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OBSERVATIONS ON ALGAL BIOSTROMES IN THE GREAT SALT LAKE, UTAH[1]

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ABSTRACT

The detailed investigation of a typical biostrome of the blue-green colonial alga *Aphanothece Packardii* along the shore of the Great Salt Lake, at Promontory Point, Utah, has shown a distinct morphological zonation of the algal growth.

The latter consists of four zones from the lake to the land: subparallel festooned ridges; tonguelike festooned ridges; composite rings and flat-topped mounds; small isolated mounds. Detailed cross sections through the biostrome have shown that the morphological zones merely reproduce and frequently exaggerate an underlying topography eroded in firm argillaceous and oölitic sands.

The conclusion is reached that these colonial algae have no characteristic growth pattern of their own but have developed on several types of positive areas separating a system of erosional channels trending at right angles to the shore line.

INTRODUCTION

In the Great Salt Lake only unicellular algae are important biostrome builders and among them the blue-green colonial alga *Aphanothece Packardii* is almost predominant, restricting the other types to mere exceptions.

The *Aphanothece* biostromes are confined to shallow waters and shore areas; they do not seem to extend in waters deeper than 10 to 12 feet. They cover at the present time an area of about 100 square miles, and their distribution parallels that of the oölitic deposits, being limited to the western part of the lake (fig. 1).

During our studies of the sediments of the Great Salt Lake (Carozzi, 1957; Grim *et al.*, 1959), we noticed that many *Aphanothece* biostromes displayed consistent and definite morphological patterns which appeared as a direct function of shore-line features. Such biostromes are of great interest for the interpretation of similar algal constructions in the geological column.

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GENERAL DESCRIPTION

The living portion of an *Aphanothece* biostrome viewed from a boat through 2–3 feet of water reveals usually an upper surface matted over with brown to pink gelatinous film of algal cell secretion. From this film extend filament-like gelatinous masses, of the same color, 0.5 to 1.5 inches long, attached at one end and rhythmically waving in the slightly agitated water.

A section cut perpendicular to the outer surface of a chunk of biostromal material shows that it consists of a superposition of indurated and porous white crusts and of layers of somewhat friable fragmental material. The dense white carbonate crusts were apparently precipitated directly by the action of the algal colonies under their gelatinous mat. The layers of fragmental material consist of debris of algal crusts, oölites, and fecal pellets, as well as some silt and clay particles. These materials were apparently crusted in by the algal porous masses. According to A. J. Eardley (1938, p. 1398), a typical algal material may contain 2 per cent organic matter, 66.4 per cent aragonite, 11.8 per cent dolomite, and 20 per cent insoluble material (silt- and sand-size silicate mineral fragments, clay particles, and fecal pellets of brine shrimps).

MORPHOLOGY OF THE BIOSTROME

The typical example reported on here is located on the east side of Promontory Point, immediately south of the Union Pacific buildings (fig. 1). The biostrome has developed parallel to the shore line with a general lenticular shape; its length is about 450 feet; its maximum width in the central portion is about 100 feet (pl. 1, *A*).

During our investigation, only half the colony was still living under a few inches of water and displayed its typical brown-pink color. The other half, which had emerged, was decaying and had a greenish color.

The sediments which surround and partially cover the biostrome are fetid oölitic sands which at a depth of 1 foot become firmer and more argillaceous. These sands are gray to whitish at the surface and black immediately beneath it.

The biostrome displays four distinct morphological zones which extend parallel to its longest axis and consequently also parallel to the shore line (fig. 2). These zones grade into each other from the lake toward the land.

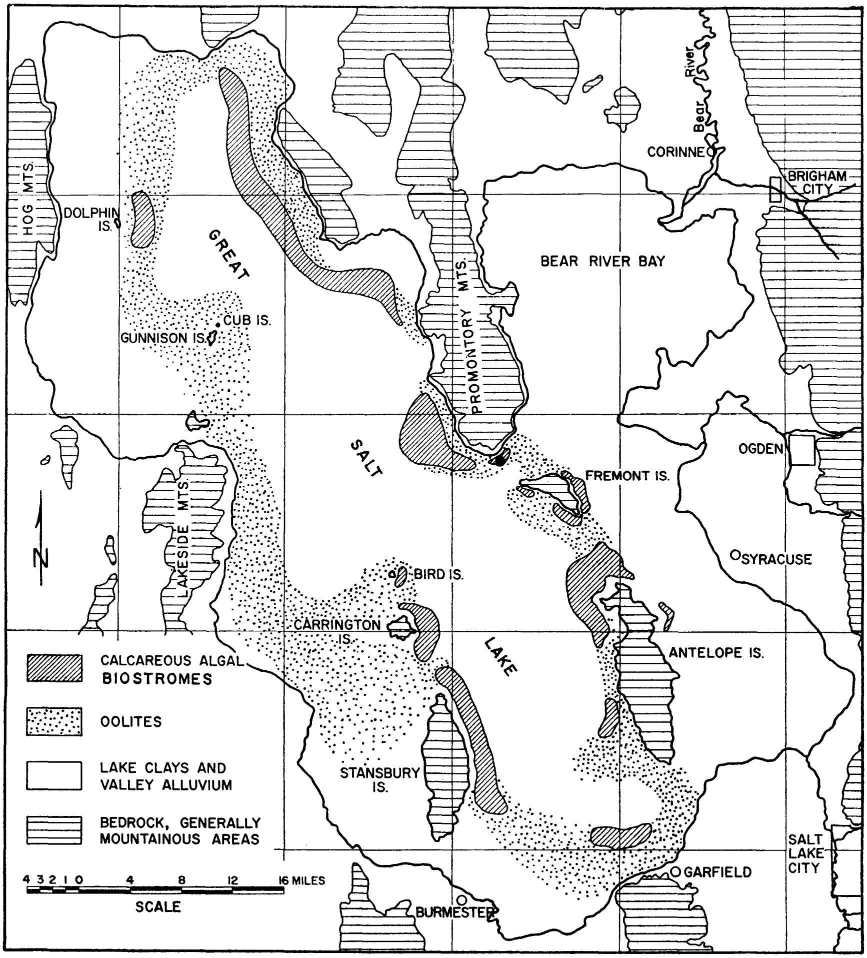


FIG. 1.—Map of distribution of sediments in the Great Salt Lake area. Black dot indicates the position of the investigated biostrome. Adapted from Eardley (1938).

1. Zone of subparallel festooned ridges
2. Zone of tonguelike festooned ridges
3. Zone of composite rings and flat-topped mounds
4. Zone of small isolated mounds

In zone 1 (fig. 3), the algal growth forms subparallel ridges associated in pairs, rising 3–4 inches above the surrounding sediments and extending for a transverse width of about 48 feet. The ridges begin lakeward with irregular patches of algal crust but very rapidly acquire their typical shape. In a given pair of ridges, each one is festooned by tance of about 2 feet; however, they frequently diverge or converge locally and may be interrupted for a distance of several feet (fig. 3; pl. 1, *B*).

When the ridges are dug out with a spade, they are seen to extend 4 to 6 inches below the surface at which depth they join on their concave and less steep side an adjacent greenish layer consisting essentially of algal material and oölites. The ridges appear as marginal apophyses of this algal layer which extend upward through the superficial oölitic sands (figs. 3 and 4, section *A–A′*).

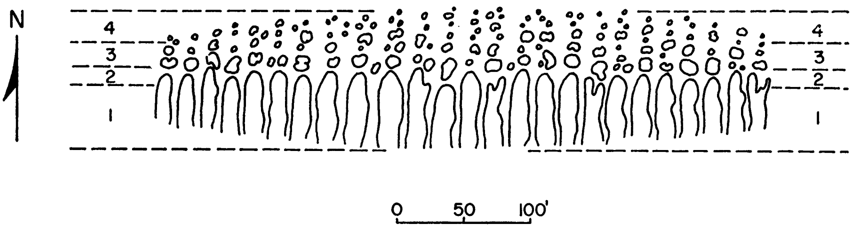


Fig. 2.—Schematic map and morphological zonation of the biostrome at Promontory Point, Utah

convex lateral growth toward the other forming on that side a rather steep wall sometimes even overhanging. On its other side, each ridge shows a steep slope with a straighter and simpler boundary (fig. 4, section *A–A′*; pl. 1, *B*).

A typical ridge is 3–5 inches wide and consists of an elongated encrustation of extremely porous and knobby algal material, rather massive, with poorly defined growth zones $\frac{1}{4}$ to 1 inch wide. The algal material is strongly encrusted at the surface but becomes more friable at depth where it also changes from a gray-pink color to a greenish one.

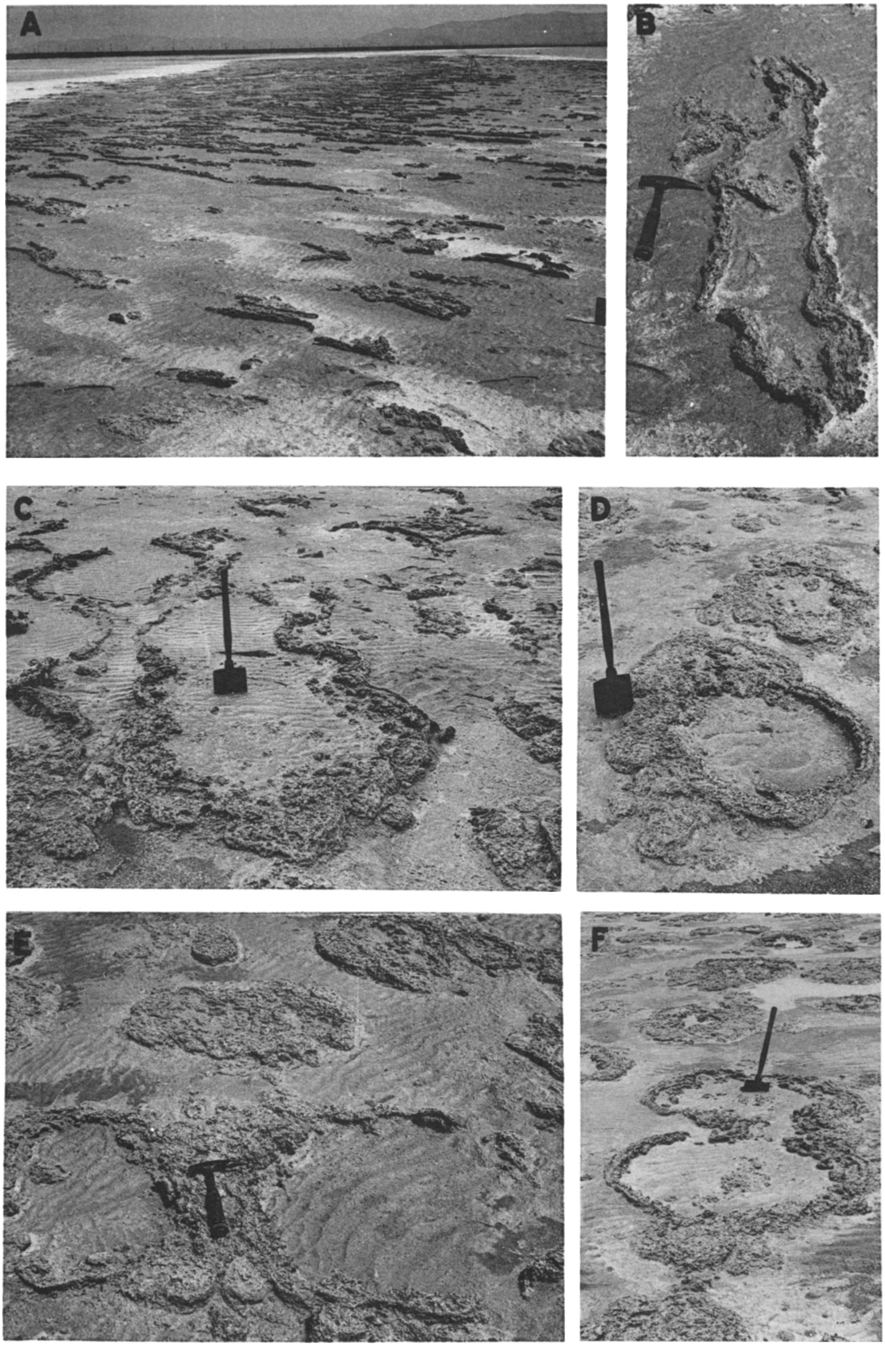
Two related ridges are usually parallel to each other and separated by an average dis-

The channel between two festooned ridges facing each other is filled with oölitic sand showing transverse ripple marks and containing little or no algal material. This sand is usually from 6 inches to 1 foot thick and at the latter depth becomes richer in clay (fig. 4, section *A–A′*).

The inter-channel areas between pairs of algal ridges consist of elongated and slightly higher zones with a rather constant width of 6 to 8 feet (fig. 4, section *A–A′*). The upper surface of these zones shows a thin layer of ripple-marked oölitic sand that is similar to the one filling the channels but only $\frac{1}{2}$ to 1 inch thick. This sand barely covers with an irregular lower contact a mushy layer of greenish algal material mixed with some

PLATE 1

Biostrome of *Aphanothece Packardii* at Promontory Point, Utah. *A*, General view; the landward side is on the left. *B*, Pair of subparallel festooned ridges enclosing a channel area. *C*, Well-developed tonguelike festooned ridges. Note ripple marking in both channel and interchannel areas. *D*, Composite ring with local flat-topped expansion of algal crust irregularly pitted. *E*, Discontinuous and interfering composite rings (*upper half*), composite flat-topped mounds (*lower half*). *F*, Typical 8-shaped pattern of two interfering composite rings.


A
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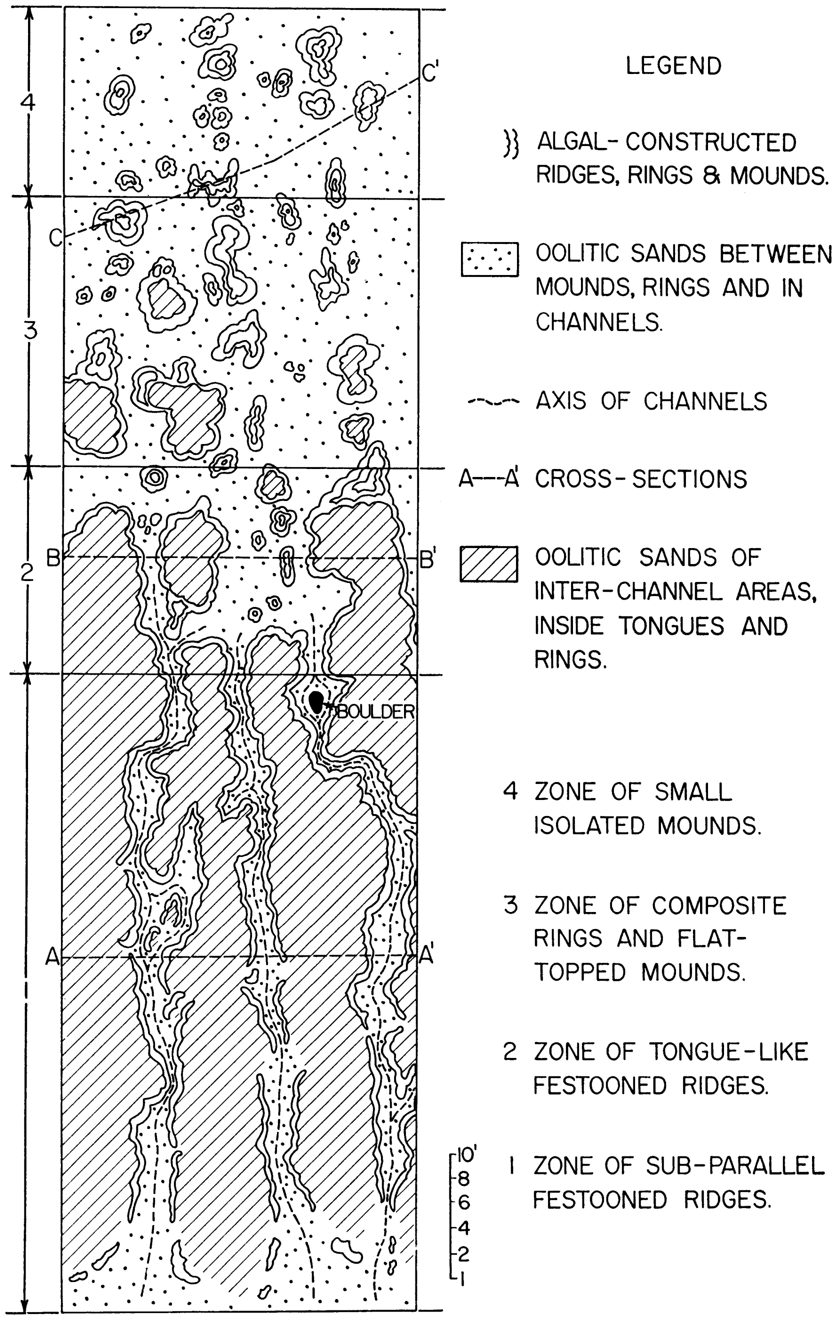

FIG. 3.—Detailed map of a typical transverse strip of the biostrome at Promontory Point, Utah

oölites and occupying the entire substratum of the inter-channel areas; it is the same layer from which the ridges extend upward as apophyses (fig. 4, section *A–A′*). The mushy algal layer is at least 6 inches thick and rests also over argillaceous oölitic sands.

The contrast in structure between channels and higher interchannel areas is striking and easy to check with a spade. It should be pointed out that the sand-filled channels are originally deeper than the interchannel areas filled with algal material (fig. 4, section *A–A′*). However, the subsequent deposition of the clean oölitic sands over the entire biostromal zone often reverses the original conditions. Hence a rapid examination of the biostrome could lead to completely erroneous conclusions about the position of the channels if based solely on the comparison of the relative level of the sand surfaces.

Zone 2 (fig. 3) is transitional to zone 1 and about 16 feet wide. In it, the festooned ridges display a slight decrease in height and gradually join each other into tonguelike structures, convex landward and closing around the interchannel areas (fig. 4, section *B-B′*; pl. 1, *C*). Consequently, the channel areas expand and gradually lose their identity by merging into larger depressed areas of ripple-marked oölitic sands.

Zone 3 (fig. 3) consists of composite rings and flat-topped mounds. Both types of features are always lower than those of zones 1 and 2 and appear scattered among areas of ripple-marked sands similar to those filling the channels and surrounding the biostrome.

The composite rings are in continuation with the axes of the interchannel areas and tonguelike structures and may be aligned along such a direction for a distance of 10 to 15 feet (fig. 3). The rings are usually irregular, 2.5 to 6 feet in diameter with an algal growth 3 to 6 inches wide and rising 2 to 3 inches above the surrounding surface. They are festooned outside in the same manner as the ridges and display also a rather steep

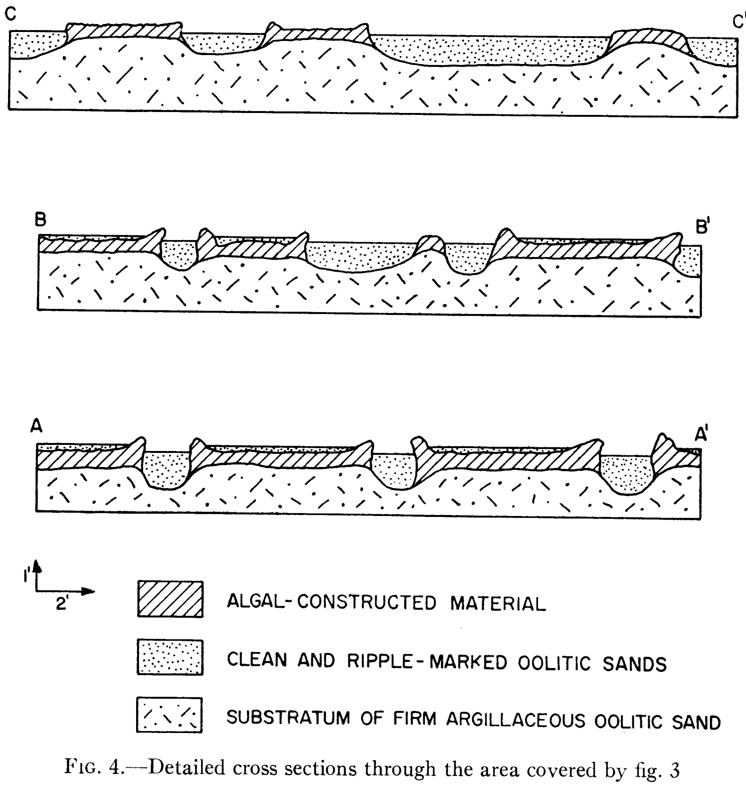

FIG. 4.—Detailed cross sections through the area covered by fig. 3

external wall. However, their internal slope is usually more abrupt than that of the ridges and may occasionally also appear as a little wall (fig. 4, section *B-B′*; pl. 1, *E*).

The depressed interior of the composite rings is higher than the surrounding oölitic sands. It is covered by a thin layer about 1 inch thick of oölitic sand which thickens to about 5 inches immediately against the internal margin of the algal ring (fig. 4, section *B-B′*). This sand layer, which is frequently ripple marked, covers with an irregular lower contact a greenish and mushy bed of algal material containing a few oölites.

In several instances, the composite rings may be discontinuous and appear as segments of circles in which the surface of the sand filling their central parts is at the same level as that of the surrounding areas. Occasionally algal rings may expand locally into flat-topped crusts irregularly pitted and slightly depressed compared to their peripheral portion (fig. 3; pl. 1, *D*) or adjacent ones may interfere in complicated pattern, some of which are **8**-shaped (pl. 1, *E* and *F*).

Associated with the composite rings but becoming more predominant in the landward portion of zone 3 are composite flat-topped mounds. They have a diameter from 2.5 to 6 feet and rise 2–3 inches above the surrounding surface. Their peripheral zones are ridgelike, festooned, and with a sheer outside wall, but their central portions are completely covered with an irregularly pitted and knobby algal crust slightly depressed in comparison with the periphery. Grossly defined growth rings become better expressed toward their margins (pl. 1, *E*).

The algal crust which builds the composite mounds is continuous downward with the greenish layer of mushy algal material described above and also rests at about 3 to 4 inches depth on firm argillaceous oölitic sand (fig. 4, section *C-C′*). Like the rings, the composite mounds may be isolated or interfere in a complex fashion and are also frequently aligned on the continuation of the interchannel areas (fig. 3).

Zone 4 (fig. 3) forms the landward boundary of the biostrome and consists of small isolated mounds, flat topped or with a convex central portion and aligned with the composite rings (fig. 4, section *C-C′*; pl. 1, *E*). Consequently, the transverse zonation extends clear across the width of the biostrome (fig. 3; pl. 1, *A*). The mounds vary in diameter from a few inches to about 4 feet and rise only 1–2 inches above the general surface of the surrounding ripple-marked oölitic sands. Their outer margins are festooned with a little outside wall; their central portion when convex is irregularly pitted and knobby and when flat topped is slightly depressed and also pitted.

The algal crust which builds the isolated mounds is continuous downward with the greenish layer of mushy algal material described underneath all the other structures. However, here it is rather thin, rarely reaching more than 2–3 inches thickness, and it also rests on firm argillaceous and oölitic sand (fig. 4, section *C-C′*).

INTERPRETATION OF THE BIOSTROME

The preceding description of the investigated biostrome has revealed a definite transverse alignment of the interchannel areas, the composite rings, the composite flat-topped mounds, and the isolated mounds interfering with the four main longitudinal zones. The transverse zonation is more obvious than the longitudinal one because it is emphasized by the trend of the subparallel festooned ridges. Very apparent on the air photos, it certainly corresponds to what A. J. Eardley (1938, p. 1392) has called the "trough-and-mound" character of the biostromes.

The cross sections and the described structural relations show that the algal growth took place over a pre-existing topography cut through the underlying argillaceous and oölitic sand. This topography consists of an erosional pattern of channels, trending at right angles to the shore line, decreasing in depth landward where they diverge and gradually lose their individuality. In between the channels are positive reliefs which form the substratum of the interchannels areas, the composite rings, the flat-topped and rounded mounds.

The algal growth took place only on these positive areas, clearly indicating that the algae have no pattern of their own but develop as a direct function of the available subaqueous topography. The subsequent deposition of clean oölitic sands has filled the channels and covered most of the algal growth except the peripheral ridges and the mounds, but this is a secondary process entirely independent from the algal development.

The preferential marginal growth of the algal ridges around the highest reliefs can be explained by the fact that the latter were partly exposed to the air. Consequently, the growth concentrated along the most favorable zones which are the margins in more continuous contact with the water. The development of the ridges isolated more and more the central areas where algal growth was slowed down. In this way were generated the subparallel festooned ridges along the sides of the channels, the tonguelike structures, and the composite rings. Over lower reliefs the algal growth took place more uniformly because they were under water in a more continuous manner, generating there flat-topped and small mounds.

The pattern of erosional channels which underlies the biostrome and which trends at right angles to the shore line is frequently displayed along the lake beaches. Moreover, the sediments located immediately offshore from the investigated biostrome display subaqueous bars of oölitic sands aligned in correspondence with the interchannel areas. Farther out in the lake, these bars grade into elongated shoals of ripple-marked sand which are separated by broad channels with smooth surfaces extending also at right angles to the shore line.

CONCLUSIONS

The morphological zonation of a characteristic *Aphanothece* biostrome along the shores of the Great Salt Lake indicates that these algal colonies have no typical growth pattern of their own but merely reproduce and frequently exaggerate an underlying topography carved in firm argillaceous and oölitic sands.

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