shows the morphology and relationship of the primary, secondary, and tertiary portions of the branch; the central stem-cell would have been at the base of the illustration, the exterior of the plant at the top.

incipient quaternaries (cf. *Dinarella*; Sokač and Nikler 1969) has also been seen, but seems likely to be due to a 'streaky' calcification of the dark infilling of the branches, since this preservation occasionally occurs in the inner portion of branches also. A vertical-tangential section near the outer surface shows numerous undivided tertiaries with diameters of 0.089–0.117 mm, reflecting levels at or just below the terminal expansions at the curved outer surface. On exposed outer surfaces the close-set pores show no clear pattern of arrangement.

Remarks. The trivial name commemorates the Dobunnian capital city of Corinium, the modern Cirencester, 4.5 km from Daglingworth.

K

Tribe DIPLOPOREAE Pia, 1920
 Genus CYLINDROPORELLA Johnson, 1954
Cylindroporella cf. *arabica* Elliott, 1957

Plate 50, figs. 2, 4

Description. Superficial ooliths show cores of fragmentary *Cylindroporella*, a genus with many species, mostly from the Upper Jurassic–Lower Cretaceous of the southern U.S.A., circum-Mediterranean, Middle East, and Madagascar. Dimensions are: outer diameter 0.405–0.455 mm, inner diameter 0.163–0.180 mm, sporangial diameter 0.081–0.117 mm, and distance between verticils 0.162 mm. There are probably six to eight sporangia per fertile verticil, set at right angles to the longitudinal axis of the stem-cell. Most of this is compatible with detail for the small species *C. arabica* Elliott (Upper Jurassic; Middle East, etc.) though the distance between verticils is greater in the English fossil. Although what are believed to be traces of sterile branches have been seen, better material is needed to confirm this distinction from *Sarfatiella* (Conrad and Peybernès 1974); *S. dubari* (Bajocian) and *C. arabica* have close similarities in size and structure. The material is insufficient for full description as a species.

Comparison-tables of *Cylindroporella* spp. are given by Fourcade *et al.* (1972) and Bernier (1971). The only species given by them as older than the Upper Jurassic is *C. ellenbergeri* (Lebouché and Lemoine 1963) from the Lower Lias of southern France. Fourcade *et al.* comment that if the emendation of the genus *Heteroporella* Pratulon by Ott (1968) is accepted, then *C. ellenbergeri* should be transferred to *Heteroporella*. Provisionally, therefore, the English *C. cf. arabica* may be the oldest known *Cylindroporella*, or share this distinction with the *Cylindroporella* sp. recorded from the late Bathonian of Israel by Derin and Reiss (1966, p. 29).

INCERTAE SEDIS

Pseudocodium convolvens Pratulon, 1964

Plate 48, fig. 2

Description. A near-vertical tangential section of an elongate fusiform or sub-cylindrical calcareous body with rounded ends, about 3.0 mm long. The outer surface shows a continuous spiral, with about fifteen turns in 1.08 mm length. Diameter of the spiral thread is 0.036–0.045 mm. The interior is recrystallized but there are traces of irregular subcortical thread-structure.

This fossil is referred to *P. convolvens* Pratulon, described from Middle or Upper Jurassic limestone in Italy (Pratulon 1964). These are elongate, subcylindrical, calcareous bodies showing an outer spiral tube, giving a surface reminiscent of certain structures in the Charophyta, and an inner structure of longitudinal medullary threads, dividing into smaller subcortical threads, reminiscent of the Codiaceae. From these resemblances it seems likely that this organism was a calcareous green alga, but its exact systematic allocation is obscure. The characters and dimensions of the English fossil are compatible with those given in Pratulon's type-description.

From the Scottish Middle Jurassic Hudson (1970, fig. 8B) has figured a similar but not identical organism, in which the internal structure is well developed, but the spiral is not well shown. This again is a single thin-section, but did not seem to be of *P. con-*

volvans itself, when Dr. Hudson kindly sent it to me for examination. It is listed by him as 'Calcareous alga of uncertain affinities, cf. *Pseudocodium convolvans* Pratulon' (Hudson 1970, p. 25, caption c).

RHODOPHYCEAE (Red Algae)
Subclass FLORIDEAE
Order CRYPTONEMIALES Schmitz, 1892
Family SOLENOPORACEAE Pia, 1927
Genus SOLENOPORA Dybowski, 1878
Solenopora jurassica Brown, 1894

Description. Rounded fragments of growths of this alga are found, sections showing the characteristic radial septate-tubular cell-rows of this species. It has already been recorded from the older part of the same quarry-complex by Richardson (1933) as a hand-specimen, and the locality is 6 km south-west of the well-known 'beetroot-stone' locality for the species at Aldgrove (Richardson 1911).

Solenopora sp.

Description. A small fragment shows in section a *Solenopora* with decisively smaller cell-diameter than that of *S. jurassica* (0.018–0.027 mm as compared with 0.036–0.045 mm). The material is insufficient for full description.

ORIGINAL ENVIRONMENTS OF THE ALGAE

Zonotrichites, *Apophoretella*, *Pycnoporidium*, *Pseudocodium*, *Solenopora*, and the oncolites occur in the intrasparite rock. This rock is largely made up of rounded pieces of carbonate sediment (over 99% soluble carbonate on analysis). They are very variable in size, mostly unfossiliferous, occasionally show contact deformation due to original slight plasticity, and are set in clear sparry cement. They are interpreted as penecontemporaneous sediment, broken up, rounded, and rapidly redeposited. The algae occur within a minority of the pieces, with the exception of the oncolites, which could have grown on the site of re-sedimentation, perhaps during slight pauses in deposition.

Of these transported algae, the myxophyceae, *Zonotrichites* and *Apophoretella*, are considered indicative of tidal calcareous mudflat or adjacent marsh conditions, with possible wide salinity fluctuations, and the 'Schizothrix-flake preservation' is a further pointer to this kind of Bahaman calcareous mud-littoral (Monty 1967). *Pycnoporidium* is compared by Johnson and Konishi (1960) to the living *Cladophoropsis*, a shallow marine warm-water alga. *Pseudocodium* is wholly extinct, and its original habitat not known. *Solenopora* was open-marine; heavily calcified in life, its rounded remains could survive considerable transport, and it is represented by a well-rounded fragment.

The Dasycladaceae and Codiacean occur in the oosparite beds. These contrast with the intrasparites in containing much more organic debris; molluscan, echinoderm, serpulid, brachiopod, and bryozoan. Remains of the dasycladacean *Dobunniella* are numerically abundant; also a lesser quantity of fragments of *Cylindroporella*.

and very rare segments of *Arabicodium*. The pieces of *Dobuniella* are broken and often worn; they occur most abundantly in concentrates of coarser materials, apparently due to size-sorting. The *Cylindroporella* remains form the cores of a small number of the superficial oolites. Like the algae of the intrasparite rock, these algal remains have been transported from their original sites of growth.

Both of the dasycladaceans grew originally in clear, shallow, warm coastal waters. Some of the *Dobuniella* remains as now preserved have a 'corroded' appearance, in which the dark infillings of the branch-cavities have resisted erosion better than the calcification. Since the original plant calcification would have been aragonitic and very fragile, some post-mortem lithification must have taken place before transport and final burial. The algae would have grown upright in patches and thickets; after death, the fragile fallen tubes would have undergone carbonate changes, infilling, and possibly other mineralization. This material, with much else, then became available for transport, and after varying wear and tear, was buried in a superficial-oolite shoal, with other skeletal debris.

The rare *Arabicodium* segments had a similar history.

The present occurrence of *Cylindroporella* is also a post-mortem phenomenon. Rey (1973) estimates the original ecology of the Lower Cretaceous *Cylindroporella* of Portugal as between tides and below low-tide level, and this is likely to have been true for the English Jurassic. In the present case a history is indicated of lithification and fragmentation of the calcareous crust from dead plants, subsequent rolling in a suitable environment to become nuclei of superficial ooliths, and final entombment. These superficial oolite developments probably indicate less rapid sedimentation than the intrasparite beds, with much more sorting of cleaner, harder materials.

Taken as a whole, the algae are indicative of warm-climate marine shallow waters. Some are characteristic of intertidal calcareous mud-flats and adjacent marsh of varying salinities like those of the present-day Bahamas, as already indicated for certain algal beds in the Scottish Great Estuarine Series of the same Middle Jurassic age by Hudson (1970). Others indicate shallow, clear, shelf waters, including both sheltered and more open environments. Their final resting-places suggest shallow-water calcareous sedimentation perhaps comparable with that of the present-day Great Bahama Bank (cf. Newell *et al.* 1959). Here living algae of types comparable to those described above grow in various habitats adjacent to or on a very extensive shallow shelf of calcareous sedimentation. This kind of marine environment is compatible with what is surmised from other evidence for the deposition of the Cotswold Great Oolite deposits.

Acknowledgements. I am grateful to Mr. D. J. Iles of Messrs. W. H. Iles & Sons (Stratton) Ltd. for facilities to collect at Daglingworth and for his interest in my investigations, to Mr. R. R. Chaplin, Gloucestershire County Surveyor for information given in the early stages of this work, to Dr. H. S. Torrens for information on ammonite records, to Mr. T. Parmenter for the photography, to Mr. M. Crawley for drawing the text-figure, and to my wife Kim Elliott for her help and encouragement both in the quarry and in ancillary fieldwork.

REFERENCES

- BERNIER, P. 1971. Deux nouvelles algues dasycladacées du Jurassique supérieur de Jura meridional. *Geobios*, **4**, 173-184.
- BILGÜTAY, U. 1968. Some Triassic calcareous algae from Plackles (Hohe Wand, Lower Austria). *Verh. geol. Bundesanst., Wien*, 1968, 65-79.
- BORNEMANN, J. G. 1887. Geologische Algenstudien. *Jb. preuss. geol. Landesanst. Bergakad.* **7**, 116-134.
- CHANNON, P. J. 1950. New and enlarged Jurassic sections in the Cotswolds. *Proc. Geol. Ass. Lond.* **61**, 242-260.
- CONRAD, M. A. and PEYBERNÈS, B. 1974. Sur quelques Dasycladales (Chlorophycées) du Dogger des Pyrénées centrales et orientales franco-espagnoles. *Arch. Sci. Genève*, **26**, 297-308.
- DERIN, B. and REISS, Z. 1966. Jurassic microfacies of Israel. *Israel Inst. Petrol., Spec. Publ.* Tel Aviv, 44 pp.
- DYBOWSKI, W. 1878. *Die Chaetetiden der ostbaltischen Silur-Formation*. Dorpat, 134 pp. (Approved for publication 1877; validly published 1878.)
- EDWARDS, W. N. 1928. On the algal nature of *Aroides sturterdi* Carruthers. *Ann. Mag. nat. Hist.* (10), **1**, 79-81.
- ELLIOTT, G. F. 1957. New calcareous algae from the Arabian Peninsula. *Micropaleontology*, **3**, 227-230.
- 1963. A Liassic *Pycnoporidium* (calcareous algae). *Eclog. geol. Helv.* **56**, 179-181.
- 1964. *Zonotrichites* (calcareous algae) from the Arabian Triassic. *Eclog. geol. Helv.* **57**, 567-570.
- 1965. The interrelationships of some Cretaceous Codiaceae (Calcareous Algae). *Palaeontology*, **8**, 199-203.
- 1973. A palaeoecological study of a Cotswold Great Oolite fossil-bed (English Jurassic). *Proc. Geol. Ass. Lond.* **84**, 43-52.
- FOURCADE, E., JEREZ, L., RODRIGUEZ, T. and JAFFREZO, M. 1972. El Jurásico terminal y el Cretácico inferior de la Sierra de la Muela (Provincia de Murcia). Consideraciones sobre las biozonas con foraminíferos del Albense-Aptense de sureste de España. *Revta Españ. Micropaleont.* num. extraord. Dec. 1972, 215-248.
- GINSBURG, R. N. 1960. Ancient analogues of Recent stromatolites. *Rept. 21st Int. Geol. Congr. Norden 1960*, **22**, 26-35.
- HUDSON, J. D. 1970. Algal limestones with pseudomorphs after gypsum from the Middle Jurassic of Scotland. *Lethaia*, **3**, 11-40. (Figs. 8b, 8c; captions accidentally transposed.)
- JOHNSON, J. H. 1951. Permian calcareous algae from the Apache Mountains, Texas. *J. Paleont.* **25**, 21-30.
- 1954. Cretaceous Dasycladaceae from Gillespie County, Texas. *Ibid.* **28**, 787-790.
- and KONISHI, K. 1960. An interesting late Cretaceous calcareous alga from Guatemala. *Ibid.* **34**, 1099-1105.
- LEBOUCHÉ, M.-C. AND LEMOINE, M. 1963. Dasycladacées nouvelles du Lias calcaire (Lotharingien) du Languedoc méditerranéen (St.-Chinian, Boutenac). *Revue Micropaléont.* **6**, 89-101.
- MASSIEUX, M. 1966. Les algues du Nummulitique égyptien et des terrains Cretacés-Éocènes de quelques régions mésogéennes. Deuxième partie. Étude critique. *Ibid.* **9**, 135-146.
- MONTY, C. L. V. 1967. Distribution and structure of Recent stromatolithic algal mats, Eastern Andros Island, Bahamas. *Anns Soc. géol. Belg.* **90**, B. 55-100.
- NEWELL, N. D., IMBRIE, J., PURDY, E. G. and THURBER, D. L. 1959. Organism communities and bottom facies, Great Bahama Bank. *Bull. Am. Mus. nat. Hist.* **117**, 177-228.
- NIKLER, L. and SOKAČ, B. 1968. Biostratigraphy of the Jurassic of Velebit (Croatia). *Geolöski Vjesnik, Zagreb*, **21**, 161-174.
- OTT, E. 1965. *Dissocladella cretica*, eine neue Kalkalge (Dasycladaceae) aus dem Mesozoikum der griechischen Inselwelt und ihre phylogenetischen Beziehungen. *Neues Jb. Geol. Paläont. Mh.* **11**, 683-693.
- 1968. Zur Nomenklatur obertriadischer Kalkalgen, besonders der Gattungen *Heteroporella* Pratulon und *Poikiloporella* Pia (Dasycladaceae). *Mitt. bayer. St. Paläont. Hist. Geol.* **8**, 253-262.
- PFENDER, J. 1939. Sur un calcaire phytogène du Lias inférieur d'Espagne et l'extension de ce faciès en quelques autres régions. *Bull. Labs Géol. Géogr. phys. Minér. Univ. Lausanne*, no. 66.
- PRATURLON, A. 1964. Calcareous algae from Jurassic-Cretaceous limestone of Central Apennines (Southern Latium-Abruzzi). *Geologica romana*, **3**, 171-202.
- REY, J. 1973. Observations sur l'écologie des Orbitolines et des Choffatelles dans le crétacé inférieur d'Estremadura (Portugal). *C.r. hebd. Séanc. Acad. Sci. Paris*, **276D**, 2517-2520.

- RICHARDSON, L. 1911. On the sections of Forest Marble and Great Oolite on the railway between Cirencester and Chedworth, Gloucestershire. *Proc. Geol. Ass. Lond.* **22**, 95-115.
- 1930. Excursion to the Mid Cotteswolds; Tuesday 13 August 1929. *Proc. Cotteswold Nat. Fld Club*, **23**, 209-213.
- 1933. The country around Cirencester. *Mem. geol. Surv. U.K.* Sheet 235. London, 119 pp.
- SOKAČ, B. and NIKLER, L. 1969. *Dinarella kochi* n. gen., n. sp. (Dasycladaceae) from the Lias of the Velebit Mountain. *Geolöski Vjesnik, Zagreb*, **22**, 303-308.
- TORRENS, H. S. 1967. The Great Oolite Limestone of the Midlands. *Trans. Leicester Lit. phil. Soc.* **61**, 65-90.
- YABE, H. and TOYAMA, S. 1949. New Dasycladaceae from the Jurassic Torinosu Limestone of the Sakawa Basin. II. *Proc. Japan Acad.* **25** (7), 40-44.

G. F. ELLIOTT

Department of Palaeontology
British Museum (Natural History)
Cromwell Road
London, SW7 5BD

Typescript received 11 June 1974

Revised typescript received 11 September 1974

Note added in proof. A very similar algal microflora to that described above, and at the same stratigraphical level, was found in temporary excavations (Autumn 1974) at Fowlers Hill, Quenington (Nat. Grid SP 147045), 14.5 km from Daglingworth Quarry.