HENSONELLA DINARICA, AN ORIGINALLY CALCITIC EARLY CRETACEOUS DASYCLADACEAN ALGA

by M. D. SIMMONS, D. EMERY *and* N. A. H. PICKARD

ABSTRACT. *Hensonella dinarica* (Radoičić) is an Early Cretaceous, Tethyan microfossil, considered to be either a dasycladacean alga or a problematicum. This is because its preservation in yellowish radial calcite is highly unusual for dasycladacean algae, which are typically preserved in drusy calcite replacing the original aragonite. Petrological, cathodoluminescence and chemical microprobe studies of specimens of *H. dinarica*, principally from the Middle East, suggest that the original mineralogy of this microfossil was calcitic. The morphology of this species is suggestive of a dasycladacean alga, and so it is considered to be an originally calcitic dasycladacean alga, an unusual phenomenon.

HENSONELLA DINARICA (Radoičić) is a microfossil which is often found in shallow water, Early Cretaceous (Hauterivian–late Aptian), Tethyan sediments, particularly those of the Middle East and Mediterranean regions (Bassoullet *et al.* 1978; Simmons 1990). The species is most typical of the Barremian–Aptian period in southern Tethys. Although originally considered to be a dasycladacean alga (*Salpingoporella dinarica* Radoičić, 1959), other authors have questioned this taxonomic assignment (usually with reference to *Hensonella cylindrica* Elliott, 1960, junior synonym of *S. dinarica*), because of the unusual preservation of specimens of this species. In thin-section it is typically preserved in fibrous, radial calcite with a yellowish tint and has a dark, micritic, inner layer to the calcitic wall (Text-fig. 1A–C). Dasycladacean algae usually have an originally aragonitic mineralogy which is replaced by drusy calcite during diagenesis (Wray 1977). The preservation of *H. dinarica* suggests an originally calcitic mineralogy. In order to determine its original mineralogy, conventional transmitted light and cathodoluminescence petrography have been employed, together with microchemical techniques using an electron microprobe.

TECHNIQUES AND RESULTS

The main specimens examined in this study are from the Early Cretaceous Kahmah Group (Glennie *et al.* 1974) of the Oman Mountains, notably the Late Barremian and Early Aptian Kharaib and Shuaiba Formations. For further details of associated fauna, flora and sedimentology see Simmons and Hart (1987), Hughes Clarke (1988) and Simmons (1990).

Topotype specimens of *S. dinarica* from the Early Cretaceous sediments of the Dinarides, Yugoslavia, were kindly made available by Dr M. A. Conrad. The type specimens of *H. cylindrica* from the Early Cretaceous sediments of the Middle East were studied at the British Museum (Natural History), and additional material from the Middle East and the Mediterranean was studied from the reference collections of the BP Research Centre, Sunbury-on-Thames.

In addition to conventional transmitted light petrography, cathodoluminescence petrography and microchemical techniques were used to ascertain the present and original mineralogy of *H. dinarica*. Polished thin-sections containing the microfossil were examined firstly in cathodoluminescent light (Marshall 1987) for evidence of diagenetic alteration (Popp *et al.* 1986). Neither the algae nor surrounding calcite matrix and cement luminesced in any of the samples examined. This indicates that the algae had not been replaced by luminescent calcite, but it is not unequivocal evidence of a primary calcite mineralogy.

The same samples examined in cathodoluminescent light were analysed on an electron microprobe for

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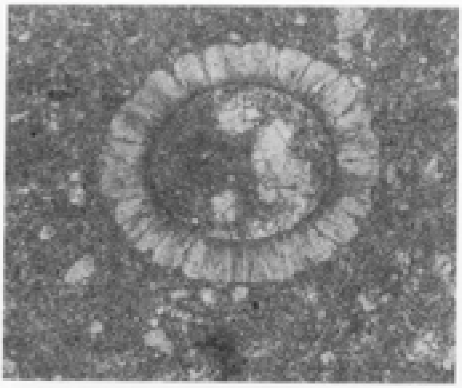

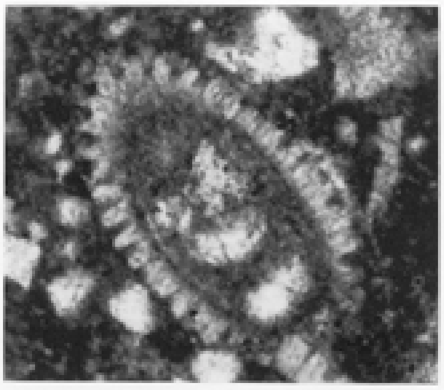

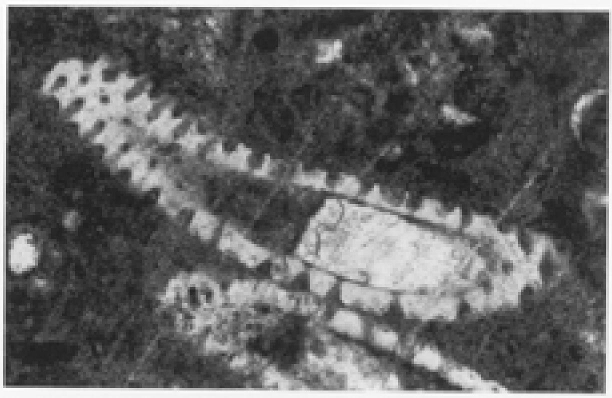

TEXT-FIG. 1. A–C, *Hensonella dinarica* (Radoičić). A, WG23; Early Aptian, Shuaiba Formation; Oman; transverse section showing inner micritic wall and radial calcitic structure, ×80. B, WM105; Hauterivian–Barremian, Kharaib Formation; Oman; transverse section showing radial structure and dasycladacean verticils, ×80. C, RR019440/A309; Barremian–Aptian; Zeta Plain, Yugoslavia; oblique transverse section of a topotype of *Salpingoporella dinarica* Radoičić, showing dasycladacean verticils and faint radial calcitic structure, ×60. Specimens WG23 and WM105 are held in the Biostratigraphy Reference Collection, BP Research Centre, Sunbury-on-Thames, UK; specimen RR018440/A309 is held in the collection of Petroconsultants, Geneva, Switzerland.

residual strontium and magnesium. High concentrations of strontium normally indicate a precursor aragonite mineralogy (Sandberg 1985). Modern aragonitic algae contain up to several hundred to a few thousand ppm strontium. High concentrations of magnesium, which may be sited in microdolomites (Lohmann and Meyers 1977; Meyers 1978) after diagenetic alteration, are indicative of an originally high magnesium calcite mineralogy.

The microprobe analyses of specimens of *H. dinarica* were obtained on a Cameca Camebax Microbeam system, operating with an accelerating voltage of 20 kV and beam current of 10 nA and a count time of 30 sec. The beam was rastered over a 7·5 μm square to reduce volatilization of CO_2. Twenty-three spot analyses were made of three samples. Four spot analyses were also made of the calcite cement. In addition to the spot analyses, a line scan was made across one alga and through the surrounding cement. Table 1 summarizes the microprobe results.

The analyses show the alga to be composed of low magnesium calcite (i.e. < 4 mole % $MgCO_3$). There is no evidence for high concentrations of strontium or magnesium in any portion of the alga. It is impossible to rule out completely a high magnesium calcite precursor, because high magnesium calcite can lose magnesium without any discernible petrographic change (Friedmann 1964; Towe and Hemleben 1976). Moreover, the magnesium levels recorded in *H. dinarica* (Table 1) are not atypical of those quoted for original high

TABLE 1. Magnesium and strontium content of algae and cement from microprobe spot analyses.

	mole % $MgCO_3$	Sr (ppm)	N
Specimen 1	1·10	508	9
Specimen 2	1.14	431	9
Specimen 3	1·05	321	5
Average	1·14	437	23
Calcite cement	1·16	523	4

magnesium calcite cements which have converted to diagenetic low magnesium calcite (e.g. see values quoted in Lochmann and Meyers 1977; Davies 1977; Marshall and Ashton 1980; Videtich 1985; Saller 1986; Carpenter and Lohmann 1989; Mazzullo *et al.* 1990). However, the algae lack microdolomite inclusions which are commonly formed during the stabilization of high magnesium calcite (cf. Lohmann and Meyers 1977; Davies 1977; Meyers 1978; Carpenter and Lohmann 1989). Combined with the lack of replacement by drusy calcite and albeit equivocal luminescence evidence, this strongly suggests that the alga had an originally calcitic and probably low magnesium calcite mineralogy. The radial fibrous calcite of the thallus and its dark inner micritic layer are hence interpreted as representing the primary mineralogy of *H. dinarica*.

DISCUSSION

Previous interpretations

Hensonella dinarica was first described by Radoičić (1959), from Early Cretaceous sediments of the Dinarides, Yugoslavia, in the genus *Salpingoporella*, and considered to be a dasycladacean alga. Independently, Elliott (1960) described *H. cylindrica* from the Early Cretaceous of the Middle East, and from its preservation (see below) classified it as a problematicum, probably a scaphopod. Most subsequent workers, including Elliott (1968; pers. comm. 1988), have agreed that *H. cylindrica* is a junior synonym of *S. dinarica*. Johnson (1969) argued that the distinctive preservation of *H. cylindrica* is not seen in *S. dinarica* and kept the two species separate: *H. cylindrica* being a problematicum, *S. dinarica* a dasycladacean alga. However, Elliott (1968, p. 77) still expressed doubts about its algal origin: 'In conclusion, I consider this organism is best classified as a problematicum'. In contrast to this, Bassoullet *et al.* (1978), Conrad (pers. comm. 1988) and Radoičić (pers. comm. 1988) are in no doubt that *S. dinarica* and *H. cylindrica* are synonyms and refer to a dasycladacean alga.

Luperto Sinni and Masse (1982, 1984, 1986) placed *S. dinarica* in synonymy with *H. cylindrica*, but under the generic name *Hensonella* in recognition of its unusual preservation. Like Elliott (1968), they suggested (although did not demonstrate) that *H. dinarica* was originally calcitic. Furthermore, they considered it to be originally high magnesium calcite, although admitting that this was difficult to determine on petrological characteristics alone. The microprobe results presented herein suggest that the species was originally formed of low magnesium calcite. Luperto Sinni and Masse (1982) suggested that the species might be typical of inner shelf environments with high salinities, 'continental influence' and fluctuations in the Mg/Ca ratio. In support of this, they noted that Jaffrezo and Renard (1979) suggested that *Zergabriella embergeri* (Bouroullec and Deloffre) and *Clypeina jurassica* Favre, species also considered by Luperto Sinni and Masse (1982) to be originally calcitic, were typical of similar inner shelf conditions. However, our studies suggest that *H. dinarica* can be found in a variety of shelf environments and is not particularly indicative of hypersaline inner shelf conditions.

Morphological characteristics

The reasons for the uncertainty over the taxonomic position of *H. dinarica* centre around the crystalline structure of the thallus wall as alluded to by Radoičić (1959), and more fully discussed by Elliott (1960). Three features are noticeable: (i) the wall appears to be formed of radial, fibrous calcite, (ii) this has a yellowish or honey coloured tint, (iii) a dark, inner micritic layer to the thallus is typically present. These features are unusual for a dasycladacean alga, and were used by Elliott (1960, 1968) to argue for a non-algal origin for this fossil. Typical *Salpingoporella*, and other dasycladaceans, have a thallus wall composed of drusy, unstructured calcite, replacing the original aragonite. Elliott (1968) was the first to suggest that the preservation of *H. dinarica* related to an original, organically formed, calcite structure. Luperto Sinni and Masse (1982) also agreed with this interpretation, while Bassoullet *et al.* (1978) and Radoičić (1959) placed little significance in the form of preservation, arguing that the radial structure originates from diagenetic alteration. Our results confirm the assertion of Elliott (1968) that *H. dinarica* was originally calcitic.

Examination of the type figures of *S. dinarica* and *H. cylindrica* strongly suggests that the two species are synonymous. This is confirmed by comparison of topotypes of *S. dinarica* and the syntypes of *H. cylindrica*. As stated by Elliott (1968, p. 76) 'Slight differences in the two authors' descriptions can be reconciled by examination of large sets of specimens'.

Specimens described as *S. dinarica* and *H. cylindrica* show considerable variability, not only in the nature of the wall, but also in terms of morphology. Some topotype specimens of *S. dinarica* clearly show a fibrous, radial wall, whilst in others this is poorly developed. The topotypes do not show a particularly strong yellowish tint, as do the syntypes of *H. cylindrica*. More importantly, the topotype specimens of *S. dinarica* (and indeed the holotype illustrations) resemble dasycladacean algae, especially the genus *Salpingoporella*. Features typical of dasycladacean algae are not clear in the syntypes of *H. cylindrica*, but as noted and illustrated by Elliott (1968), they do occur 'not uncommonly' in Middle eastern specimens referred to *H. cylindrica*. This is confirmed by examination of specimens from the Kahmah Group of the Oman Mountains. Much of the morphological variation associated with this species can be attributed to preservation problems (erosion, etc.), and variability with depth and orientation of thin section.

Of particular note is the presence of 'pores' which are regularly spaced, alternating in position through progressively higher levels in the thallus. These can be interpreted as verticils of lateral branches (see Elliott 1968, plate 22, fig. 2; Text-fig. 1c). Overall the morphology is closely comparable with that of *S. muehlbergii* (Lorenz), the type species of *Salpingoporella*. The thallus is unsegmented with a wide axial hollow and only primary branches are present. The dark inner micritic layer to the thallus wall (thickness 0·012–0·018 mm) can be interpreted as being the preserved organic membrane lining the main axis of the thallus. Elliott (1968) noted that crushed specimens are still held together by this layer, suggesting that it had an original organic nature with some flexibility.

Other records of algae which show all the features of dasycladaceans, but are considered to be originally calcitic include the Visean 'dasycladacean' alga, *Koninckopora* (Wright 1981). This fossil is preserved in very fine-grained, sometimes acicular calcite. Like *H. dinarica*, *Koninckopora* often displays a micritic lining to the thallus wall. Other possible examples include the Late Jurassic species *Salpingoporella sellii* (Crescenti) and *Griphoporella*? *minima* Nikler and Sokač, both sometimes preserved in fine radial calcite. Elliott (1963) considered that *Pseudovermiporella* Elliott, a questionable Permian dasycladacean, was of calatic origin. Some species of the Late Jurassic–Early Cretaceous dasycladacean *Zergabriella embergeri* display fibro-radial walls with a yellowish tint and a micritic inner layer to the thallus wall, as in *H. dinarica* (see illustrations in Granier 1989). Further research is needed to establish how well developed is this feature in this species, and if it relates to an original calcitic mineralogy as suggested by Luperto Sinni and Masse (1982). These authors also considered *Clypeina jurassica* to be originally calcitic, and (Luperto Sinni and Masse 1984, 1986) placed *Salpingoporella urladanasi* Conrad, Peybernes and Radoičić in the genus *Hensonella* on account of its similar preservation to *H. dinarica*, but differing in its larger dimensions.

Thus whilst the majority of fossil dasycladaceans were originally aragonitic, there may have been a few taxa which were originally calcitic. Pending further research to establish the number of calcitic 'dasycladaceans', and the reasons for their unusual mineralogy, no new suprageneric taxonomic group is established here. Interestingly, the majority of occurrences of possible originally calcitic 'dasycladaceans' is within the Late Jurassic–Early Cretaceous and Early Carboniferous. These were periods when, according to Sandberg (1983), non-skeletal carbonates were dominated by calcite rather than aragonite ('aragonite inhibiting episodes'). These may have been brought about by plate-tectonically influenced oscillations in the vapour pressure of CO_2, which in turn correlate with other known global oscillations in eustacy and climate. However, it should be stated that originally aragonitic dasycladaceans are also abundant during these periods, and it is uncertain whether the occurrence of originally calcitic dasycladaceans can simply be attributed to an 'aragonite inhibiting' process.

It is worth noting that other mineral phases besides aragonite are known within dasycladaceans. For example, calcium oxalate has been recorded in reproductive discs of *Acetabularia* (Elliott 1979).

CONCLUSIONS

The preservation of *H. dinarica* relates to a primary organic calcitic mineralogy, although the morphology of the species is in keeping with the dasycladacean genus *Salpingoporella* Pia. Such an original mineralogy is almost unique in the family Dasycladaceae where primary mineralogy is normally aragonitic (Wray 1977). In fossils this is usually replaced by drusy calcite. The genus *Hensonella* Elliott is therefore retained to identify originally calcitic homeomorphs of *Salpingoporella*. Further research is in progress which may lead to the identification of other originally calcitic 'dasycladacean' taxa. If further taxa are identified, it may be necessary to erect a new suprageneric group to accommodate such forms (e.g. 'Hensonellaceae'), or to amend the diagnosis of the Dasycladaceae.

The recognition that *H. dinarica* was originally calcitic, not aragonitic, has important implications for diagenetic studies of the carbonates in which this microfossil occurs (e.g. the oil-bearing Shuaiba Formation of the Middle East). Because it was originally calcitic it would not have been leached during meteoric diagenesis, resulting in possible underestimations of the amount of meteoric diagenesis in previous studies.

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