NEW AND LITTLE-KNOWN PERMIAN AND CRETACEOUS CODIACEAE (CALCAREOUS ALGAE) FROM THE MIDDLE EAST

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ABSTRACT. Four Codiaceae (calcareous chlorophyte algae) are described from the Middle East. *Anchicodium sindbadi* sp. nov., *Tauridium kurdistanensis* sp. nov., and *Aphroditicodium aurantium* gen. et sp. nov. are from the Permian: *Boueina hochstetteri* Toula (Lower Cretaceous) is a first Middle East record. *Aphroditicodium* is compared with other segmented Codiaceae from Ordovician to Recent, and their characters are tabulated.

AMONGST calcareous green algae the family Codiaceae have shown a much less-detailed and less-varied evolution than the family Dasycladaceae: this arises from the different basic structures peculiar to the two families. In consequence, the Codiaceae, although often abundant, have yielded few fossils of zonal value. Those encountered by me during studies of the calcareous algae of the Middle East have been listed or described (Elliott 1960, 1965); the present note describes four which are new or not previously recorded from the area.

Genus ANCHICODIUM Johnson 1946

Remarks. This Upper Palaeozoic genus was described by Johnson (1946, 1961, 1963). In thin-section it shows the characteristic codiacid pattern of poorly calcified central threads and more heavily calcified marginal radial threads. The macro-structure, however, is unusual in being described as 'a crustose mass from which straight or nearly straight cylindrical stems develop': these stems are unusual in not being segmented so far as is known. In consequence, evaluation of the orientation of random thin sections is often difficult. The Middle East species now described falls in this category, but is clearly an *Anchicodium*.

Anchicodium sindbadi sp. nov.

Plate 61, figs. 3, 4

Description. This species is seen in thin-section as a fragment about 7·5 mm. long and 0·68 mm. wide: it shows one lateral calcified cortical layer only. The fragment is worn and crusted on both sides with obscure organic growths, in part formed by myxophyte algae.

On one side of the fragment the calcite is clear and shows few threads: this is interpreted as part of the pith-like medullary zone of a cylindrical stem, with largely post-mortem calcification. On the other side the calcification, presumed original plant-structure in origin, is crowded with codiacid-like plant threads, parallel to sub-parallel in orientation, and directed more or less at right angles or oblique-transversely to the longitudinal axis of the fragment. The threads are from 0·020 to 0·040 mm. in diameter, the majority typically of 0·026–0·028 mm. diameter, the individual threads varying

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somewhat throughout their length. Very few of them show undoubted branching. These features show most clearly in the middle of the fragment: towards the ends the plane of section cuts through the threads transversely, due to the curvature of the piece.

Holotype. The specimen figured in Plate 61, fig. 3, from Permian limestone occurring as derived fragments in the Cretaceous Hawasina Formation (Morton 1959); Jebel Qamar, Peninsular Oman, Arabia. Brit. Mus. (Nat. Hist.), Dept. Palaeont. reg. no. V.54131.

Other material. A second fragment, largely recrystallized, in the same thin section.

Remarks. The Cretaceous Hawasina is full of derived Permian limestone boulders, some of great size, from which a varied Permian microflora and fauna have been obtained. The particular thin-section from which the new *Anchicodium* comes also shows fragments of the dasyclad *Epimastopora*, and pseudopunctate brachiopod debris.

This is the first *Anchicodium* recognized in this area: the record of Elliott (1960) for Iraqi Kurdistan is now found to be a *Tauridium*. The specific name commemorates the legendary Arab traveller, whose voyages from Basra would certainly have touched at this desolate part of Arabia.

Genus *Tauridium* Güvenç 1966

Remarks. This genus, described by Güvenç (1966) from the Permian of Turkey, with type species *T. cuvillieri*, is a typical segmented calcified codiacid. Comminuted debris of what is probably the species described by Güvenç as *T. fragilis* was earlier described by me in error as the 'dasyclad' *Epimastopora minima* (Elliott 1956), from the other side of the Turkish–Iraqi frontier.

Translated diagnosis (free translation from Güvenç). Alga occurring as more or less flattened units, open at their bases. The interiors of these units are uncalcified and hollow (matrix-filled). Only the calcified cortical zone is at present known. This is formed of filaments sometimes oblique, sometimes perpendicular to the outer surface. Regular and constant narrowings and swellings of the filaments give them a characteristic 'moniliform' appearance. The filaments divide dichotomously and their diameters diminish towards the outer surface. Mode of reproduction unknown. Medullary filaments rarely preserved and not well known. (Type species *T. cuvillieri* Güvenç.) Upper Permian: Western Taurus, Turkey.

Tauridium kurdistanensis sp. nov.

Plate 62, figs. 3, 4

1960 *Anchicodium* sp.; Elliott, p. 219.

Description. Rounded-turbinate codiacid segments as seen in thin-section outline and presumed slightly flattened in the three-dimensional segments: length about 2 mm. or

EXPLANATION OF PLATE 61

Figs. 1, 2. *Boueina hochstetteri* Toula. Transverse and longitudinal thin sections of small segments, ×40. Lower Cretaceous, Garagu Formation (Valanginian-Hauterivian); subsurface, Kirkuk no. 116 well, NE. Iraq. Reg. nos. V.54135, V.54136.

Figs. 3, 4. *Anchicodium sindbadi* sp. nov. Permian: from derived fragment in Cretaceous Hawasina Formation; Jebel Qamar, Peninsular Oman, Arabia. Reg. no. V.54131. 3, Longitudinal thin section of holotype, ×15. 4, Portion enlarged, to show thread-detail, ×40.

more, width about 2 mm. The calcified cortical zone is about 0·6 mm. thick; the interior, now matrix-filled, was filled with largely uncalcified plant matter during life, and by analogy with other species of *Tauridium*, would at best have shown a few weakly calcified medullary threads.

TABLE 1. Dimensions of one swollen and constricted cortical thread throughout its full length. (S = swellings; C = constrictions).

(Inner)	S.	C.	S.	C.	S.	C.	S.	C.	S.	C.	S.	(Outer)
Length	182	26	104	13	104	13	65	39	91	13	52	
Width	78	13-20	52	13	52	20	26	20	26	13	26	microns.

The cortical zone shows very numerous typically codiacid threads showing a repeated 'swollen-and-constricted' pattern throughout their length. They bifurcate repeatedly at angles of from 30° to 60°, the alternating diameters diminishing towards the exterior along all branches. Table 1 gives the dimensions of one thread traced from the interior margin of the cortical zone to the periphery, ignoring all side branches. The threads are crowded, with irregular banded zones of wider spacing due to the concentricity of periodic branching.

Holotype. Specimen shown in Plate 62, fig. 4 from the Zinnar Formation, Permian (? Artinskian); Harur, Mosul Liwa, Northern Iraq. Brit. Mus. (Nat. Hist.), Dept. Palaeont., reg. no. V.54132.

Paratype. Specimen shown in Plate 62, fig. 3 from the Darari Formation, Upper Permian: Ora, Mosul Liwa, Northern Iraq. Brit. Mus. (Nat. Hist.), Dept. Palaeont., reg. no. V.54133.

Other material. Debris has been seen sporadically in other thin-sections from these two formations.

Remarks. Tauridium kurdistanensis differs from the type-species in size and shape of segment (*T. cuvillieri* is longer and ellipsoidal), in the much greater thickness of the cortical zone (double or more), and in the more variable and often greater angle of thread-division. From *T. fragilis* Güvenç it is easily distinguishable, this Turkish species being very thin-walled (0·12–0·15 mm.).

The holotype is associated with the coral *Waagenophyllum indicum* (Waagen and Wentzel) var. nov. (Hudson 1958). The paratype is accompanied by the algae *Mizzia velebitana* Schubert, *Gymnocodium bellerophontis* (Rothpl.) Pia, *Permocalculus fragilis* (Pia) Elliott and *P. tenellus* (Pia) Elliott.

Genus APHRODITICODIUM gen. nov.

Diagnosis. Ovoid codiacid segments, probably slightly flattened, showing three distinct zones in section: from within outwards, firstly, a lightly calcified medullary zone of tangled threads more or less longitudinally arranged; secondly, a more heavily calcified cortical zone of irregular branching and obscurely radial threads; thirdly, a very thin, densely calcified subdermal zone showing a single layer of small subdeltoid thread-terminations widening outwards. Type-species *A. aurantium* sp. nov., Permian of Northern Iraq.

Remarks. From the algae of the Permian of Iraqi Kurdistan, a new codiacid is very rare in my experience, but the specimen now described is distinctive.

Aphroditicodium aurantium sp. nov.

Plate 62, figs. 1, 2

1960 *Succodium* sp.; Elliott, p. 219.

Description. Codiacid segment of 2·86 mm. length and 2·21 mm. width, ovoid in near-vertical section with the presumed base incomplete, and interpreted as a terminal segment. It shows clearly marked medullary, cortical, and subdermal zones described below: the measured proportions of these suggest that the section is a near-vertical (slightly oblique) cut of a terminal ovoid segment as stated, and not a more oblique cut of a cylindrical unit. By analogy with similar segmented codiaceae, living and fossil, the segment was likely to be somewhat flattened (thickness less than width). Older (lower) segments from the same plant may well have differed in shape, but have not been seen.

The inner, medullary, zone has a diameter of 0·858 mm. It shows a tangle of indistinct ramifying threads of 0·020–0·026 mm. diameter, more or less longitudinally arranged. This zone was only lightly calcified in life, as in other segmented codiaceae: and is now infilled with secondary calcification.

The cortical zone surrounds the medullary zone except at the base, where the medullary threads united this segment to the preceding one. The cortical zone is from 0·572 to 0·598 mm. thickness, and shows a tangle of more distinct branching and apparently anastomosing threads of similar diameter to the medullary threads (0·020–0·026 mm.). These tangled threads show a very irregular and obscurely radial orientation. The original plant calcification was probably heavier in this zone, thus accounting for the clearer appearance of the threads.

The subdermal layer is very thin, varying from 0·052 to 0·078 mm. in thickness, and shows dense calcification probably of original plant origin. The margin shows a single peripheral layer of fairly close-set thread-terminations, of narrow subdeltoid outline in section and expanding outwards. They have an external diameter of about 0·015 mm., and are seen to taper inwards for about 0·025 mm. They are spaced apart peripherally by about their own diameters. Occasionally, preservation shows their connections with the cortical threads.

Holotype. The specimen figured in Plate 62, figs. 1, 2, from the Zinnar Formation, Permian (? Artinskian–Kungurian); Ora, Mosul Liwa, Northern Iraq. Brit. Mus. (Nat. Hist.), Dept. Palaeont., reg. no. V.54134.

Remarks. Segmented codiaceae are known from the Lower Palaeozoic to the present day. They have in common the tripartite zoning of threads and calcification described above for *Aphroditicodium*, and the classification is largely based on the differences in the characters, at least when dealing with dissociated fossil segments. Table 2 lists the

EXPLANATION OF PLATE 62

Figs. 1, 2. *Aphroditicodium aurantium* gen. et sp. nov. Lr. Permian, Zinnar Formation; Ora, Mosul, N. Iraq. Reg. no. V.54134. 1, Slightly oblique–vertical thin-section of terminal segment (holotype), ×28. 2, Portion of sub-dermal layer enlarged, to show detail, ×84.

Fig. 3. *Tauridium kurdistanensis* sp. nov. Paratype: random thin-section to show thread-detail, ×40. Upper Permian, Darari Formation: Ora, Mosul, N. Iraq. Reg. no. V.54133.

Fig. 4. *Tauridium kurdistanensis* sp. nov. Holotype: oblique–vertical thin-section of segment, ×40. Lower Permian, Zinnar Formation: Harur, Mosul, N. Iraq. Reg. no. V.54132.

differences between the principal genera. These are set out as distinguishable in normal calcified thin-sections. Kozłowski and Kaźmierczak (1968) have recently described *Palaeoporella variabilis* Stolley in detail from acid digests of exceptionally well-preserved material. Detail as normally distinguishable may be seen in Obrhel's comparison of the same species with his new *Maslovina meyenii* (Obrhel 1968). Hurka (1968) who also had access to unusually well-preserved material, decided that *Palaeoporella* is a dasy-

TABLE 2. Key to internal characters of some genera of Codiaceae.

Genus	Author and Age	Longitudinal Medullary Threads	Radial or Oblique Cortical Threads	Subdermal Zone
Aphroditicodium	Gen. nov. Permian.	Fine, tangled.	Fine, tangled.	Tiny close-set deltoid terminations.
Arabicodium	Elliott 1957 Jur.-Cret.	Fine, skeinlike.	Fine, branching.	Widening terminations.
Boueina	Toula 1884 Jur.-Cret.	Coarse, tangled.	Medium, branching.	Close-set terminal branchlets.
Dimorphosiphon	Høeg 1927 Ordovician.	Coarse, few, straight.	Branching, thinning, radial.	Fine branchlets.
Halimeda	Lamouroux 1812 Cret.-Rec.	Thick, few, close, straight.	Branching, radial, swollen.	Widening terminations.
Maslovina	Obrhel 1968 Silurian.	Medium, adjacent.	Medium, branching, oblique.	Expanded adjacent branch-terminations.
Palaeoporella	Stolley 1893 Ord.-Dev.	Fine, straight.	Branching, thinning, oblique.	Finest branchlets with terminal widenings.
Succodium	Konishi 1954 Permian.	Fine, skeinlike.	Fine, branching.	Small, flasklike swollen utricles.

cladacean, and not a codiacean, alga. I have not myself had access to material other than in normal calcified limestone preservation: the English Devonian *Palaeoporella* (Elliott 1961) certainly seemed to be a codiacean. A very detailed modern account of *Halimeda* is that of Hillis (1959).

Aphroditicodium is thus seen to be another variant on the basic segmented-codiacid plan. It bears some resemblance to *Succodium*, but the subdermal layer is distinctive. The generic name commemorates Aphrodite, fabled to have risen from the shallow sunlit seas in which living codiaceae thrive; the specific name refers to the segment-shape.

Genus BOUEINA Toula 1884

Remarks. This genus was described from the Lower Cretaceous of Serbia (Toula 1884), and has since been recognized from both Jurassic and Cretaceous in various countries around the Mediterranean and in the Middle East. Although *Boueina hochstetteri* Toula was extremely abundant at the Balkan type locality, and is known also from Italy and France, and the older variety *liasica* occurs as far apart as Algeria and Iraq, this is the first record of the type species in the Middle East.

Boueina hochstetteri Toula 1884

Plate 61, Figs. 1, 2

Description. Represented by clear longitudinal and transverse sections: the central core is missing in both cases. Length of the former is 2·0 mm. incomplete; diameter of the latter 1·2 mm. This is much smaller than the dimensions of the type material, where 2·5–3·5 mm. diameter and up to 10 mm. in length is indicated. The branch-detail of the calcified cortical zone corresponds exactly, however, and the specimens, earlier considered as a new *Arabicodium* sp., are now referred to *B. hochstetteri*. They come from the subsurface Garagu Formation (Lower Cretaceous, Valanginian-Hauterivian) of Kirkuk no. 116 well, north-east Iraq. Associated is debris of the chaetangiacid alga *Permocalculus*, corals and echinoderms.

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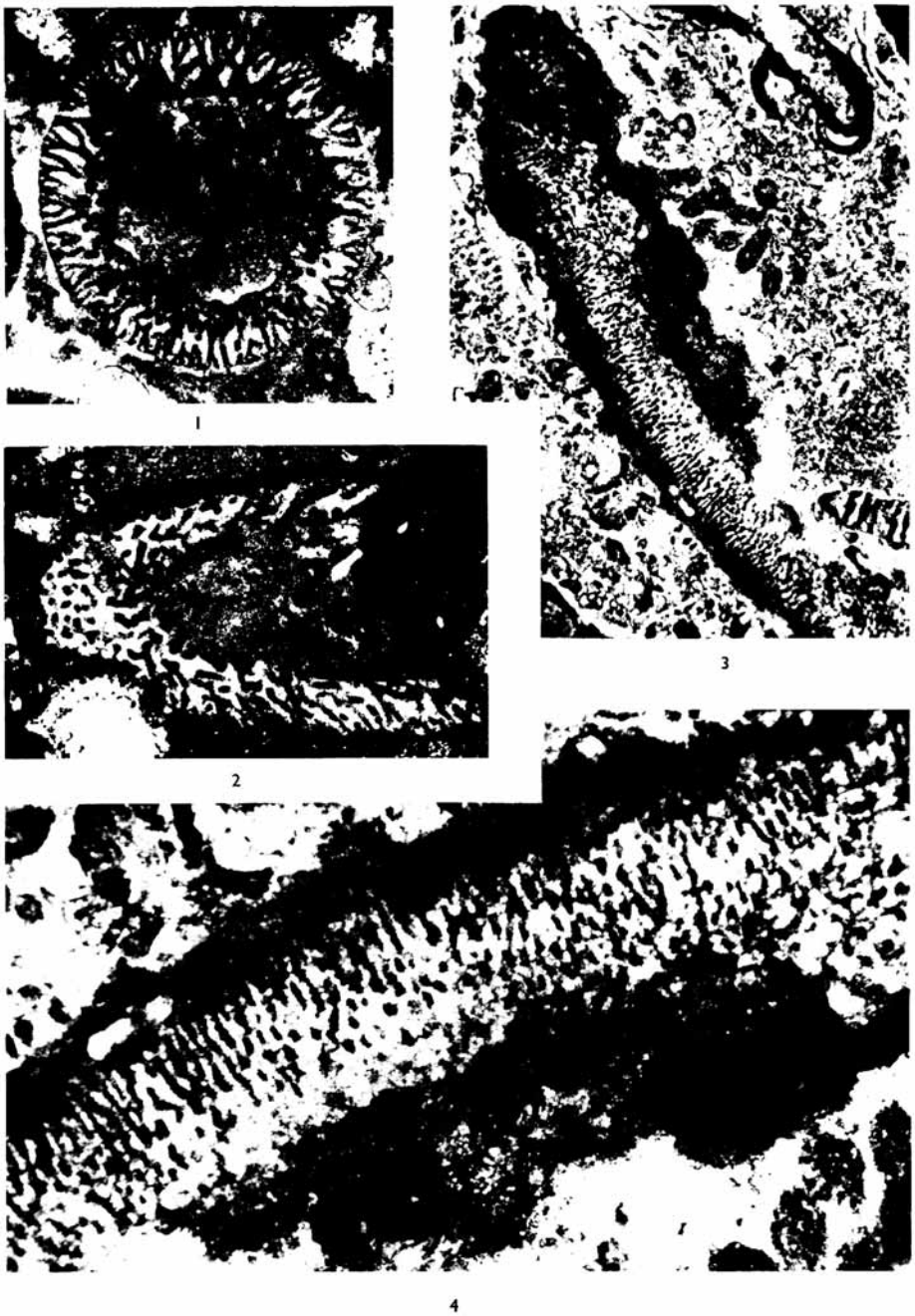

ELLIOTT, Permian and Cretaceous Codiaceae (Algae)

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