ALGAL DEBRIS-FACIES IN THE CRETACEOUS OF THE MIDDLE EAST

by GRAHAM F. ELLIOTT

Abstract. A rock-type common in the Lower and Middle Cretaceous of the Middle East consists of fine algal debris in a calcareous marly matrix. The algae, of which *Permocalculus* and *Munieria* are the commonest, are described and illustrated both as fragments and as complete segments; the origin of the deposits is discussed by analogy with present-day algal sediments.

INTRODUCTION

A CHARACTERISTIC rock-facies in the Cretaceous of the Middle East is that of fine-grained limy marls and marly limestones containing numerous fragments of calcareous algae: in thin section these rocks show the algal fragments as white against a grey background. This 'debris-facies' is known from Iraq, Oman, and the Hadhramaut: the component algal genera are known variously from Europe and North Africa, and the facies probably has a wide Tethyan distribution. In the Middle East it occurs locally at various Lower and Middle Cretaceous levels, but is particularly characteristic of the Barremian-Aptian horizon.

The algae are sometimes accompanied by foraminifera, and occasionally by other organisms, and there is a varying proportion of non-algal debris, but it is the algal fragments which are the distinctive features of the rock: so much so, that particular types of fragments were used for stratigraphic purposes before they were definitely recognized and referred to genera and species. Much of this debris is too small for the particles to be individually recognizable: identification has therefore depended upon rare fortunate preservation of larger pieces, patient comparison of all fragments with theoretically-possible sections of suspected identification-species, and such illustrations of fragments in thin-section as exist in the general literature.

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THE FLORA

The genera represented are few in number; they are most commonly *Permocalculus* and *Munieria*, secondarily *Actinoporella*, *Clypeina*, and *Salpingoporella*, and more rarely *Triploporella* and one or two dasyclads and codiacids not yet determined. Acicularian spicules are not uncommon: these are naturally dissociated after the death of the plant, and behave similarly during sedimentation to the mechanically broken fragments of the other genera.

Permocalculus (Pl. 45, 47, 48) is represented by at least two species: the common *P. inopinatus* (Elliott 1956) in the Barremian-Aptian, and a new species from the Albian-Cenomanian, described below. Other species are not yet fully known. The genus, which ranges from the Permian, has many points in common with the modern *Galaxaura* (Pl. 46, figs. 1, 2), a segmented chaetangiacid alga which is an inhabitant of warm shallow

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littoral waters in the Pacific, West Indies, and elsewhere: the relationship has been discussed elsewhere in detail (Elliott 1955*a*, 1956), but it seems likely that this kind of plant has always grown in much the same environment. Cretaceous *Permocalculus* are known also from France and North Africa. In the Middle East innumerable fragments of segments are common, and are recognizable by the denticulated edge occasioned by pores in the calcified crust: single complete segments, and two or more attached segments, are very rare.

Munieria baconica Deecke was described from the Hungarian Lower Cretaceous (Deecke 1883), and subsequently recorded by Taeger (1936) from the Aptian of this area. A reconstruction attempted by Pia (1920) shows the alga to have a thin main stem with well-spaced horizontal whorls or verticils of about twelve or fourteen relatively coarse straight primary branches. Both stem and verticils are coated with calcareous matter, the latter very thickly, so that around the stem they are fused into coarse ring-like structures. Carozzi (1948) recorded this species from the Swiss Purbeckian, giving a valuable set of figures of thin-sections of debris. His material seems to be of a larger form having a proportionally wider central stem-canal than that of the type, and about sixteen primary branches per whorl. The Middle East material comes from the same approximate horizon as the type-material, as dated by foraminifera and other fossils, but it shows the characters of the older, Swiss, material, and is identified by reference to Carozzi's text-figures.

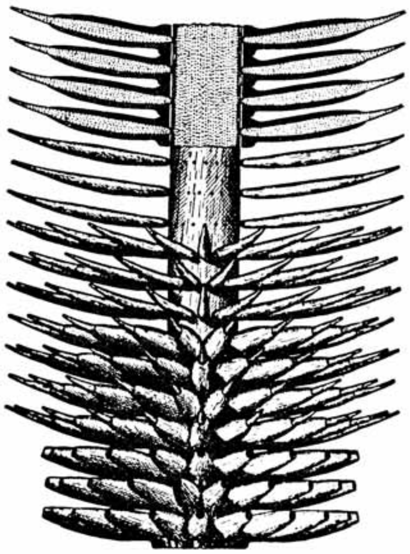
Munieria is the most fragmentary alga of all in the debris-facies (Pl. 45, fig. 4), and most of the finer fragments, associated with recognizable *Munieria*-crumbs are intrinsically quite indeterminable. The coarser fragments show in thin-section as little hooked and looped scraps. Such as have been recognized have been correlated with Carozzi's Swiss specimens determined by him as *M. baconia*, and this applies also to the very rare sections of complete whorls (Pl. 48, fig. 1). It is especially characteristic of the Barremian-Aptian, though met with rarely in the older Cretaceous, and it extends up also into the Albian.

Actinoporella was described from the Polish Portlandian (Alth 1878, 1882), and *A. podolica* (Alth) has been recorded from the Swiss Purbeckian (Carozzi 1948) and the north Iraq Valanginian-Hauterivian (Elliott 1955*b*, and Pl. 47, fig. 5 of this paper). Somewhat similar in general plan to *Munieria* (see Pia's restoration reproduced here in text-fig. 1) but differing in proportions and number of primary branches to a whorl, the calcareous skeleton is more delicate. Curiously, in spite of this, it seems to have been less fragile, and the fossil remains in the debris-facies are less fragmentary (Pl. 45, fig. 1), often showing in section as chains of connected rings. Possibly the calcareous coating was less porous than in *Munieria*.

Of the minor elements in the debris-flora, *Clypeina*, long known from Jurassic and Tertiary, has now been recorded from many levels in the Cretaceous (Emberger 1957); it is uncommon so far as known in the Middle East Cretaceous. *Salpingoporella* is represented by occasional remains (Pl. 46, fig. 3) comparable with the type *S. mühlbergi* (Lorenz), known from the Barremian-Aptian of Switzerland and France. Dissociated acicularian spicules (Pl. 45, fig. 2), some identified as *Acicularia* cf. *antiqua* Pia, a Cretaceous species, are not uncommon. Such spicules are the skeletal remains of the terminal disks of *Acicularia*, a genus still surviving and somewhat like the more familiar Recent *Acetabularia* or 'Mermaids' wineglass', a shallow warm-water genus.

CONDITIONS OF ACCUMULATION

Living algae comparable to those listed above are all littoral or lagoonal inhabitants of warm, very shallow waters, and it is reasonable to suppose that the Cretaceous flora grew under similar conditions. The rocks in which their fragmentary remains occur,



TEXT-FIG. 1. *Actinoporella podolica* (Alth), from the Upper Jurassic of Poland, as reconstructed by Pia (1920): × 20 approx.

EXPLANATION OF PLATE 45

Thin-sections in the collections of the Geological Department, Iraq Petroleum Co., Ltd., London.

1. Debris-facies, showing *Actinoporella podolica* (Alth), × 28. Valanginian-Hauterivian of Banik, Mosul Liwa, northern Iraq; reg. no. WI. 11539.
2. Debris-facies, showing *Acicularia sp.*, × 55. Barremian of Sarmord, Sulemania Liwa, north-eastern Iraq; reg. no. WI. 10381.
3. Debris-facies; *Permocalculus inopinatus* Elliott and *Orbitolina sp.*, × 15. Aptian of Koi Sanjak, Erbil Liwa, north-eastern Iraq; reg. no. DM. 539.
4. Debris-facies; fine debris including '*Munieria baconica* Deecke', × 15. Aptian-Albian of Surdash, Sulemania Liwa, north-eastern Iraq; reg. no. WI. 10396.

EXPLANATION OF PLATE 46

1. *Galaxaura cylindrica* (Sol.) Kjellm. Portion of growth × 2, to show calcified segments as they occur during life. Recent; Boston Beach, Portland Parish, Jamaica, B.W.I.
2. *Galaxaura sp.* Flattened segments × 5, to illustrate paired growth of segments in this type of alga. Recent; West Indies.
3. Debris-facies, showing *Salpingoporella* cf. *annulata* (Lorenz), × 30. Valanginian-Hauterivian of Jebel Gara, Mosul Liwa, northern Iraq; reg. no. WI. 6380, in the Geological Department, Iraq Petroleum Co., Ltd., London.

however, are old fine-grained sediments, often with no other fossils but small foraminifera, whatever depth of water is tentatively assigned for their accumulation.

Examination of the extensive literature on Recent marine deposits is helpful, but does not give an exact analogy. *Halimeda*, a modern warm-water green calcareous alga of the type under consideration, is the cause of extensive deposits of calcareous segments, whole and broken, within atoll lagoons in the Indo-Pacific (cf. Chapman and Mawson 1906). The rock thus formed is analogous with fossil deposits showing an identifiable profusion of calcareous algae associated with remains of numerous shallow-water invertebrates, and is very different from the debris-facies. Outside the reefs a common algal deposit is a mechanically-produced lime-sand formed mostly of debris from the reef-building red algae, though *Halimeda*-material may be present as a minority constituent. Other largely algal deposits are the fine calcareous flour produced as a digestion-product by the parrot-fishes and their allies, which browse on coral and algal reefs, as early noted by Darwin and others, and a sediment of microscopic dissociated aragonite-needles from various green algae (Lowenstam 1955). None of these are comparable to the debris-facies.

From the reports of the U.S. project at Bikini (Emery, Tracey, and Ladd 1954) the following details were gleaned as to the occurrence of *Halimeda*-remains outside the reefs, on the steep outer atoll-slope, which at certain points descends to 1,500 fathoms in 4 miles and 2,000 fathoms in 7 miles. At 80 fathoms there occurred a sediment with whole unbroken *Halimeda*-segments and large foraminifera of up to 12 mm. diameter, both having slipped down from above. At 240 fathoms coarse *Halimeda*-debris (pieces of 6 mm. diameter) was a constituent, while at 410 fathoms there was fine *Halimeda*-debris, of 1 mm. maximum diameter and mostly much less. True *Globigerina*-ooze was found at 1,000 fathoms depth. Although the Cretaceous debris varies from medium-sized algal fragments associated with the larger foraminifer *Orbitolina* to fine fragments without *Orbitolina*, no exact analogy is possible between the Recent calcareous 'slope-sediments' and the Cretaceous 'debris-facies', and it would seem that the latter is a product of conditions existing in the Middle East in Cretaceous times, which are not now well developed.

Three such conditions seem necessary and are in accord with other evidence. They are, firstly, abundance of a warm-water littoral flora of small, separate-growing calcareous algae, like members of the modern families codiaceae, dasycladaceae, and chaetangiaceae, and the absence of extensive growths of the more massive crusting, nodular, and reef-forming algae, included in the family corallinaceae. These latter are in fact rare in the Lower Cretaceous, achieve local abundance in the Upper, and only occur commonly and in profusion in the Tertiary and at the present day.

Secondly, extensive post-mortem fragmentation and dissociation of the calcareous algal skeletons is necessary. These skeletons are fragile tubes and units, with very many pores and sporangial and other cavities: they are known to break down naturally at the present day into sediment-constituents of various sizes which are subject to normal marine transport.

Finally, the existence of a shelf-sea of shallow to moderate water-depth seems called for: this was the normal inter-orogenic Mesozoic pattern, rather than the sharper post-glacial features of the present day. During sedimentation, fine calcareous mud particles were accompanied by the relatively larger algal fragments of lower specific gravity: the presence or absence of *Orbitolina* may indicate different depths, but nothing comparable to the submarine slopes at Bikini.

Thus the debris-facies may be regarded as indirect witness to both topographical and biological conditions during the Cretaceous, in that portion of the Tethyan Ocean which now, upheaved and desiccated, forms the Middle East.

DESCRIPTION

Permocalculus irenae sp. nov.

Plate 47, fig. 2; Plate 48, figs. 2–6

Description. Thallus segmented, formed of units or segments about 2·3 mm. long by 0·75–1·0 mm. wide, each segment giving rise to two segments distally, the latter occasionally preserved as small terminal growths, indicating fossilization of growing segments. Segments approximately circular in cross-section: calcification variable between a thin peripheral zone and a nearly solid segment: sporangia internal, subcortical, often numerous but ill defined, apparently ovoid, one example measuring 0·100 by 0·175 mm. Pores clearly visible at the outer edge of the calcification, where they are fine and irregularly curved.

Holotype. The specimen figured in Pl. 48, fig. 2 from the subsurface Cenomanian of Mileh Tharthar Well, Dulaim Liwa, northern Iraq. Iraq Petroleum Company, Ltd., Geological Dept. Coll., reg. no. MT. 356A.

Paratypes. The specimens figured in Pl. 48, figs. 3, 4, 5, from the same locality and horizon, reg. nos. MT. 356A, B, MT. 360.

Other material. Numerous specimens from the same locality and horizon; also known from about the same horizon, Zubair Wells, Basra, south Iraq; also a specimen from the Albian of Surdash, Sulemania Liwa, north-eastern Iraq.

EXPLANATION OF PLATE 47

1. Typical pores of *Permocalculus inopinatus* Elliott, tangential cut, × 100. Aptian of Jebel Gara, Mosul Liwa, northern Iraq; reg. no. Wl. 6405.
2. Typical pores of *Permocalculus irenae* sp. nov., tangential cut, × 100. Subsurface Cenomanian of Mileh Tharthar Well, Dulaim Liwa, northern Iraq; reg. no. MT. 358.

3, 4. Longitudinal and transverse sections of segments of *P. inopinatus*, × 30. Aptian of Ru Kuchuk, Chama, Mosul Liwa, northern Iraq; reg. nos. DM. 1286, 1284.

5. Horizontal section through a verticil of *Actinoporella podolica* (Alth), × 60. Valanginian-Hauterivian of Jebel Gara, Mosul Liwa, northern Iraq; reg. no. Wl. 6379.

EXPLANATION OF PLATE 48

Thin-sections in the collection of the Geological Department, Iraq Petroleum Co., Ltd., London.

1. Horizontal section through a verticil of '*Munieria baconica* Deecke', × 50. Aptian-Albian of Surdash, Sulemania Liwa, north-eastern Iraq; reg. no. Wl. 10418.

2–6. *Permocalculus irenae* sp. nov. Subsurface Cenomanian of Mileh Tharthar Well, Dulaim Liwa, Iraq; reg. nos. MT. 356A, B; MT. 360. All × 28. 2, Near-vertical section, holotype. 3, Segments in association: 4, Transverse section: 5, Longitudinal section; all paratypes. 6, Typical coarse debris.

Remarks. Permocalculus irenae is very similar to the older *P. inopinatus* Elliott (Pl. 47, figs. 1, 3, 4) from the Barremian-Aptian, and may be regarded as its descendant. The distinguishing features are pore-diameter, condition of common occurrence, and segment-size. In *P. inopinatus* the diameter of the pores where they widen at the surface to notch the profile in section is usually about 0·020 mm. (occasionally up to 0·030 mm.): in heavily-calcified stem segments they may be only 0·010 mm. or less, but these specimens are a minority. In *P. irenae* they are all about 0·010 mm. (observed limits 0·007–0·015 mm.). *P. inopinatus* usually occurs as fine debris, almost comminuted, with complete or near-complete segments very rare: *P. irenae* is fragmentary but not comminuted, and complete and associated segments are not uncommon. When found, such segments are smaller in *P. irenae* than in *P. inopinatus*, where they may attain dimensions of 5·0 by 1·75 mm.

This species is dedicated to Mrs. Irene Barber, to whom the writer is indebted for the typing of most of his papers for the last decade.

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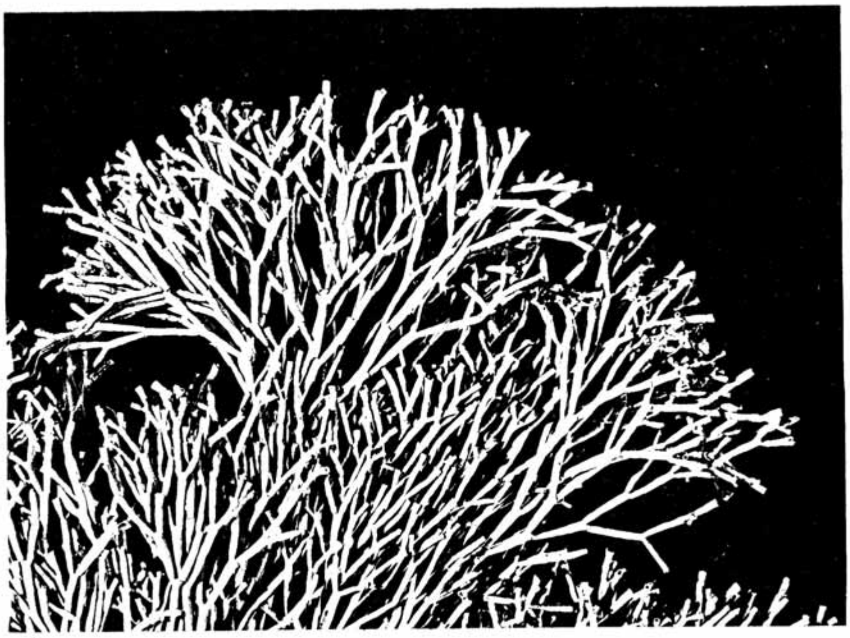
ELLIOTT, Cretaceous algae



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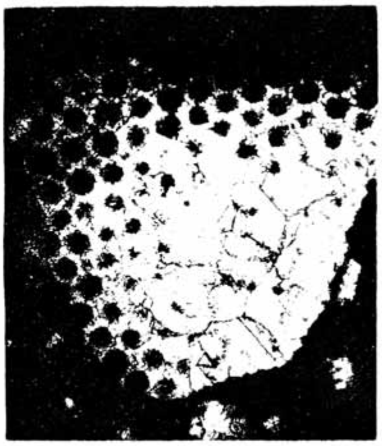

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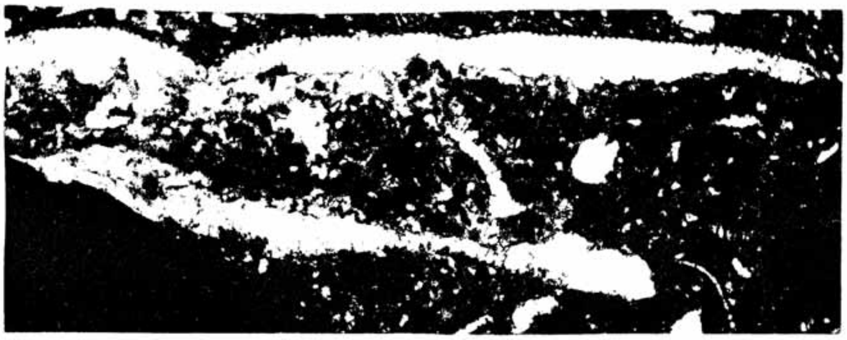

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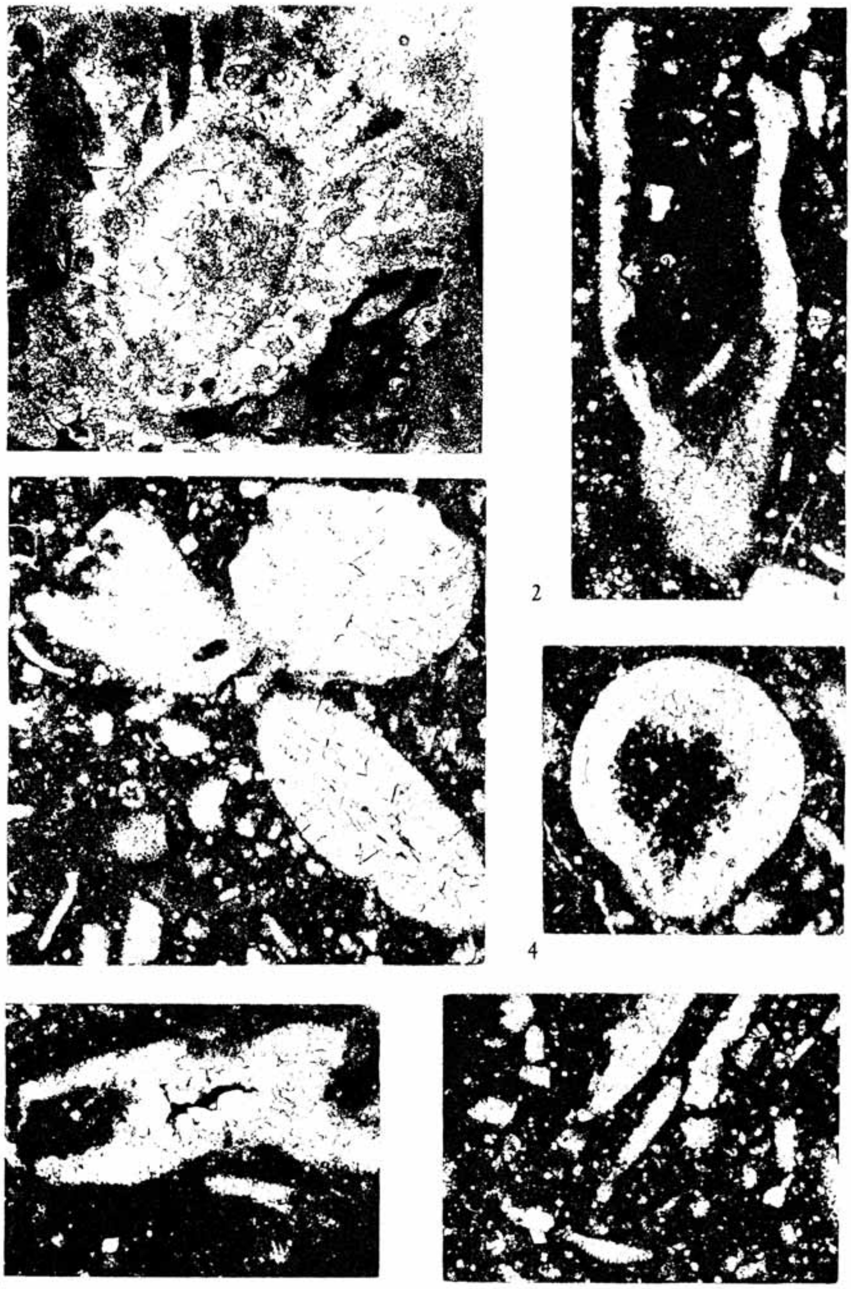

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