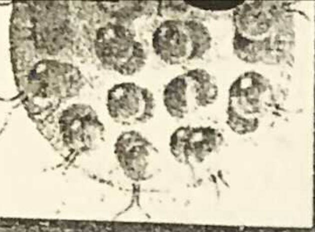


FOSSIL ALGAE

19.1 WHAT ARE FOSSILS AND FOSSIL ALGAE?

The relics or traces of some plants or animals, which have been preserved by natural processes in rocks of the past, are called *fossils*. Fossils provide important clues to the history and evolution of living organisms.

Since, almost all algae are soft and delicate, they generally do not contain parts which are preservable as fossils. Majority of algae are therefore imperfectly preserved as fossils. Only very few algal fossils are well-preserved and hence identified with certainty. Due to silicified walls of some algal members (e.g. diatoms), they are well-preserved and thus have been identified and studied in great details. Various ways of preservation of algae as fossils include *impressions*, *molds*, *casts* and *petrifications*, of which petrifications are more important and common. Of course, the earliest known plant fossils are algal fossils.

19.2 HOW OLD ARE THE ALGAL FOSSILS?

Fossil record proposed by Schopf (1970) indicates that the most ancient organisms that contained chlorophyll *a* where "probably" blue-green algae with a fossil record extending back possibly 3 billion years into the Precambrian. Schopf and Blacic (1971) later suggested that these were followed in Late Precambrian times by several groups of eukaryotic algae. The most ancient recognizable algae were, therefore, prokaryotic i.e. members of Cyanophyceae, e.g. *Archaeosphaeroides barbertonensis* (a sphaeroidal, alga-like fossil from Early Precambrian). *Stromatolites*, which are layered calcareous structures similar to the growth patterns of some modern blue-green algae, are approximately 2.8 billion years old. Well-preserved members of Stigonemataceae have been reported in Scotland in the Devonian chert at Rhynie.

The diversity of microfossils, including algal, increased during the Middle Precambrian i.e. from 2.5 to 1.7 billion years ago. Several coccoid algae and heterocystous and non-heterocystous filaments of blue-green algal fossils have been reported by Barghoorn and Tyler (1965) and Licari and Cloud (1969) from the Middle Precambrian. Schopf (1974) described Precambrian as the *age of blue-green algae*.

Fossils of over two dozen blue-green algal species have been discovered from the black cherts of Late Precambrian (i.e. about 900 million years ago). These also included some members of Chlorophyceae and Rhodophyceae. Cloud *et al.* (1969) described fossils of some green algal species of Chlorococcales from 1.2 to 1.4 billion years old strata.

The geological history of some algal groups, as proposed by Schopf (1970), is mentioned in Table 19.1.

19.3 SOME FOSSIL RECORDS OF CYANOPHYCEAE

The first autotrophic organisms, the cyanophytes, made their appearance in the Early Precambrian i.e. approximately 3 billion years ago (Schopf and Walter, 1982). In the latter part of the Precambrian (i.e. approx. 2.6 billion to 0.5 billon years ago) they were omnipresent. In the fossil record of this period, the representatives of most of the present-day cyanophytes were present. Schopf and Walter (1982) referred this as the "*age of Cyanophytes*" or "*age of Cyanobacteria*".

Most of the blue-green algal fossils are in the form of impressions, which are globular or thread-like. They have built nodule-like structures, usually referred as *stromatolites*. They show concentric zones which are supposed to be laid down by repeated depositions of lime by colonial genera like *Microcystis*, *Gloeocapsa*, *Rivularia* or *Aphanothece*. *Girvanella* is a calcareous blue-green algal fossil reported from Cambrian to Cretaceous. Extensive Silurian deposits have been reported due to cyanophyte *Gloeocapsomorpha*, an alga similar to the present-day *Gloeocapsa*. *Lyngbya*, *Schizothrix* and *Rivularia* are some other lime-depositing Cyanophytes. *Nostocites* from Carboniferous shows oscillatorian affinity white *Morpolia* is fossil Cyanophyte similar to present-day *Schizothrix*.

In India, the cyanophycean stromatolites are found in Precambrian carbonate series. Majority of the stromatolites

Table 19.1 Geological history of some algal groups

S. No.	Group	Geological Periods
1.	Cyanophyceae	Precambrian
2.	Chlorophyceae	Precambrian
3.	Rhodophyceae	Cambrian
4.	Phaeophyceae	Late Precambrian
5.	Charophyceae	Silurian
6.	Prymnesiophyceae	Triassic
7.	Xanthophyceae	Cretaceous
8.	Euglenophyceae	Cretaceous
9.	Bacillariophyceae	Cretaceous
10.	Chrysophyceae	Cretaceous

are younger than 1.5 billion years and found in India in Cuddappa system, Karnool system, Chattisgarh system and Vindhyans. Fossil *Synechocystis* and *Scytonema* showing false branching have been reported in lignites of Kashmir while *Aphanocapsa* fossils are found in Carboniferous beds of Rewa in Madhya Pradesh. Heterocyst-containing *Palaeonostoc* has been reported from Ganga Valley.

19.4 SOME FOSSIL RECORDS OF RHODOPHYCEAE

Fossil record of Florideophycidae is incompletely known. Johansen (1981) has, however, given fossil record of the calcified coralline members of red algae. Four families of calcified red algae-containing fossils are Solenoporaceae, Gymnocodiaceae, Squamariaceae and Corallinaceae. Of these, Solenoporaceae and Gymnocodiaceae are extinct. Solenoporaceae appeared first during Upper Cambrian period (i.e. about 1.6 billion years ago) and were abundant by the Ordovician (i.e. about 500 million years ago; see Table 19.2). *Parachaetetes* and *Solenopora* are two examples of Solenoporaceae fossils of Ordovician period.

Non-articulated coralline red algae, which occur as free-living nodular structures are known as *rhodoliths* in the fossil and living state. Living rhodoliths (e.g. *Limnothamnion glaciale*) occur from 50 to 200m deep in the water on the floor of the ocean. They are widely distributed and very slow-growing. Fossil rhodoliths have been recorded from Eocene, Oligocene and Miocene (i.e. from 55 to 7 million years before present; see Table. 19.2).

Fossil record of soft members of red algae is poorly known, except that of members like *Palaeoconchocelis starmachii* (Campbell, 1980) from Upper Silurian (i.e. about 425 million years ago) of Poland. Its endolithic filaments resemble with some life cycle stages of *Porphyra* and *Bangia*. Some *Bangia*-like fossils have been reported from Proterozoic period (i.e. about 1.9 billion years ago), linking the origin of red algae quite close to that of eukaryotic organisms (Tappan, 1976).

Majority of fossil red algae belong to Corallinaceae. It is so because Corallinaceae is the group of lime-incrustated members. These fossils are very abundant in Cretaceous and Tertiary. Huge calcareous masses, called *coral reefs*, have been formed by these genera, particularly in tropics. Sometimes these reefs become as thick as 300 m or even more. Common coral reef forming red algal genera of Indian Ocean are *Lithophyllum, Gonilithon, Porolithon* and *Lithothamnion*. Some of the red algal Indian fossil genera along with their place of recordings are *Archaeolithothamnion* (Pondicherry), *Lithothamnion* (Assam and Surat), *Corallina* (Andaman and Nicobar) and *Lithophyllum* and *Solenopora* (Pondicherry).

19.5 SOME FOSSIL RECORDS OF PHAEOPHYCEAE

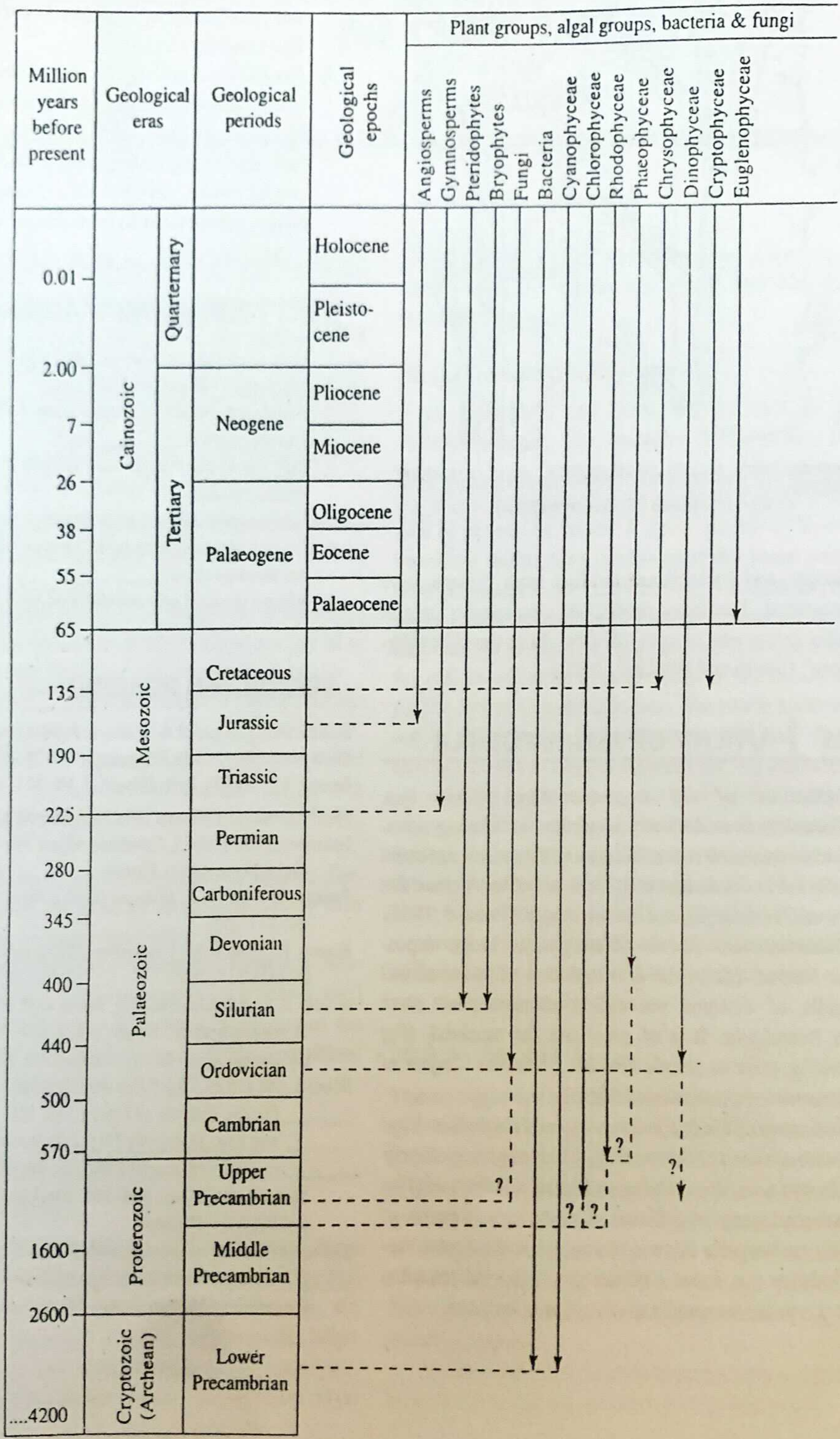
According to Parker and Dawson (1965), the record of the best fossil brown algae are from Miocene (about 25 million years ago), and these include members of Laminariales (e.g. *Julescraneia*) and Fucales (e.g. *Paleocystophora, Paleohalidrys, Cystoseirites*). Scientists, however, suggest a possible Precambrian origin for Phaeophyceae (i.e. about 570 million years ago; see Table 19.2), and some fossils of brown algae, similar to the members of the modern-day Fucales, Dictyotales and Sphacelariales (Scagel *et al*., 1982) have been reported from Silurian and Devonian (see Table 19.2).

The characteristic fossil of phaeophycean type is *Prototaxites*, as described by Dawson from Upper Devonian period. It attained a length upto 2.2–2.3 m and a diameter of about a meter, Fossils of some other brown algae, including *Ectocarpus, Dictyota, Cutleria* and *Fucus* have also been described from later periods. A *Dictyota*-like fossil of another brown alga, *Thamnocladus*, has also been described from Devonian period of New York by Fry and Banks (1955). The little known fossil record of brown algae provides little evidence in support of phylogenetic considerations.

19.6 SOME FOSSIL RECORDS OF BACILLARIOPHYCEAE

Members of *Bacillariophyceae* are most recognizable fossils because their silicious walls are easily preserved.

Table 19.2 Geological ranges of the main plant groups, including algal groups, bacteria and fungi (Modified from Scagel *et al.* 1982 and Sudgen, 1984)



According to Tappan (1980), the earliest of diatom fossils are from Lower Cretaceous. However, some report them to be from quite early period i.e. from Precambrian. Round and Crawford (1981) mentioned that "these data should be re-examined". The earliest diatom fossils were centric, e.g. *Stephanophyxis*. Extensive fossil diatom deposits, in the form of *diatomaceous earth* (also known as *kieselguhr*), have been laid down in both freshwater and marine habitats. Diatoms evolved from a "eukaryote, flagellate ancestor with siliceous scales" as per the available reports.

Some reports mention that the oldest known diatom is *Pyxidiculla bollensis* from Jurassic. As many as 60 to 70 genera of Bacillariophyceae are known from the Upper Cretaceous to the present. Since, majority of the early fossils belong to centric, it is presumed that centric diatoms are more primitive than pennate diatoms. Lompoc in California (USA) has the largest known littoral diatom deposits on the earth, where the diatomaceous beds run in several kilometers with a depth of about 350 m or more. In India, fossil diatoms have been reported from Orissa, Kashmir and Andaman and Nicobar Islands.

Some freshwater fossil diatoms present in the waters of high alkalinity include species of *Gyrosigma* and *Cymatopleura* while those in the more acidic waters include the species of *Anomoeoneis* and *Eunotia* (Chapman and Chapman, 1973).

19.7 SOME FOSSIL RECORDS OF CHRYSOPHYCEAE

Except silicoflagellates, the vegetative stages of *Chrysophyceae* are only rarely represented as fossils. Fossils of silicoflagellates occur commonly in marine siliceous deposits. Tappan (1980) described several marine cysts of fossil Archaeomonadaceae from the Upper Cretaceous to Holocene (Table 19.2). They specially occur as diatomites, making as much as 50% of the rock mass. The little known fossil record of chrysophycean algae does not provide any specific indication of their origin and evolution.

19.8 SOME FOSSIL RECORDS OF PRYMNESIOPHYCEAE (= HAPTOPHYCEAE)

Calcified scales (*coccoliths*) of members of *Prymnesiophyceae* fossilize readily and are seen prominently in fossil oozes. The available records indicate that these algal members may have been more abundant than at present, especially in the Mesozoic, the Jurassic and Late Cretaceous periods (i.e. 205–125million years before present). Many species of Prymnesiophyceae were present in Tertiary even between 5–10 million years ago and several have been persisting even up to the present. Fossil records of Prymnesiophyceae and Chrysophyceae suggest a possible common ancestry of both these groups.

19.9 SOME FOSSIL RECORDS OF DINOPHYCEAE

Several fossil dinophytes have already been reported, but the earliest records are from the Jurassic, and many of the fossil forms could be ascribed to *extant* (species which exist at present) genera, such as *Ceratium, Gonyaulax, Gymnodinium* and *Peridinium*. The *extinct* genera of Dinophyceae include *Hystrichodinium* (Fig. 19.1A), *Peridinites, Hystrichosphaeridium* (Fig. 19.2B) and *Diconodinium* from Cretaceous, *Palaeoperidinium* from Jurassic to Tertiary, *Rhynchodiniopsis* and *Raphiododinium* from Cretaceous. They all possess characteristic dinoflagellate orientation with clear girdle.

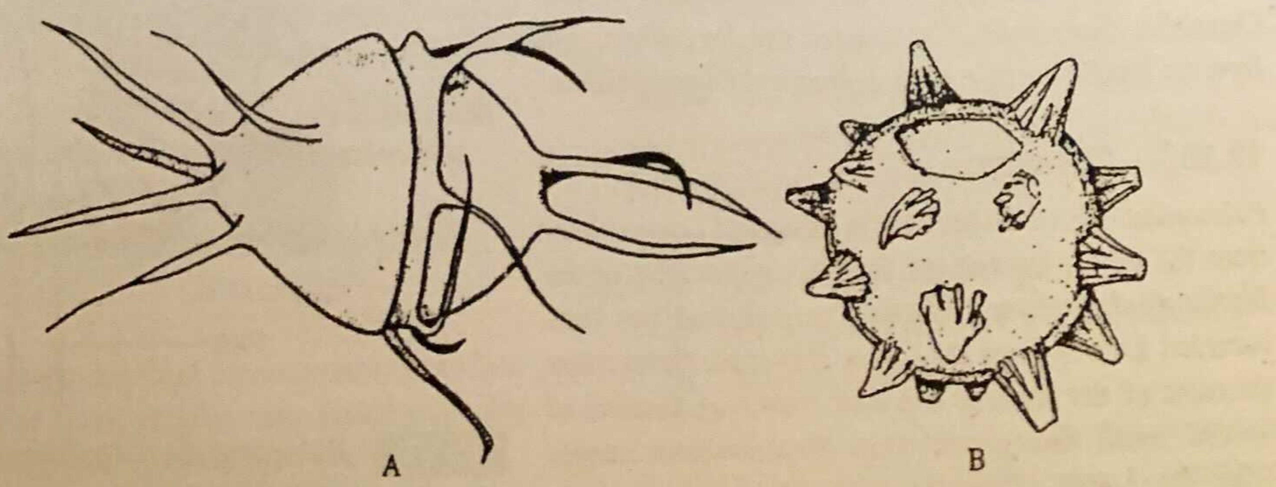


Fig. 19.1 A, *Hystrichodinium oligacanthum*, showing characteristic dinoflagellate orientation; B, *Hystrichosphaeridium striatoconus*.

Loeblich (1974) opined that dinophytes were probably derived from ancestral chromophytes in the Late Precambrian. The Silurian *Arpylorus* may be the earliest dinoflagellate fossil, according to Dodge (1983).

19.10 SOME FOSSIL RECORDS OF CHLOROPHYCEAE

The chlorophytes have the oldest geological record extending from the Precambrian (Table. 19.2) to the present. They are also the best known of any algae. The siphonous members are especially significant as major rock-builders. It is believed that chlorophytes reached their maximum in the Middle Cretaceous, and since then have declined more or less continuously.

19.10.1 Dasycladaceae

Over 95% of the described genera of Dasycladaceae (Dasycladales, Chlorophyceae) are now extinct (Tappan, 1980). They may be exemplified by *Palaeodasycladus mediterraneus* (Fig. 19.2A) from the Lower Jurassic of Italy and *Cymopolia paktia* (Fig. 19.2B) from Eocene of Afghanistan.

Beginning in Precambrian (e.g. *Templuma*), Dasycladaceae members became more complex during Palaeozoic and diversified prominently in the Mesozoic. *Cyclocrinus* (Fig. 19.3) looked like a miniature golf ball developed on the end of a stalk.

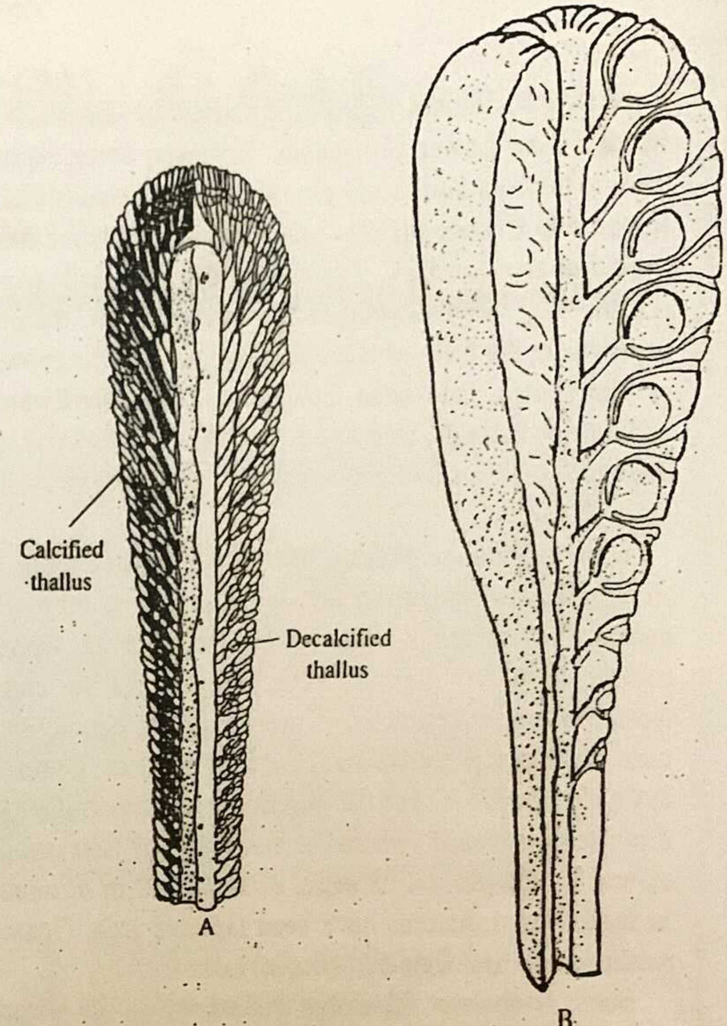


Fig. 19.2 Some fossil Dasycladales. A, Reconstruction of a L.S. showing calcified thallus of *Palaeodasycladus mediterraneus*; B, L.S. thallus of *Cymopolia paktia*. (A, after Pia; B, after Kaever)

19.10.2 Codiaceae

Codiaceae was the best represented family of rock-building algae, mainly from the Ordovician to the Carboniferous and from the Jurassic to the present. Some of the examples include *Boueina* from the Lower Cretaceous, *Palaeoporella* from the Lower Silurian, *Dimorphosiphon* (oldest known Codiaceae) from the Ordovician, and *Abecella* and *Lancicula* (Fig. 19.4) from the Devonian.

Fossil Codiaceae reported from the Permian include *Ortonella*, *Garwoodia*, *Calcifolium* and *Succodium*, and from the Triassic include *Anchicodium* and *Eugonophyllum*.

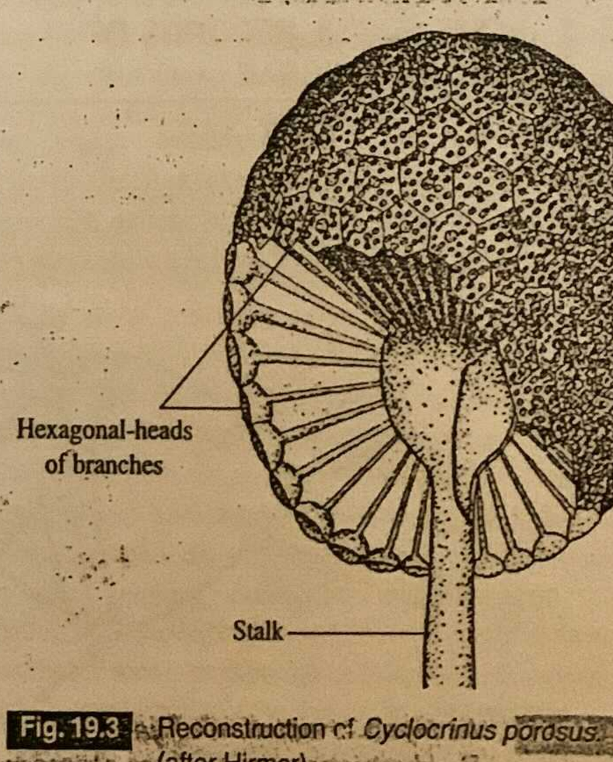


Fig. 19.3 Reconstruction of *Cyclocrinus porosus*. (after Hirmer)

19.10.3 Characeae

Palaeonitella from the Middle Devonian and *Lagynophora* from the Lower Eocene are the known examples of the fossils of charophytes. *Trochiliscus podolicus* has been recorded from beds of the Lower Devonian. *Gyrogonites* (remains of the oogonia and their encircling sheaths) of several fossil charophytes (e.g. *Stephanochara caupta* from the Lower Oligocene, *Kosmogyra superba* from

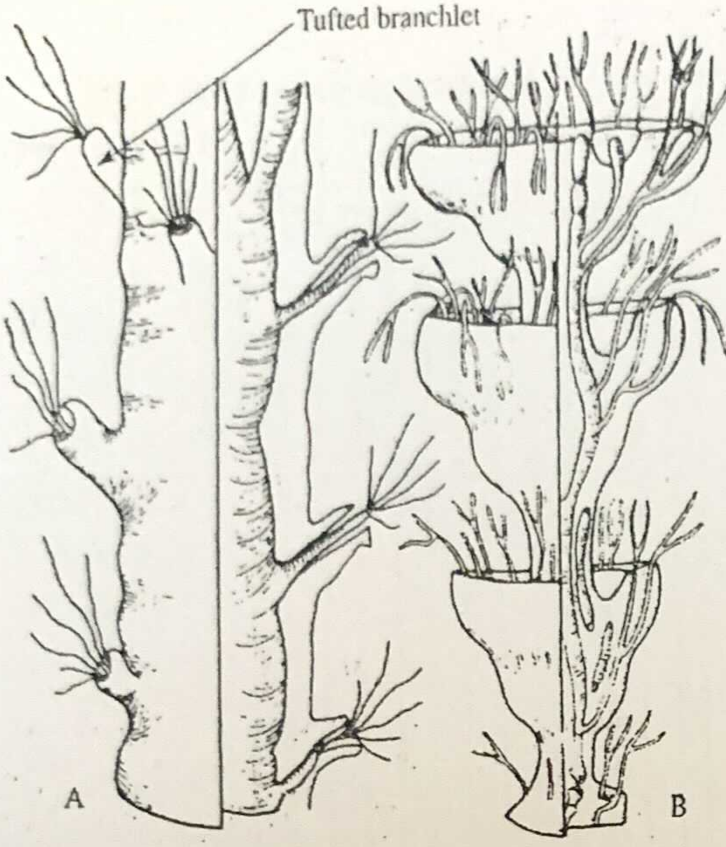


Fig. 19.4 Reconstruction of *Abacella pertusa* (A) and *Lancicula alta* (B). (after Maslor)

Palaeocene, and *Psilochara undulata* from Eocene) have been reported. The fossil records of charophytes suggest "that this group was an early offshoot from the chlorophycean line" (South and Whittick, 1987).

19.11 UTILITY OF ALGAL FOSSILS

1. *Indicators of Oil Deposits:* Algal fossils (e.g. Coccolithophorides) are important in locating petroleum-bearing oil rocks. Because of the presence of about 11% oil in the diatom cell, some are of the opinion that "world's oil supply is of diatom origin" (Prescott, 1969).
2. *Diatomaceous Earth (Kieselguhr):* Large deposits formed due to the accumulation of siliceous cell walls of diatoms are called *diatomaceous earth* or *Kieselguhr*. It is of great use for mankind. (For details, refer to Article No. 22. 2.9 in the Chapter of Economic Importance of Algae).
3. *Indicators of Early Environment and Evolution:* Algal fossils are used in determining different geological periods and eras, thus helping in finding out the evolution and phylogeny of different algal groups. Presence of only prokaryotes (blue-green algae) in the Lower Precambrian (i.e. about 3 billion years ago) indicates that prokaryotes are more primitive than eukaryotes.

4. ***Indicators of Changing Ecological Conditions:*** Diatoms prove useful as indicators of changing ecological conditions, as exemplified by different species of *Melosira*. *M.ambigua* is an indicator of warm water and rich nutrients whereas *M.italica* indicates cold water and poor nutrients.
5. ***Fossils as Building Stones:*** Very large limestone rocks, consisting mainly of algae as *Lithothamnion* of Miocene age, are used in making bricks, which are light and strong and used for making buildings. Light weight bricks, which have a constant temperature in rooms, are also made from diatomaceous earth.