

# ALGAL LIMESTONES

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**ABSTRACT.**—The author traces the history and development of the study of fossil algae and limestones and the economic aspect of the study. An account of various rock building algae through the geological ages is given.

## INTRODUCTION

**F**ossil algae and limestones, supposedly formed by algae, were reported in the literature as far back as about 1870, but



the mentions are few and very casual. It was not until Garwood, in 1913, in his Presidential Address to the Geological Society of London, called attention to algal limestones that geologists in general began to look for them and to recognize them when they saw them.

During the last ten years geologists have become interested in various types of biohermal and biostromal limestones and have begun to pay serious attention to algae and algal limestones. When I first began a study of algal limestones twenty five years ago, in order to get material I asked many of my former students who were practicing geology in various parts of the country, and various friends among the geologists, to please send me specimens of algal limestones if they happened to run across any. At least nine times out of ten, I received the reply: "I'll be very glad to do it, Prof., but what do they look like?"

Garwood in his two reviews on fossil calcareous algae in 1913, and in 1931, gave résumés of the literature up to that time. He presented a very clear picture of what was known about them at those dates. In his several publications on the Carboni-

ferous stratigraphy of northern England, he also described a number of algal limestones, and really called the attention of British geologists to their existence by discussing their characteristics and recognition.

In France, Madame Lemoine began her classic studies about 1910 and continued them at intervals until 1940. She was interested primarily in fossil coralline algae, but she mentions and describes the work of those organisms in building limestones. Her studies made European geologists conscious of the existence of this type of algae, and laid a good foundation for later work.

Julius Pia, working in the Natural History Museum at Vienna for many years, studied algal limestones and fossil algae. He was particularly interested in the *Dasycladaceae*, and published many papers describing fossil forms, as well as a number of general discussions on the evolution and geologic work of algae. His classic work, *Pflanzen als Gesteinsbildner* published in 1920, probably did more to acquaint geologists in general with fossil algae, and the work of algae in building limestones, than any publication that has been issued to date. It had a profound effect upon European students. Unfortunately, most American geologists have a very poor background in foreign languages. Consequently, only a few of them managed to read Pia's and Madame Lemoine's papers. Johnson endeavored to remedy this situation by preparing an *Annotated Bibliography* on the geologic importance and geologic work of calcareous algae which was published in 1943.

During the last ten years, several things have stimulated the study of algal limestones. In 1947, the U.S. Navy organized the Bikini



Resurvey Expedition to study conditions at Bikini a year after the bomb blast. Among the several hundred scientists on the expedition were some geologists who went to study the geology of the coral reefs. They even cored deeply into the reefs. These studies of the reefs and materials obtained from the borings indicated that calcareous algae were very important as reef-builders. The geologic report on the expedition has been published as U.S. Geological Survey Professional Paper 260. During 1950 William Randolph Taylor's report on "The Plants of Bikini" appeared. This not only describes the various land and marine plants found in and around the atoll, but repeatedly emphasizes the importance of the coralline algae in building the reefs.

During this period also, the petroleum geologists have become greatly interested in reefs and reef limestones because a number of fossil reefs have proved to be excellent reservoirs for oil. This has led to a study of the organic limestones forming the reefs, demonstrating the importance of calcareous algae as reef-builders in the past.

#### ROCK-BUILDING ALGAE

Any algae which deposit or secrete lime may assist in building limestones. During their long and complicated evolution, a number of different and widely separated groups of algae have developed the ability to deposit lime. These various types are listed in Table 1, below.

IMPORTANT FAMILIES OF ROCK-BUILDING ALGAE

<i>Class</i>	<i>Family</i>	<i>Characteristic Structures</i> (in thin section)
RHODOPHYTA (Red Algae)	Corallinaceae	Rows of closely packed rectangular cells—commonly arranged in regular rows.
	Solenopraceae	Rows of closely packed cells with polygonal cross sections. Cross partitions present too, frequently very thin.
CHLOROPHYTA (Green Algae)	Charophyta	Highly developed, small, bushy plants. Fossils usually consist of calcified, heavily ribbed spherical oogonia and the whorled branches which bear them.
	Dasycladaceae	A central stalk, preserved as a tube or bulb, surrounded by tufts of leaves or leaf bases, preserved as knobs or brush-like protuberances.
	Codiaceae	Small tubes loosely arranged so as to form segmented stems. Tubes round in cross section and branching.
CYANOPHYTA (Possibly Chlorophyta)	Porostromata	Small tubes so loosely arranged as not to compress each other. No cross partitions visible.
CYANOPHYTA (Blu-Green Algae)	Spongiostromata	Cellular structure seldom preserved. The $\text{CaCO}_3$ is deposited as crusts on the outside of the colony or cell, or between the tissues—not in the cell wall. Classified on the basis of growth habit and form of the colony.



Of these, only the red coralline algae actually secrete lime in the sense of depositing it within and between their cell walls, and using it as a supporting framework. Consequently, they are the only type in which the full cellular structure can be recognized in thin sections and slides. Some of the green algae belonging to the family Codiaceae undergo a calcification of the tissue which may be complete in older specimens. All other calcareous algae deposit lime around the plant tissues, and the fossils or rock that is formed consists of delicate calcareous molds of a mat of filaments and stems and other parts of the plant. These are very porous, and consequently easily altered by percolating ground waters and become recrystallized.

#### RHODOPHYTA : CORALLINE ALGAE

Today the red coralline algae, especially the non-articulated *Lithothamnium*, occur in all seas and in both cold and warm waters. Locally, they are so abundant as to be rock-builders. Foslie (1929) in his classic work on the Arctic *Lithothamnium* repeatedly mentions their importance as rock-builders. Studies by several algalogists along the coast of France and in the Mediterranean have emphasized their importance in depositing lime and building limestone banks and marl deposits. Recent studies of the so-called "coral reefs" of the tropical Pacific show that the *Lithothamnioid* algae play a very important part in the building of such reefs by (1) contributing to the limestone, that is, to the mass of the reef itself; (2) by forming the outer algal or "Lithothamnion ridge" which protects the entire reef from destruction by the waves; and (3) binding action of numerous thin, encrusting forms which cement coral heads and other objects together to form the solid core of the reef. These features are described in detail in the Bikini report (Emery, Tracey, Ladd 1954).

Recent types of coralline algae have existed since at least late Cretaceous times and

most of the present-day genera were present during the Eocene (Pl. 3, fig. 1). They have been very active throughout the Tertiary and Pleistocene and are today in warm waters. A few forerunners belonging to the family Solenoporaceae appear in the Paleozoic, but they were not nearly so important relatively as the corallines are today. (Pl. 4, fig. 2).

The articulated coralline algae were abundant during Eocene and had commenced in the Cretaceous. Very seldom do they occur in sufficient numbers to become important contributors to limestone building, but fossils of their tiny segments are found in many Tertiary and Pleistocene limestones.

#### CHLOROPHYTA : GREEN ALGAE

Members of several families of green algae have developed the lime-depositing habit. The Codiaceae and Dasycladaceae have both left a long fossil record and at times have been rock-builders.

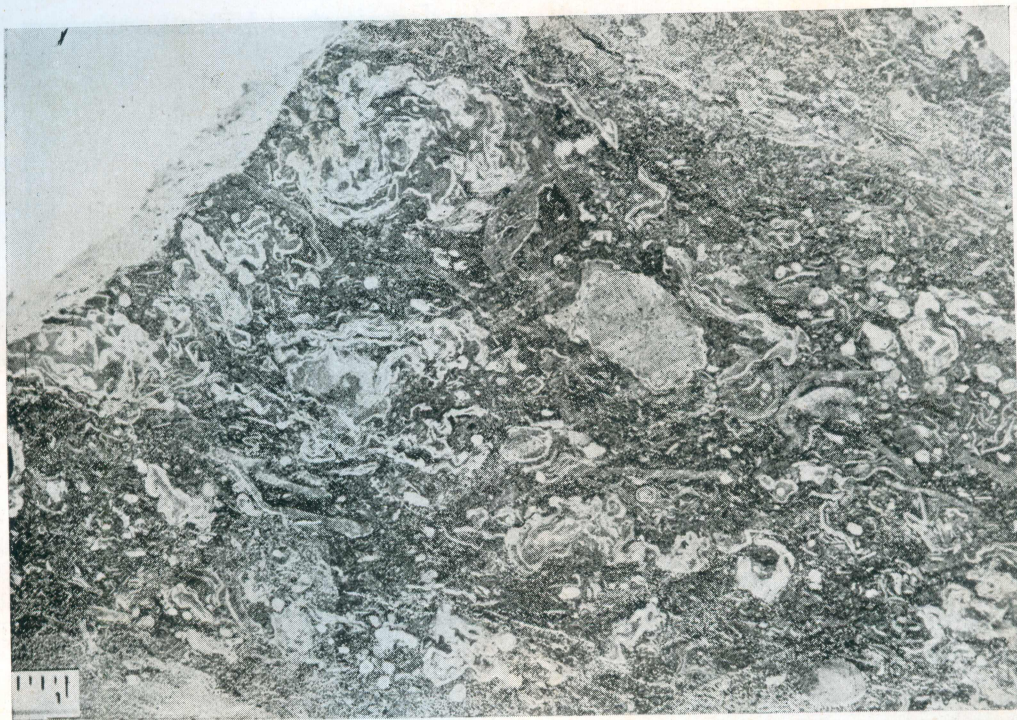
The Codiaceae have been important from the late Paleozoic to the present as limestone builders. Some plants have segmented stems which become encrusted with lime, leaving fossils suggestive of small leaves, or in some cases rounded beads. Others form rounded nodular masses. They may grow on unconsolidated, muddy flats, as well as along rocky shores and on reef flats in environments similar to the coralline algae. Consequently, their remains may occur in sediments of quite different facies than those of the coralline algae. In the Permian beds of West Texas, and the Carlsbad region of New Mexico, we find an abundance of the remains of the genus *Gymnocodium*, which apparently lived under conditions very similar to the recent *Halimeda*.

Today species of *Halimeda* are widely distributed in warm marine waters. They grow abundantly in the lagoonal deposits of recent and Tertiary reefs. Their importance has been emphasized by most students of reef deposits. In his work on the geology

#### EXPLANATION OF PLATE 3

- FIG. 1—Limestone with abundant coralline algae, both crustose and branching forms. (xl). Eocene, Ryukyu Islands.  
2—*Halimeda* limestone (xl). Miocene, Saipan, Marianna Islands. (Courtesy U.S. Geological Survey).



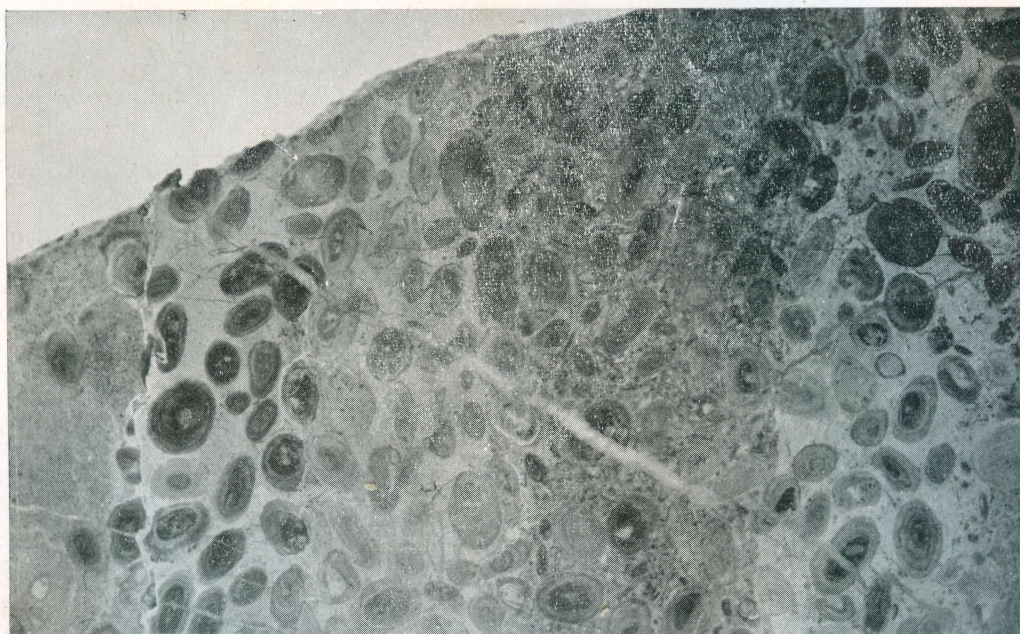


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of some of the Pacific Islands, the writer has run across many examples of typical *Halimeda* limestones. One of the most spectacular was along the northern coast of the Island of Angular in the Palau group (Pl. 3, fig. 2.). Samples dredged from the bottoms of lagoons of the atolls at Bikini, Eniwetok, and elsewhere, have yielded specimens consisting largely of *Halimeda* remains.

The Dasycladaceae commonly develop small bushy plants having single or segmented stems which become encrusted with lime, leaving fossils suggestive of beads, small clubs, and brushlike objects. In most cases the individual segments are very small, but a few have been recorded which were over a foot long. Members of this family appear early in the geologic record, and locally, helped to build limestones as far back as the middle Ordovician. During Ordovician times they were quite abundant in certain areas in Texas and in the Baltic region of Europe. They became very important during the Permian, when the genus *Mizzia* was an important rock-builder in practically all the warm waters of the world. They continued abundantly throughout the early Mesozoic, contributing liberally to rock-building, especially in south central Europe and around the Mediterranean. The family appears to have reached its zenith during Jurassic times, when it was represented by a very great variety of forms, and attained the most complicated structural development. After that, there was a very gradual decline in variety which apparently has been accentuated during Recent times. During the same period there was a tendency toward a simplification of structure.

Dasycladacean limestones are known from the Ordovician of Texas and Norway (Pl. 5, fig. 1) and in the Ordovician and Silurian of the Baltic region. *Mizzia* limestones occur abundantly in the Permian reef facies of West Texas and in adjoining parts of New Mexico and Mexico (Pl. 5, fig. 3). Recently they have been found in rocks of the same age in Japan. The genus *Diplopora* reached its greatest development during the Triassic,

though it lingered on throughout much of the Mesozoic. During Triassic times members of the genus built extensive limestones in the Tyrol region, and in Yugoslavia.

#### CHARA LIMESTONES

The *Chara* are a specialized group of lime-depositing algae which grow abundantly in many lakes, ponds, and in the brackish waters of some estuaries and lagoons. During Paleozoic times, some representatives of the group may have been marine. Their remains are found sparingly in late Paleozoic deposits and throughout the earlier Mesozoic. During Jurassic times, they seem to have become very important—particularly in brackish and fresh waters. In the Morrison formation of Colorado, they form lenticular masses of fresh water limestone (Pl. 5, fig. 2), and similar deposits have been recorded from rocks of later geologic periods. Such limestones have been found in the late Mesozoic and Cenozoic deposits of Europe, India, and China.

The *Chara* aid greatly in the formation of certain marls which are now actively forming in many glacial lakes in Wisconsin, Minnesota, Iowa, and Ohio. Locally, farmers used them to enrich lime-deficient soils.

The algae discussed so far, all have structures which are more or less preserved in the fossils. Consequently, they can be recognized with certainty, and classified with fair accuracy in thin sections of limestone. However, in addition to these, there are many algal limestones which show vague, cloudy structures in thin section, and they often form colonies which show quite characteristic structures on weathered surfaces. Colonies of this sort are being formed today by certain assemblages of Green, and Blue-Green algae, and by combinations of the two. Many occurrences of "algal biscuits" have been recorded as being formed in streams, lakes, and estuaries, under present conditions. Great quantities seem to be developing around Andros Island in the Bahamas.

#### EXPLANATION OF PLATE 4

- FIG. 1—*Girvanella* limestone (xl). Cambrian, Sonora, Mexico.  
2—*Solenopora* limestone (xl). Ordovician, Oxford, Ohio.



Similar deposits occur commonly in rocks of all ages. They are especially abundant in the older rocks. Some of them are the oldest known fossils. For convenience in study, Julius Pia classed them under two artificial families—the *Porostromata* and the *Spongiostromata*.

Among the *Porostromata* some indication of the original structure is preserved. In many cases, the colonies form rounded masses which may range in size from that of a small bead to objects several inches across. In thin section, they are seen to consist of molds of tabular threads of filaments which may, or may not, branch. Commonly they occur as masses of twisted tubes, which in thin section strongly suggest a mass of spaghetti. The genus *Girvanella* is the most common representative of this type. It has a time range from the Cambrian to the Jurassic.

Fossil algae belonging to the *Porostromata* developed in great abundance during the Paleozoic, particularly in the Ordovician, Silurian, and Mississippian times. They were world-wide in their distribution, and frequently were important rock-builders. *Girvanella* limestones are known from the middle and upper Cambrian of all the continents (Pl. 4, fig. 1), and developed locally in numerous areas during the Ordovician, Silurian, Devonian, Mississippian and Jurassic times. Other *Porostromata* limestones are known to occur but with diminishing importance throughout the Mesozoic. They have not been abundant nor important, however, since the end of the Mesozoic era.

The *Spongiostromata* consist of molds of felt-like masses of very fine thread-like filaments. On the death of the plant, they represent a soft, extremely porous type of limestone which is very easily attacked by solution and recrystallization. Consequently in thin section they show little structure—only vague molds of threads. Frequently, however, they form very characteristic

colonies which may have quite definite size and shape. They have been classified purely on the basis of the form of the colony. Such forms developed very early in geologic time, far back in the pre-Cambrian. They form the oldest known fossils. During the late pre-Cambrian they became important limestone builders in many parts of the world. Such limestones are common in the Belt series of Montana and adjoining regions. They have been described from Canada, China, Manchuria, Siberia, India, Morocco, Algeria, the Belgian Congo, Rhodesia, the Union of South Africa, Australia, Russia, and Scandinavia. The majority of these limestones were built by algae belonging to the genus *Collenia* which continues into the early Paleozoic. *Collenia* limestones are also widespread in the upper Cambrian.

During the early Paleozoic the *Spongiostromata* were also important. The genus *Cryptozoon*, during late Cambrian and Ordovician times, had a world-wide distribution. *Cryptozoon* limestones are well known from the maritime provinces of Canada, New England, New York, the Appalachian region, Minnesota, Wisconsin and Missouri. Other *Spongiostromata* occur—though in much less abundance—throughout the Paleozoic, Mesozoic and down to the present (Pl. 6).

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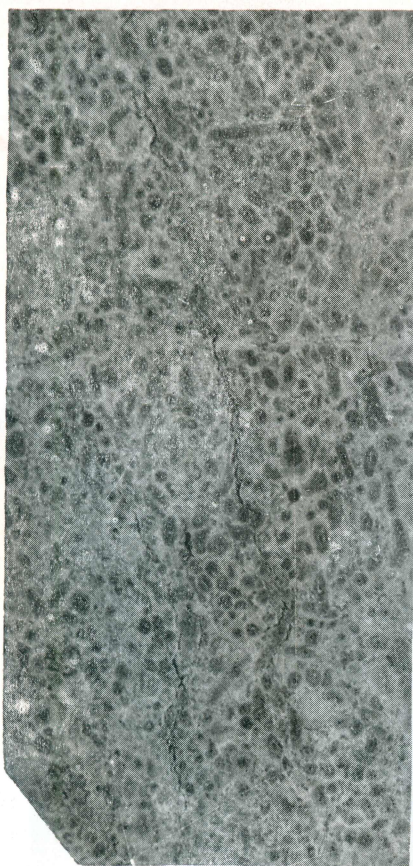
#### EXPLANATION OF PLATE 5

- FIG. 1—Limestone with the large dasycladacean alga *Coelasphaeridium* (x1). Ordovician, Helgoya, Norway.
- 2—*Chara* limestone (x2). Jurassic (Morrison formation) Perry Park, Colorado.
- 3—*Mizzia* limestone (x3). Permian, Apache Mountains, Texas.





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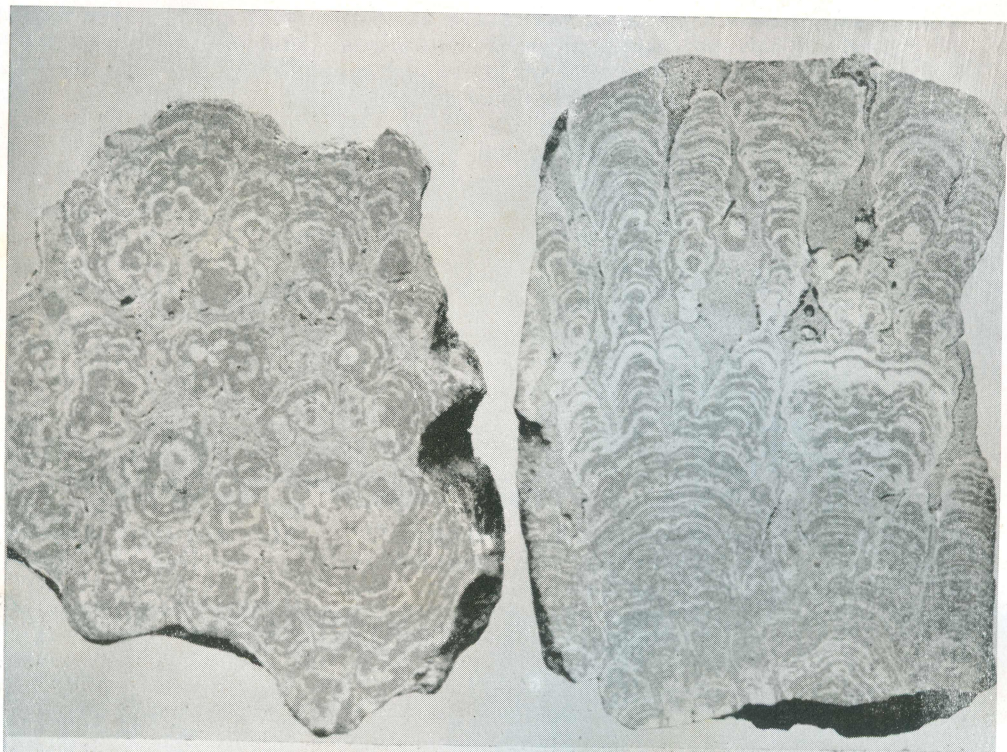


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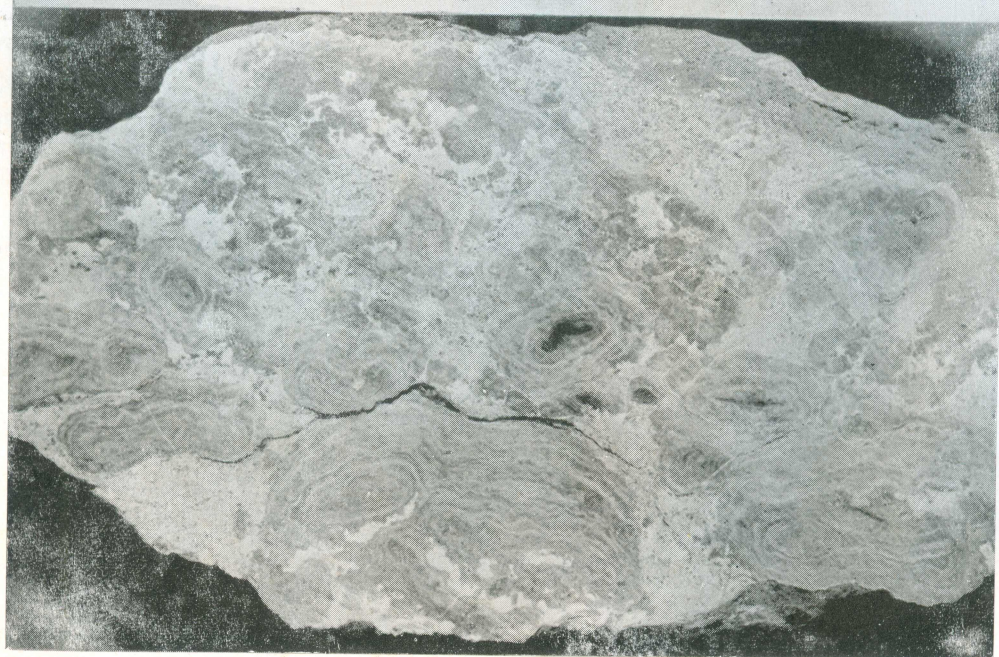


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## EXPLANATION OF PLATE 6

## SPONGIOSTROMATA LIMESTONES

- FIG. 1—Oligocene fresh water limestone (x1). South Park, Colorado. Shows the finger-like growths characteristic of many of the algae of this group. Specimens cut perpendicular and parallel to growth.
- 2—An "algal ball" limestone (x1). Mississippian, near East Saint Louis, Illinois.