

Aufsätze

- HUDSON, J. D., & TAN, F. C.: Carbonate diagenesis in the Middle Jurassic of Scotland (Abs.). — Prog. VIII Int. Sed. Congress, Heidelberg, p. 45, 1971.
- KINSMAN, D. J. J.: Interpretation of Sr⁺² concentrations in carbonate minerals and rocks. — J. Sediment. Petrol., **39**, 486—508, 1969.
- LAND, L. S.: Diagenesis of skeletal carbonates. — J. Sediment. Petrol., **37**, 914—930, 1967.
- LAND, L. S., & GOREAU, T. F.: Submarine lithification of Jamaican reefs. — J. Sediment. Petrol., **40**, 457—462, 1970.
- MATTHEWS, R. K.: Carbonate diagenesis: equilibration of sedimentary mineralogy to the subaerial environment. — J. Sediment. Petrol., **38**, 1110—1119, 1968.
- PURDY, E. G.: Carbonate diagenesis: an environmental study. — Geol. Rom., **7**, 183—228, 1968.
- SHEARMAN, D. J., & SKIPWITH, Sir P. A. D'E.: Organic matter in Recent and ancient limestones and its role in their diagenesis. — Nature, **208**, 1310—1311, 1965.
- TALBOT, M. R.: Calcite cements in the Corallian Beds (Upper Oxfordian) of southern England. — J. Sediment. Petrol., **41**, 261—273, 1971 a.
- : The deposition and diagenesis of the Corallian Beds of southern England. — 259 p. Unpub. Ph. D. Thesis, University of Bristol, 1971 b.

Recent Algal Stromatolitic Deposits, Andros Island, Bahamas. Preliminary Report

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With 32 figures and 1 table

Zusammenfassung

Nach einem einführenden Kommentar über den Bau und die Funktion von Süßwasser-algen unter besonderer Berücksichtigung ihrer Bedeutung beim Aufbau von Stromatolithen wird die Verteilung und Struktur des Cyanophyceen-Wachstums auf der Insel Andros (Bahamas) und den angrenzenden Meeresplattformen dargestellt. Auf den „flats“ periodischer Seen im nordöstlichen Teil von Andros läßt sich die morphologische Differenzierung stromatolithischer Biostrome zeigen. Es wurden in einem dreimonatigen Beobachtungszeitraum die Wachstumsphasen der Stromatolithe erfaßt, das heißt in einer Periode von der vollen Wässerung des Sees bis zur allmählichen Austrocknung am Anfang der trockenen Jahreszeit.

Abstract

After some introductory comments on fresh water bluegreen algal calcareous formations, the general features and the ruling mechanisms of which are of fundamental importance for the interpretation of stromatolites, the distribution and general features of algal deposits across Andros Id, Bahama, and adjacent marine platforms are briefly reported.

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Morphological differentiations characterizing Recent stromatolitic biostromes in process of formation over the flats of seasonal lakes (N-Eastern Andros) are then briefly analyzed. The interpretation of structures relies on the various data gathered during an observation period of three months encompassing the phase of prolific stromatolitic growth during the complete flooding of the lakes, and ending with the progressive drying up and exposure of the algal flat at the beginning of the dry season.

Résumé

Après un commentaire introductif sur les constructions algaires d'eau douce et l'intérêt qu'elles revêtent pour la compréhension des stromatolithes tant par leur organisation que pour les mécanismes qu'elles révèlent, l'auteur rapporte rapidement la distribution et la structure des tapis à Cyanophycées de part et d'autre d'Andros Island, Bahama, et des plateformes marines adjacentes.

Il décrit ensuite brièvement les différenciations morphologiques rencontrées au sein de biostromes stromatolithiques en voie de formation sur les flats de lacs saisonniers de la région nord orientale d'Andros Island. L'interprétation des structures observées se base sur les données recueillies au cours d'une période d'observation de trois mois couvrant la phase de pleine croissance des stromatolithes, au moment d'inondation maximale du lac, jusqu'à la phase de dessiccation progressive à l'approche de la saison sèche.

Краткое содержание

После вспушительного замечания о строении и функции пресноводных водорослей с упором на их роль при образовании строматолитов описаны распределение и структуры колоний цианофитов острова Andros (Bahama) и соседних морских платформ. По „flats“ периодических озер в северо-восточной части Andros наблюдается морфологическая дифференциация строматолитовых Biostrome. В течение трех месяцев удалось полностью изучить фазы роста строматолитов, т. е. от периода полного заполнения озера водой до постепенного высыхания к началу засушливого времени года.

Introductory Comments

Only one fifth of Recent blue-green algae are marine (DESIKASHARY, 1959; ECHLIN, 1966) whereas 80% of the group colonize freshwater and various terrestrial environments; as many of the latter thrive in alkaline carbonate rich waters, characterized by pH ranging from 7 to 9.5 (BAAS-BECKING & MOORE, 1960), they are by far the most important lime-depositing and rock-building algae in the non marine settings, which accounts for the abundance and diversification of structures that they originate there.

The significance of non marine Cyanophyta appears still greater when we consider these algae which participate into the formation of organic rich sediments like sapropels (see KORDE, 1947, 1950, 1960) or which accumulate loose laminated muddy deposits on the bottom of eutrophic lakes to build up the so-called "epipythmenic formations" (see review in NAUMAN, 1925; DECKSBACH, 1926, etc.).

Since the end of the XIXth century, when concretions built by blue-green algae attracted the attention of many scientists in Europe as well as in the States (SEWARD, 1885; MURRAY, 1895; TILDEN, 1897; CHODAT, 1897) numerous studies were devoted to this flora and yielded an enormous amount of informa-

tions. In a first approach, we can distribute the most interesting structures into three main types (beside the simple algal mat or algal film):

(1) *crusts*, a few mm. to a few cm. thick, variously calcified and organized, have been reported from diverse hard substrates of fluvial (BLUM, 1956, 1960; CEDERGEN, 1938; FRITSCH, 1929, 1949; HOWE, 1931, etc.) as well as of lacustrine environments (BREHM & RUTNER, 1926; FOREL, 1902; GEITLER, 1930; GOLUBIČ, 1962, 1967; KANN, 1933, 1940, 1941 a, 1941 b; LAUTERBORN, 1922, etc.).

(2) *oncolites*, a few mm. to 10—25 cm. in diameter have similarly been described from fluvial (CLARKE, 1900; FRITSCH and PANTIN, 1946; GLAZEK, 1965; RODDY, 1915, etc.) and from lacustrine settings (BAUMAN, 1911; MAWSON, 1929; SCHMIDLE, 1910; SCHÖTTLE, 1967; SCHÖTTLE & MÜLLER, 1968; PIA, 1926, 1933; POLLOCK, 1918, etc.).

(3) a third important group of structures, that we may gather under the general name of *tufa*, are known in lakes, where they can build up important reef like mounds (BAUMAN, 1911; BRADLEY, 1929 a, 1929 b; EGGLETON, 1956; SCHOLL & TAFT, 1960, etc.) as well as in springs, brooks, rivers where they can form very resistant dams (GRÜNINGER, 1965; IRION & MÜLLER, 1968; STIRN, 1964; SYMOENS, 1949; SYMOENS et al., 1951; SYMOENS & MALAISSE, 1967, etc.).

A special mention should finally be made of BLACK's historical paper (1933), which, for the first time, reported important fresh water stromatolitic deposits on Andros Island, Bahamas; pityfully, BLACK did not find any opportunity to work in detail the structures he had discovered during his reconnaissance field trip, and the subject was dropped until the author started a new project in 1963 (MONTY, 1965 b, 1967, this paper).

Surely, BLACK's paper and the striking resemblance between fresh water algal biscuits and fossil oncolites impressed many geologists, but the latter rarely went any further than reporting gross structural similarities between Recent and fossil structures without investigating the detailed mechanisms of formation nor matching the respective intimate microstructures. The enormous amount of work that had been done on fresh water algae (see above and in MONTY, 1965 b) was also generally disregarded either (1) because it concerned non marine settings and hence should interest but the geologists working on fresh water stromatolites (like BRADLEY, 1928; COLOM, 1965; FREYET & PLAZIAT, 1965; JOHNSON, 1936, 1937; RUTTE, 1935, etc.) or (2) because most of these results were confined to botanical and limnological literature. However, we — geologists — cannot interpret the morphology and the microstructure of Recent or fossil stromatolites in the same terms nor along the same lines as the ones applied to the study of ripple marks, turbidites or lime muds for, beside evident intervention of physical processes, stromatolites result before all from much more complex ones i.e. the processes associated with life. The latter processes have been best studied there where benthonic blue-green algae are abundant and colonize a very wide range of particular settings, that is in the non marine environments. These studies give us much to *think about* and to put together if we really want to understand what stromatolites are and mean; they give us a bright lesson on the "every day life" of blue-green algae, on the "mechanics" of algal coenoses, on the biological, physiological and even on the symbiotal organization of these fascinating microcosms (see review in MONTY, 1965 b, p. 1—150, GOLUBIČ, 1967).

Everybody will agree that these are very basic points that "stromatolitologists"

should know at first; they will provide us with the necessary and fundamental botanical background to neatly investigate the algal mats that we find on our tidal flats. Moreover if, by understanding and deciphering the dynamics of Recent fresh water structures, we can thoroughly account for the mode of growth, of formation, for the leading ecological requirements and environmental responses of fossil fresh water stromatolites like those illustrated by JOHNSON (1936, Fig. 1, pl. 1, Fig. 3), then the field is open to sound, natural and realistic understanding of Paleozoic and Precambrian stromatolites (like those illustrated by DONALDSON, 1963, pl. 5 for instance); even if Johnson's and Donaldson's stromatolites originated in different chemical environments, they appear to me not only as analogous¹⁾ but furthermore as homologous structures, the growth form and building up of which was in equilibrium with homologous general environmental factors²⁾ (see also points 1 and 2 page 747).

A similar line of reasoning may be applied to oncolites; I doubt that the soft and unfossilizable algal biscuits described by GINSBURG (1960), GEBELEIN (1969) and MONTY (1965 a, 1967) from shallow marine settings of Florida, Bermuda and Andros Id are the actual Recent analogues of the lithified calcareous oncolites found in the geological column up to Cretaceous times; in my opinion the actual analogues are the algal balls and biscuits presently living in freshwaters and that switched definitely toward non marine settings during Early Cenozoic time when Red algae outcompeted them from the sea and occupied their niche and habitat (MONTY, 1972, in press); this seems to be confirmed by the great morphological, structural and microstructural similarity that exists between the Recent fresh water oncolites and the fossil marine ones. Now, if we accept that the former are not only Recent analogues but also homologues of the latter then we can define a sound line of interpretation; indeed, the studies reported p. 744 show that Recent fresh water oncolites generally grow in rather quiet environments (which does not exclude temporary turbulence during floods) such as found in the slow portions of streams or on the benches or the flats of lakes, but not in the agitated back and forth shifting waters generally postulated in paleoecological literature. Oncolites furthermore appear as a morphological and ecological adaptation of the crust building communities to soft substrates and/or to low energy environments (where a rock or shell fragment constitute the initial hard substrate for the encrusting community to settle); so, transposing these data into the past we can at least define two typical settings where oncolites may have grown (1) sheltered and quiet back reef or lagoonal waters (2) flats (like the ones described by MAWSON, 1929), abandoned by a regressive sea leaving broken skeletons behind, or invaded by a transgressive sea that periodically washes fragments of marine organisms that will be incrustated³⁾; the latter occurrences will be associated with

¹⁾ As is the case for Black's type c algal polygons and many analogues found in the Triassic or the Precambrian (Belt formation for instance).

²⁾ Only critical analysis of analogies and homologies between Recent crusts or mats and fossil ones will lead to the understanding of these branching and variously shaped Precambrian and Paleozoic marine stromatolites.

³⁾ In both cases however oncolites may show important traces of corrosion or erosion: a receding sea will abandon them to a somewhat prolonged atmospheric alteration, whereas a transgressive sea will rework the previously formed structures as it progresses; these features will add to the confusion that the oncolites originated in agitated waters.

stratigraphical gaps or discordances as repeatedly occur at the base or at the top of oncolitic bed in Mesozoic rocks (see review in MONTY, 1972). Similarly, by projecting into the past the results of fresh water studies which show that — as opposed to oncolites — algal crusts are generally associated with hard substrates and/or environments of rather high energy, stratigraphical successions such as “encrusting stromatolites-oncolitic bed” may be more lucidly interpreted.

Reviewing the geological literature and considering the commonest concepts and definitions of stromatolites, I am afraid that the present-day overemphasis put on the inter- to supratidal marine settings as an *habitat*, on the entrapment of detrital particles as a *process* of formation, and on a passive behavior towards environmental factors as a *coenotic attitude*, may not only bias our ecological and biological interpretation of Recent and fossil stromatolites, but furthermore hide many existing problems or yet originate “false” ones due to failure or limitations of the theory. What does it matter that the studies reported p. 744 concern fresh water algae, if they show us the way blue-green algal coenoses do actually work, if they give us clues to their taxonomical and/or structural distribution from the drying up shores down the dark lake bottoms, if they provide us with autoecological data that will help us to understand the adaptationnal potentials of Cyanophyta and hence to account in biological terms for the marine supratidal stromatolites, and for the deep water ones reported in the geological column (see brief review in MONTY, 1971).

As far as the processes of formation are concerned, there is no doubt that the trapping and binding of detrital grains is the leading one in Recent shallow marine and intertidal algal mats and that it has most probably been effective in the past; however we should *balance* this statement, for many fossil stromatolites undoubtedly originated in the precipitation of fine-grained carbonate within the algal mats; if the mechanisms ruling the first process are quite easy to decipher, the processes of precipitation are on the contrary very complex and yield a wide range of microstructural features (cf. MONTY, 1965 b, p. 232—256), the more that the intimate conditions within the algal mat may be very different from the ones characterizing the general environment. Fresh water structures show us an interesting series of stages of cohesion or consolidation resulting at one pole in the formation of earthy algal deposits (BLACK, 1933, MONTY, 1965 b, 1967, this paper), at the other in the building up of hard lithified calcareous objects. If this rich pool of data does not show us dolomitic stromatolites, it however brings into light very interesting processes and relations that surely may help us in the analysis of fossil structures; it has for instance been shown that the site of precipitation within the mat strongly influences the size and morphology of crystals (MONTY *id.*) and that these crystal properties may change with the leading participating alga, be it *Rivularia*, *Phormidium* or *Schizothrix* (ULRICH, 1927, WALNER, 1934, 1935, IRION & MÜLLER, 1968, etc.); we can therefore visualize the strong control of the life processes on the feeding and nucleation of incipient crystals, hence on the overall microstructure of the stromatolite and probably on the carbonate phase involved: such control may depend on the type of mucilage, its organic nature and density, on the physiological properties of the participating algae which — constantly or seasonally — produce various organic products that may complex the calcium and release it at variable rates, etc.

Finally, confining us to the tidal flats may hinder our perception of apparently

insignificant problems, the solution of which might however have a strong bearing on our understanding of the present status of modern stromatolites as well as of their ecological history; it is the author's experience, that many specific algae seem to lose their faculty of precipitating calcium carbonate when traced from fresh water settings to marine ones where they rather entrap ready-made grains (MONTY, 1965 b, 1967, 1972, this paper p. 750). The case is quite evident with *Schizothrix calcicola* which builds calcified films (MONTY, 1965 b, 1967) or even strongly lithified structures in non marine waters (BREHM & RUTTNER, 1926, KANN, 1941, IRION & MÜLLER, 1968, etc.) but which, in the sea, forms soft gelatinous mats or domes trapping detrital grains (MONTY, 1965 a, 1967, GEBELEIN, 1969, SCOFFIN, 1970, etc.). Detailed study of such problems, may help us understanding what is going on and what is wrong (or appears such to us) with Recent marine blue-green algae.

Why all these comments which have no pretention of originality? It seems detrimental to our scientific progress that such a big gap exists between the studies carried by geologists on marine inter-supratidal flats, where algal mats are rather roughly analysed and considered in terms of sedimentological structures and processes (concept which is pityfully extended to the fossil record except in much of the Russian literature) and the studies carried by botanists and limnologists, in fresh waters or in the laboratory, and where blue-green algae and algal structures are studied for themselves as biological entities. Of course biologists are not concerned with stromatolites and sedimentation so why should they try to bridge the gap? But WE, paleontologists, are deeply concerned with the understanding and correct interpretation of blue-green algal structures, accordingly we have to dig out of the non geological literature as many data as required to work out properly the Recent and fossil stromatolites.

In very general words, the kind of information and understanding that we need can be splitted into 3 hierarchised categories: (1) Informations on blue-green algae ecology, physiology, metabolism as well as a rational understanding of the concept of blue-green algal coenose (see GOLUBIČ, 1967); this will facilitate and re-focus our interpretation of the "algal mat", the fundamental unit of stromatolites.

(2) Precise data on the structure, microstructure, organization of the various types of crusts (oncolites, etc.) of their ecological adaptations, of their specific and/or morphological zonation across various fresh water settings. This will give us tangible clues to the understanding of the coenotic response of blue-green algae to a wide range of environmental factors (drought, degree of substratal moisture, turbulence, depth, alkalinity, transparency of the water, competitive plants, etc.). Such results are of course of direct application to the study of Cenozoic stromatolitic and oncolitic beds (most of which are non marine), but furthermore, by putting together and working out these data collected in various environments we may find proper ways of reasoning when interpreting a whole stromatolite, as well as its successive morphological and structural features from base to top.

(3) We finally need to go further than collecting data from studies carried in isolated lakes and rivers and applying them to the interpretation of given fossil stromatolites through the channel of autopalaeoecological analysis; we have to widen the scope and investigate realms where fresh water stromatolitic deposits pass progressively to marine ones. Indeed, the understanding of regional distributional patterns as well as of the particular characteristics of stromatolitic de-

posits in a continuous series of Recent environments is of prime importance for the deciphering and correct interpretation of fossil stromatolitic formations; data gathered that way may be quite helpful in the particular study of shallowing up cycles (such as reported in MONRY, 1963), or of any stromatolitic bed associated with the end of a regression or the beginning of a transgression. In these cases indeed, the stromatolitic phase may, at a given time, originate in a series of synchronous environments ranging from normal marine to hypersaline to fresh water conditions (heteropic facies changes in a given stromatolitic member or bed) whereas shallowing up cycles may stratigraphically synthesize a succession of isopic stromatolitic facies ending up with the formation of subterrestrial environments and the development of fresh water deposits.

From this point of view, Andros Island and the surrounding marine platforms provide a fascinating field of observation as from West to East it shows a sub-continuous succession of very different environments.

Bird's eye view of the distribution of blue-green algal structures across Andros Id and adjacent marine banks.

West of Andros, i. e. in the lee of the island, the proximal Great Bahama bank is covered by highly saline to hypersaline shallow waters; the generally muddy bottom supports algal lumps and algal limestone flakes (PURDY, 1963 a, 1963 b; ILLING, 1954) whereas important areas are covered with mats of *Lyngbya aestuarii* (BATHURST, 1967)⁴⁾; this halophylic alga acts as a bottom stabilizer and traps grains in the baffle-like carpet of its long flexible filaments; as it grows almost continuously and faster than the depositional rate of the constantly shifted detrital grains, it does not yield banded stromatolitic-like deposits but rather accumulations similar to the ones associated with the turtle grass. Furthermore, beneath the living mat, in which the filaments can grow flat or erected according to the local conditions, many slender filaments permeate the substrate in all direction; seasonally, when the alga blooms, it can peel off the substrate, as was observed by the author, and carry away the whole mat and underlying sediments; this process also prevents the formation of stromatolitic laminations that would result from the piling up of seasonal layers.

The *intertidal zone proper* is rather limited in extent with respect to the Bahama Bank and the supratidal flats⁵⁾. Life conditions change abruptly, as organisms have to withstand daily exposures and floodings whereas the tides *periodically* wash detrital grains over the mats. The most conspicuous alga in the lower half of the intertidal zone is probably *Schizothrix calcicola* a very tiny blue-green alga which agglutinates the grains in a mesh of filaments and mucilage; generally, it does not originate laminated structures there, for these tiny algae are constantly swamped with grains during the flood and cannot add much growth during the ebb when they suffer severe conditions (see MONRY, 1967, p. 86). On somewhat exposed headlands, these mats may be interspersed with cushions and growths of *Rivularia* which has much bigger tufted filaments

⁴⁾ The interested reader will find penetrating studies on the structure and sand stabilizing potentials of the *Lyngbya* mats in SCOFFIN, 1970, and NEWMAN et al., 1970.

⁵⁾ A very interesting description of the morphology of these inter- to supratidal settings has been recently published by SHINN et al., 1969.

between which many grains remains trapped; as opposed to the fresh water *Rivularia haematites*, these *Rivularia biasolettiana* do not build laminated nor calcified structures. In the upper part of the intertidal zone (SHINN et al., 1969) as well as in many brackish tidal marshes appear conspicuous laminated growths of *Scytonema* stat. *crustaceum*; this alga, which on the West as well as on the East coast is characteristic of transitional environments between the sea and the land, has deeply stained sheaths which absorb much of the noxious solar radiations; the thickness of the mat and the prominence of the lamination varies according to local conditions; precipitation of fine-grained carbonate and local cementation by tiny carbonate crystals appears in the mats (SHINN et al., 1969, Fig. 12, p. 11) and seem to increase up flat (MONTY, 1965 b, 1967).

The *supratidal zone* comprizes a variety of environments among which the flats and the marshes are the more interesting ones to our purpose. The phases of algal growth, of sedimentary influx and of dessication become now strongly separated in time with respect to their periodicity in the intertidal zone, whereas their pattern changes also: periodical floodings of the flats are now due to exceptionally high tides and more generally to seasonal storms or hurricanes; there is no more continuous or subcontinuous washing of particles over the mats but a sudden and brutal influx of sediment-laden waters which deposit a continuous sheet of detrital grains over the algal mats; according to the conditions of substratal humidity, the algal filaments will either permeate the storm deposit more or less rapidly to re-establish a new mat on top, or remain in a "dormant" state just beneath the surface. During the rainy reason, or when westerly winds pile up waters onto the flats, a second seasonal phenomenon occurs: the suddenly re-juvenated filaments grow and bloom to originate a significant algal layer. These particular processes, generally widely separated in time, give birth to the typical algal laminated sediments found in this supratidal zone. They are however complicated by several secondary factors: in such harsh conditions the surficial algal films may become dormant or just survive without adding any growth to the structure; they then act as a deeply stained screen which shades the underlying filaments from noxious radiations and reduce evaporation of the substratal water; at this stage, most of the growth is *internal* and the mat thickens *from the inside* (as discussed later in this paper). As far as the mineral matter is concerned, strong diagenetic phenomena may affect the deposits and end up with the formation of dolomite-rich layers or crusts (SHINN et al., 1969).

The marine supratidal flats and associated structures pass, sometimes progressively, sometimes very rapidly, to *fresh water environments* characterized by the "terrestrial" mat building alga *Scytonema myochrous* which is everywhere on the island; the dominant sediment is a very fine-grained white calcitic mud which floors the lake bottom or forms a very thin layer over the Pleistocene basement in low lying areas; fine grained calcite is also abundantly precipitated in the *Scytonema* mats which however remain generally unlithified. This general environment will be described in the following pages (see also BLACK, 1933; MONTY, 1965 b, 1967).

The distributional pattern of algal mats from the fresh water settings to the windgard lagoon and reef have been described in MONTY (1965 b, part II, 1967) and will be rapidly summarized here.

According to the local coastal geomorphology, fresh water environments may pass directly to the typical marine intertidal zone of the East coast, or pass progressively to brackish water settings which characterize the "swash" (that is a system of protected tidal marshes which develop just behind the coastal ridges and are more or less connected to the sea by a system of channels and creeks). There where a continuous and regular increase in salinity can be observed, the algal mats show a progressive decrease in the participation of *Sc. myochrous*, while the concurrent euryhaline alga *Schizothrix* becomes more and more abundant; this is reflected in the progressive transformation of the organization of mats which pass progressively from type 1 to type 3 and then to type 2 of MONTY, 1967 (p. 70—72).

The *swash* proper is characterized by salinities averaging 25‰, the replacement of *Sc. myochrous* by *Sc. stat. crustaceum*, a net decrease in the precipitated calcite, and a strong contamination of mats by debris of marine organisms and a resulting increase in the complexity of the mineralogy of mats. Here are found

(1) laminated mats and crusts built by *Sc. stat. myochrous* (together with *Schizothrix calcicola* and *Entophysalis deusta*) which are characterized by an alternation of rather plain algal layers with layers of trapped detrital grains (MONTY, 1967, p. 80—82);

(2) crusty flakes, built by *Schizothrix* and unicells (Id. p. 77—80), which are very reminiscent of the "limestone flakes" that PURDY (1963 a, 1963 b) described from the Great Bahama Bank, and

(3) various types of algal lumps (MONTY, id. p. 82—84).

Reaching the East coast, we hit true *intertidal settings* which are no more (or very rarely) hypersaline as was the case on the West coast, but face the windward lagoon and reef. The entrapment of detrital particles becomes the leading process in the mineralization of mats and very little precipitation has been observed by the author. Non laminated mats are built by *Rivularia biasolettiana* (MONTY, 1967, p. 85, pl. 16), *Dichothrix bornetiana* (id. pl. 15), *Schizothrix calcicola* (id. pl. 16, Fig. 2, pl. 17, Figs. 1 and 2). There where local conditions are not too severe, i. e. where the influx of bioclastic material is not too heavy and where the moisture is sufficient at low tide (zone of splash, or on muddy substrate), *Schizothrix calcicola* grows in pure cultures and forms laminated domes and mats in which the lamination is daily (MONTY, 1965 a, 1967 b, p. 88—92). BLACK (1933) also reported intertidal laminated deposits where all of the mineral matter is similarly composed of detrital grains: his "type A", which is built by the filamentous blue-greens *Symploca laete-viridis* and *Phormidium tenue*, appears as rather flat mats growing in the uppermost intertidal zone; the sedimentary layers show evident traces of flood deposition such as a positive grain sorting from base to top (these structures should probably be put together with the supratidal ones); his "type B", which forms at about high water mark, occurs as conspicuous laminated domes built by a rich community of unicells (*Gloeocapsa* and *Entophysalis*) permeated by filamentous algae.

The most abundant stromatolites found in the *windward lagoon* (the depth of which never exceeds 10 feet) are undoubtedly the laminated domes built by pure cultures of *Schizothrix calcicola* (MONTY, 1965 a, 1967, p. 88—92); these domes proliferate seasonally and are most conspicuous in Summer. Sand sheets

bound by *Lyngbya aestuarii* and similar to the ones found on the Great Bahama Bank may also be locally abundant.

Some *Schizothrix* laminated domes are still found on the reef proper but most of the structures become generally loose as they are invaded by their cousin competitor, the blue-green *Lyngbya*, the long and slender filaments of which disorganize the compact structure of the basic *Schizothrix* domes.

This bird's eye view of the general distributional pattern of blue-green algal structures across Andros Id. and adjacent marine platforms shows significant differentiation that would still be more prominent if the characteristics of the associated fauna, flora and sediments were considered. The purpose of the author's actual project is now to consider and study in detail each particular settings surveyed previously; the present preliminary report will focuss on fresh water settings and will tend to describe rapidly the general features of vast stromatolitic flats which crowd many inland lakes. Detailed relationships and microstructures of mats will be exposed elsewhere.

General setting of fresh water stromatolitic flats (Fig. 1)

West of Andros Town, passed a belt of densely vegetated oolitic coastal ridges, the island shows an alternation of wooded area (pine barren) or of strands and patches of intricate bush characterized by *Sabal bahamensis*, with desolate, low lying savanah-like regions crowded with sawgrass and some small *Avicennia*; the pitted oolitic basement may outcrop at the margin of these very shallow depressions but it is most of the time covered by no more than 30 cm. of white, sticky and calcitic mud (the thickness of this mud is the greatest in the central "deepest" part of the depression).

Much of these "plains" are completely flooded during the rainy season but dry up rapidly when rain recesses, leaving a ground covered with shrunk, contorted and dried up "polygons" (BLACK's type D).

Other depressions, a little bit lower still in altitude, remain flooded during a much longer period of time and originate this lake system that characterizes Andros Island (Fig. 2). Most of these lakes are not directly connected with the sea by tidal channels or creeks as occurs on the N.W. half of the island; they are accordingly fresh; strikingly enough some of them may show small tidal fluctuations, which means that they would rest on a lense of sea water through an intricate pattern of underground pits and holes which open in the Andros lagoon or even on the upper wall of the tongue of the ocean.

In many instances the lakes show 2 distinct physiographic parts (Fig. 3, 6):

- a) A broad eulitoral zone, flooded at least twice a year (late spring and late fall-winter) and characterized by a rather regular floor, sometimes sub-horizontal, sometimes sloping very gently toward the central part of the lake. We shall refer to it as the **stromatolitic flat**.
- b) One (sometimes two) central permanent lakelet or pond, 1 to 10 feet deep during the rainy season. These ponds are generally flooded with a white, very clotty mud, appearing like unconsolidated bird's eye limestone; each constitutive clot, ranging from a few hundred microns to about 2 mm in diameter, is formed of an agglomerate of diatoms and blue-

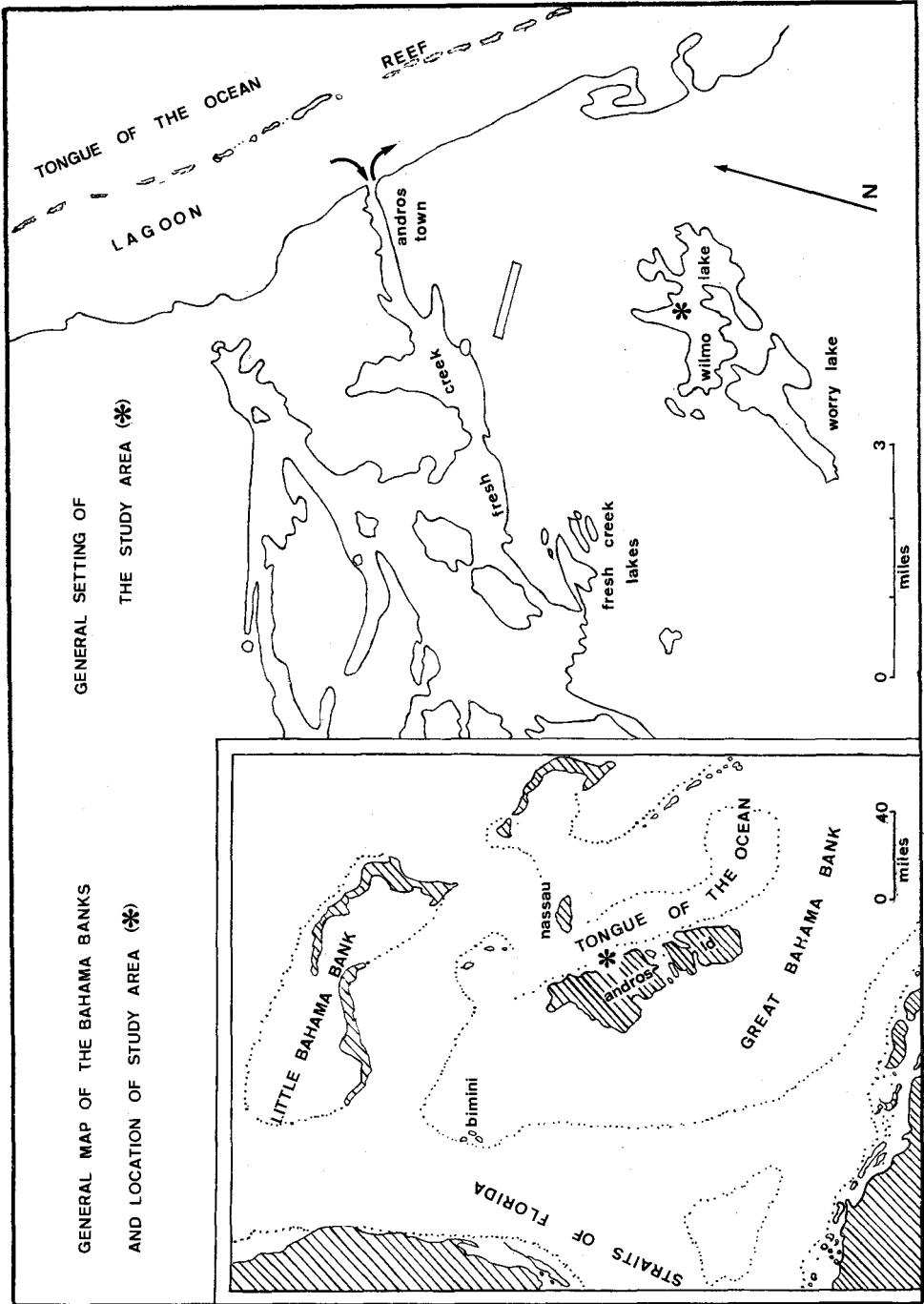


Fig. 1. Location of study area.

green algae surrounded by an abundant mucilage loaded with crystals of calcite; such substrate composed of about 70% water and 30% mineral and organic matter, is generally too soft for the establishment of stromatolites; I have however seen instances in central Andros where tiny films of *Schizothrix* first grow over the deposit, "floating" initially over it, then thicken progressively to originate a subcontinuous buoyant algal mat up to 10 cm thick stretching over the substrate which progressively compacts.

The morphology as well as the chemistry of these lakes (tab. 1) fall into that of eutrophic "cyanophycean lakes", were it not for the phosphate content which apparently is too low here and the ratio Na/K which is too high.

Particular attention was given to Wilmo and adjacent lakes (Fig. 6), 3 to 4 miles South of Andros town (Fig. 1).

Table 1. Routine water analysis of 3 fresh water lakes. Sampling was done during the mid water level (January 1970). Complete alkaline titre (T.A.C.) measured at pH 4.6, and given in m eq.gr./l.

	pH field	pH lab	T.A.C.	Ca mgr/l	Mg mgr/l	Na mgr/l	K mgr/l	Cl- mgr/l	PO ₄ ⁻⁻⁻
Wilmo lake (Fig. 1)	8	7.1	1.93	29.8	6	28.8	2.6	57	traces
Worry lake (Fig. 1)	8	7.3	1.55	25.6	5.2	25.3	1.8	55	not detected
Unnamed lake, centre of N. E. Andros	8.1	7.1	1.52	26	3.6	20.6	1.9	48	not detected

The lakes and their flats were studied at the end of the winter period of flooding, that is from January to early March; the water depth over the flats was about 1—2 feet (Figs. 4, 6) when the survey was undertaken; stromatolites were fully growing at that time. Observations were carried until the lake dries out almost completely and the stromatolite growth recesses (Fig. 7). Because of the poor quality of underwater photographs, only terrestrial photographs, taken during the shallowing up of the lake, will be given.

Zonation of the algal flat

The description of the algal flat will be presented under the form of an ideal cross section from the margin of the flat toward its central deepest part, the idea being to show the variation of stromatolite morphologies and behaviour in a very quiet and uniform environment.

The general morphological zonation originates in depths variations of but a few centimeters due to the general slope of the flat and local irregularities of its floor; these centimeters have a fundamental importance on such somewhat flat-bottomed temporary lakes in that they determine:

- (1) The length of time during which prolific algal growth will last underwater. The greater the original depth of water, the longer the underwater period of growth before the lakes dries out.



Fig. 3

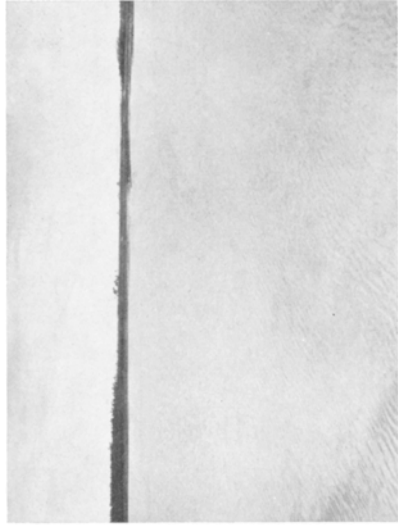


Fig. 5

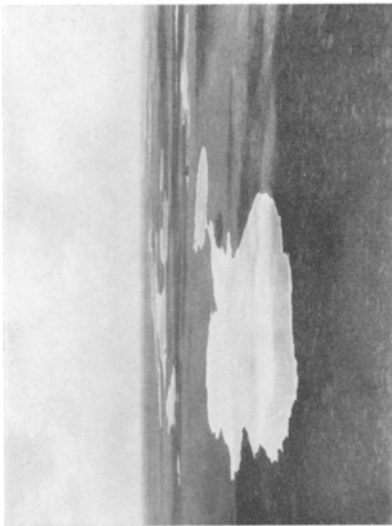


Fig. 2

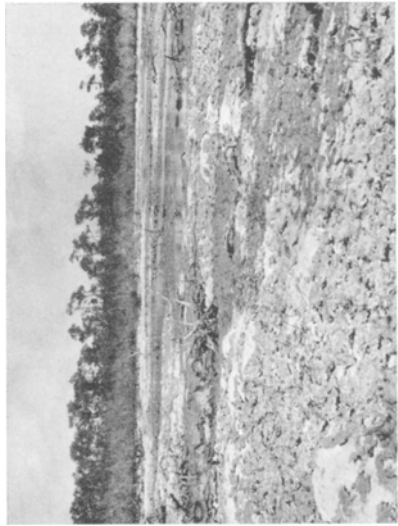


Fig. 4

Fig. 2. Fresh water lakes at the beginning of the dry season, N.E. Andros Island. Strands of pines or bush patches appear in dark whereas low lying "plains" covered with contorted algal polygons appear much lighter.

Fig. 3. Vertical view of the margin of a fresh water lake; from top to base of the photograph: pine barren; algal flat stretching over the eu littoral zone; permanent residual lakelet floored with calcitic mud.

Fig. 4. Wilmo Lake during high water level (late December).

Fig. 5. Wilmo Lake; uppermost eu littoral zone. Shrunk algal polygons over Pleistocene substrate; mid low water level.



Fig. 6. View toward the North of 2 water bodies of Wilmo lake separated by a small transverse ridge — photograph taken during mid water level. The eu littoral zone covers the whole algal flat; in the Northern arm, the flat shows a central depression floored with white calcite mud, depression which constitutes a residual lakelet during the dry season. A drainage channel appearing as a white line connects the two arms.



Fig. 7. Wilmo Lake — mid eu littoral zone. Stromatolite flat proper during very low water level (early March); the wide flat shows a pavement of well developed algal domes 10 to 20 cm in diameter.

- (2) Slight and/or local variations in the depth of the phreatic water when, during the progressive drying up of the lake, stromatolites are confined to grow subaerially on a more or less humid substrate. Other important superimposed factors will be mentioned when necessary.



Fig. 9



Fig. 11



Fig. 8



Fig. 10

1. Upper shore

The highest parts of the shore are the least proper to the development of significant stromatolitic deposits as this belt is flooded during the shortest period of time; the Blue-Green algal mats, that grow hastingly during the very brief flood, dry up and shrink rapidly to form sorts of torn down draperies around the rock edges, irregular cracked films scattered over the drying mud flooring eventual depressions, or yet turn to sorts of polygons identical to the ones that cover huge areas of Andros Island (Fig. 5).

Locally, putrid and reducing areas of the shore are covered by a thick algal grit overlying a dark brownish mud; this greenish-brown grit, which was originally considered as reworked fragments of algal mats, is in fact composed of organic particles up to $\frac{1}{2}$ cm in size, exclusively made of huge colonies of the Blue-Green alga *Gloeocapsa* surrounded by very thick protective mucilaginous deposits.

2. Belt of smooth stromatolites

The main stromatolitic deposit starts in the mid eulittoral zone and develops downflat toward the central residual lakes (Figs. 6, 7). The upper belt shows subcontinuous irregular structures (Fig. 8) resting on rock or on algal grit; they are about 2 mm thick, very irregular in vertical section and happen to show 2 poorly defined laminae. No doubt these structures are destroyed seasonally.

A transitionnal zone (Fig. 9) brings about somewhat larger domes, about 5–10 cm in diameter and 3 mm in thickness, showing four to five laminae; they do not form coherent structures and are easily disrupted when the water cover disappears; a reason may be that they generally rest on coarse algal grit which is an unstable substrate, the more that anaerobic processes in the grit originate gas production which disrupts the overlying domes. This transitionnal zone passes to the stromatolitic flat proper, which may be several hundred meters wide (Fig. 7) and displays a variety of rather contiguous perfectly individualized domes.

The first series (Fig. 10) is characterized by subcircular, rather flat and smooth-topped domes, about 10–15 cm in diameter. They show a prominent lamination made of alternating micritic, calcitic layers and highly organic somewhat soft layers; the general microstructure is very similar to the one I described from algal domes growing in sinkholes and originating in the combined growth of *Schizothrix calcicola* and *Scytonema myochroscus* (MONTY, 1965, 1967). These stromatolites remain rather thin (2–3 cm) when growing in rock, but usually get much thicker when on mud (Fig. 22) in which the lamination extends (Fig. 13).

Down the flat, i.e. but a few cm “deeper”, the prolonged underwater growth of these subcircular domes originates amoeboid stromatolites which spread in every directions and may overgrow each other; the eventual interstices or depressions between adjacent domes are rapidly filled by lateral expansions of some prosperous domes or the rapid development of interstitial mats (Fig. 11). This

Fig. 8. Wilmo Lake; upper mid eulittoral zone. Irregular and very thin stromatolitic deposit at the margin of the stromatolitic flat proper; length of knife 35 cm.

Fig. 9. Transitionnal zone toward the stromatolitic flat proper; deposit made of rather small and thin algal domes, though much more clearly individualized than Fig. 8.

Fig. 10. Belt of smooth stromatolites, mid eulittoral zone. Domes subcircular in outline, about 15 cm in diameter, characterized by a very regular and smooth upper surface; prominent and persistent lamination appears in vertical section. Length of knife: 35 cm.

Fig. 11. Very closely spaced, elongated to amoeboid algal domes, which may locally overgrow each other; in the lower half, note the filling up of eventual interstices between algal domes by lateral stromatolitic expansions. Length of knife: 35 cm.



Fig. 12

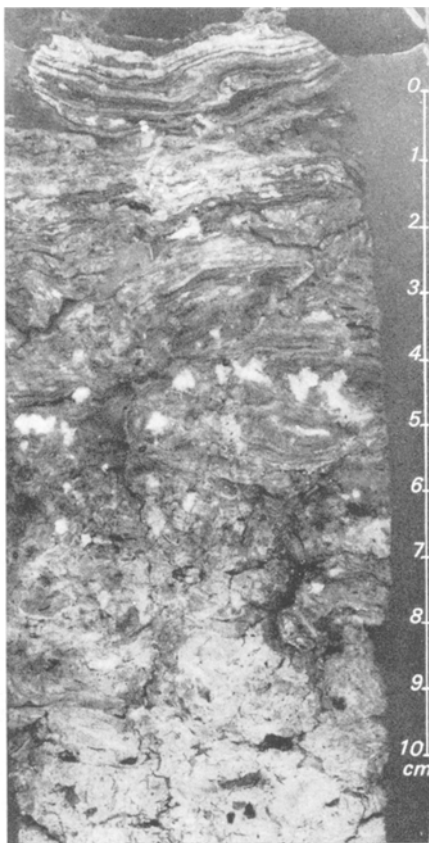


Fig. 13

Fig. 12. Lower mid eulittoral zone: transition downflat of algal domes covered with small pinnacles to column-bearing stromatolites.

Fig. 13. Vertical section through a core taken under the stromatolite deposit; shows the piling up of highly compacted stromatolitic domes resting on white calcitic, strongly reworked mud.

over and lateral growth may bring about the fusion of individual stromatolites to form larger compound structures.

3. Belt of stromatolites with pinnacles and columns

The first phase of differentiation, that we have followed up to now, was rather straightforward and monotonous; it consisted primarily in the succession downflat of larger and thicker stromatolites, most of which were characterized by a rather regular and smooth upper surface. The prolonged underwater growth toward the center of the temporary lake (i.e. the actual flat) is now going to originate new structures superimposed on the previous ones.

C o l u m n s. The appearance of erected columns, up to 5—6 cm high and 3—4 cm wide (Fig. 14) overgrowing stromatolitic domes, individualizes a prominent belt. The formation of these columns is twofold: active clones of *Scytonema/Lyngbya* have time to bloom, as a result of a longer underwater growth; they grow hairy tufts, a few cm high, composed of juxtaposed flexuous filaments grouped in vertical bundles. Once formed, these tufts constitute a core, a new substrate, that will be overgrown by successive mats, as any other substrate, to originate a rigid column (Fig. 15).

Such columns can only form underwater and at an appropriate depth. In the initial stages indeed, the growth of the tufts results from the irregular piling up of slightly interwoven and flexuous successive bundles of filaments; these structures, which collapse at once when taken experimentally out of the water, stand vertically because of their buoyancy and of the support provided by the water mass. They become a little bit more coherent after encrustation by thin calcified films of *Schizothrix* which drape themselves around this initial substrate; the successive blue-green algal communities that can now settle on a firmer substrate will consolidate the structure, and originate a concentric banding (in cross section) similar to the one which they form around pieces of wood (Fig. 31).

By their very structure, the initial tufts are very fragile and are easily destroyed or "reaped" by heavy rains; that is why they cannot form at the periphery of the eulittoral zone where the original water depth does not afford the required protection at the time of their formation. As for the tufts which appear in the right zoneographic belt, but too late in the season (that is when the water level gets low and drops more and more rapidly), they will not be preserved either; they will collapse as the lake dries out, or will be destroyed by the atmospheric agents: this is the fate of most of the tufts shown on Fig. 14.

The base of beheaded tufts may remain firmly attached to the underlying stromatolitic dome and become encrusted by seasonal mats to form small rounded projecting knobs such as shown on Fig. 16.

These columns, composed of a core surrounded by concentric cones formed by successive encrustations may be quite reminiscent of "mini-Conophyton". Furthermore, as shown on Fig. 14, some columns are vertical, others variously inclined while some did collapse on the stromatolitic substrate in which they are reincorporated by successive overgrowths.

P i n n a c l e s. Quite often, between the littoral belt crowded with rather smooth domes and the belt where columns do form, may appear a transitional zone, characterized by stromatolites overgrown by small pinnacles (Fig. 12). The first pinnacles to differentiate are only a few millimeters high but they become rapidly more conspicuous farther offshore (Fig. 18) i. e. toward the zone with columns in the ideal scheme.

The pinnacles appear as incipient tufts of *Scytonema* that would not have had time nor chances to grow into prominent columns, during the span of the seasonal growth, and would have been readily encrusted by successive mats. This is justified by their being confined to an intermediate belt, a little bit higher on the flat than the zone where columns do form, or by their capping local reliefs protruding through the latter zone; this means that the incipient tufts were subjected to a shorter period of underwater growth and during the drying out of the lake, were more rapidly exposed to surface turbulence.

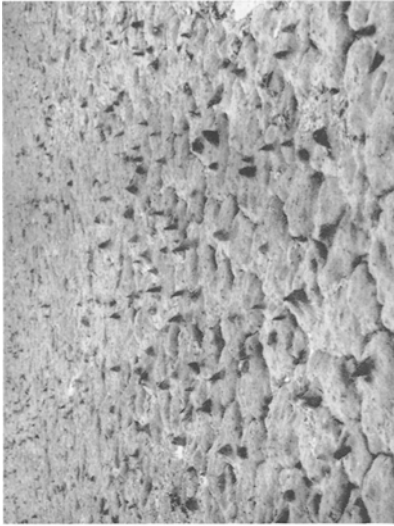


Fig. 15



Fig. 17



Fig. 14

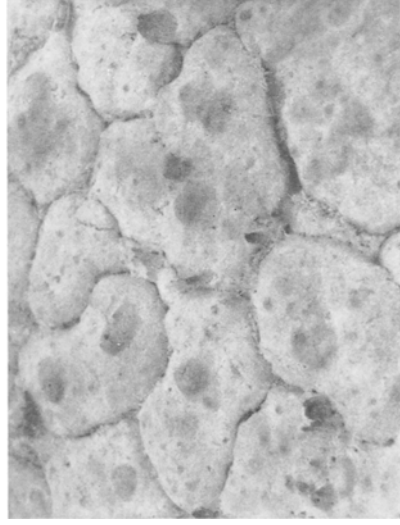


Fig. 16

The influence of the wind rippling the surface somewhat alters the overall morphology of these pinnacles: in settings directly exposed to the trade winds, pinnacles are indeed deflected downwind and grow flat on the stromatolites, originating a lineation parallel to the wind direction (Fig. 19). If they are sufficiently close to each other, the deflected pinnacles may coalesce laterally to form subcontinuous sets of ridges perpendicular to the trade winds.

According to the slope and the local geomorphology, these 2 types of pinnacled stromatolites may be by far the most abundant on wide flats exposed to the trade winds. This may be accounted for by the fact that the general overall conditions

are favorable to a prolific growth, hence the "littoral stage" represented by the flat smooth stromatolites is by-passed, but the water depth is too small and the surface turbulence too high to permit the formation and/or the preservation of columns.

4. Belt of competition

A third set of modifications, found toward the central part of the flats or in local pools, occurs when the original water depth is such that the floor remains submerged a longer period of time still, than in the precedent zone with columns.

In general, the stromatolite deposit becomes more continuous (Figs. 17, 20) and the individuality of the domes is lost as a result of lateral fusion and accretion. The reeds that grow in this belt are encrusted on about 30—40 cm of their height; this gives an idea of the minimum water depth during the flood; when water recesses, they collapse over the stromatolite deposits and become part of it (Fig. 17).

Stromatolites also become abundantly covered with small rod-shaped coprolites of gastropods and fishes that continuously feed on the algae (Fig. 17). The deposit may furthermore be invaded by green algae and a variety of hard water phanerogames (Fig. 20) to the point that its surficial features become much less apparent; in vertical section however, the classical lamination still clearly appears.

This complex community which now develops (Fig. 20) defines areas where the relative stability of the water cover makes it possible for less resistant plant to settle and compete with blue green algae; they generally start their growth in the eventual small valleys and depressions cutting through the stromatolitic deposit and spread over the floor. The upper surfaces of the leaves of these higher plants (such as *Elodea*) is generally covered with a brittle scaly layer of calcium carbonate; this shows, beside microscopic examination and the presence of whittings, that active precipitation of calcite goes on in the lake. This community generally leads to the rim of the permanent residual lakelet floored, as seen above, with "bird's eye" type of mud.

Fig. 14. Zone of columns, lower mid eulittoral zone. Algal domes are overgrown by tufts of *Scytonema* partly encrusted by films of *Schizothrix*; encrusted tufts appear light gray with rounded tips. The non, or partially, encrusted tufts (incipient columns) look much darker, with acute tips and seem to protrude through the algal dome. Note the various orientations of the tufts and columns, some of which collapsed on the underlying domes. Most of the non encrusted tufts will be destroyed by rain; they formed late in the season and became exposed before being consolidated by sufficient overgrowth (see Fig. 15).

Fig. 15. Tuft of *Scytonema* that has been encrusted by *Schizothrix* and various algal communities to form a coherent column, about 5 cm. high. Note the continuity of the uppermost layer of the fragment of basal algal dome, layer which completely envelopes the column.

Fig. 16. Algal domes with beheaded columns, the base of which has been overgrown by seasonal mats and projects as small rounded knobs. Diameter of domes, about 15 cm.

Fig. 17. Lower eulittoral zone. Subcontinuous stromatolitic deposit, with columns and knobs, invaded by reeds and covered with abundant rod-shaped slightly curved coprolites from grazing fishes. Length of knife: 35 cm. Water depth about 5 cm. Late February.



Fig. 18. Algal domes with well developed pinnacles, some of which may coalesce laterally to form small irregular ridges. The erected pattern of the pinnacles and ridges shows that they formed in a microenvironment protected from the trade winds (compare with Fig. 19).



Fig. 19. Development of lineation on pinnacle-bearing stromatolites subjected to persistent trade winds. The pinnacles and small ridges, such as shown on Fig. 18 are deflected downwind and keep on growing flat on the algal domes. Trade wind blow from left to right. Water depth about 3 cm., late February. Length of knife: 35 cm.

Microstructure of the mats and origin of the carbonate

The microstructure of these deposits, although very similar to that of algal heads described from sinkholes (MONTY, 1965, p. 217 on) will be considered and illustrated elsewhere. The ever changing features of this microstructure, according to the season and time of sampling, make it difficult to provide an objective and synthetic description. During the period of successful underwater growth

for instance, the surficial blooming lamina thickens to 1—1.5 cm. It is composed of long vertical filaments of *Scytonema*, generally calcified below their growing tips (MONTY, 1967, pl. 6) and permeating horizontal thin and calcified daily films of *Schizothrix calcicola*; the overall pattern yields a sort of palissade type of structure. The upper layers are furthermore expanded by important gaseous vacuoles and the development of large colonies of *Entophysalis* (MONTY, 1967, pl. 3, Fig. 3; pl. 8, Fig. 1 and 2).

As growth recesses, when the water level drops below the upper surface of the algal dome, this surficial layer shrinks and collapses considerably (it will



Fig. 20. Lower eulittoral zone: the stromatolitic deposit becomes invaded by competitive communities of green algae and phanerogames. Note white scaly deposit of calcium carbonate on the upper surface of the leaves of *Elodea* — depth 5—8 cm., late February. Length of knife: 35 cm.

be reduced to but 1—2 mm); many algal cells become dormant (MONTY, 1971, p. 220) while very short, deeply stained filaments of *Scytonema* form a sort of surficial close-cropped lawn. This stained and compact surficial layer acts now as a screen that protects the underlying filaments; the latter, shaded from noxious radiations and enjoying a sufficient amount of water coming from the substrate, start growing, the more that the capillary water is trapped by the watertight upper film; these internally growing filaments are no more deeply stained, they look whitish or greenish, rarely yellow or brown like the surficial ones. This internal growth, thickens the stromatolites from the inside and originates new uncalcified layers, whereas the overall microstructure is disturbed. Things change in surface too, for the general conditions are such now that only the resistant but slow growing alga *Scytonema* can grow, whereas *Schizothrix* recesses; accordingly, the palissade structure disappears. All these metabolic and structural changes are accompanied by a succession of different micro-environments within the mats, causing solution of carbonate here, reprecipitation there, consumption of mucilagenous matter and polysaccharides by anaerobic communities, etc. (see MONTY, 1965, pp. 226—253).

The result of these successive and/or superimposed phenomena, occurring at different scales, acting in the same or in opposite directions, including physical, chemical, biological (micro-) processes, hinders considerably the investigation and understanding of the microstructure of these mats.

Things are not more simple when deciphering the origin of the carbonate as precipitation occurs at different scales and follows different pathways:

1. Calcite is precipitated in the lake and on the plants as a result of a chemical desequilibrium which is reached sometimes after the filling up of the lake: while the "original" rain water gets more and more enriched in $\text{Ca}(\text{HCO}_3)_2$, by solution of the karstic substrate, the rejuvenated filaments enter an ever increasing growth phase leading to the bloom; accordingly, a point of desequilibrium is reached sooner or later due to the increasing demand for CO_2 .

2. The resulting small crystals floating in the whitening water *may* become a substrate for the tiny filaments of *Schizothrix calcicola*; the latter develop around the grains, bind some of them together and originate small loose flocs; the very active growth of *Schizothrix* and the high but very localized demand for CO_2 enhance precipitation around, or, in the floc.

3. Precipitation abundantly occurs around the filaments and within the mat as described in MONTY, 1965 (pp. 232—253), and 1967 (pp. 72—76).

4. Precipitation occurs still when the lake dries out; at that time the supersaturation of the residual carbonate may originate conspicuous whittings.

The carbonate phase involved in these mats is a low magnesian calcite⁶⁾ appearing sometimes as perfect rhombs sometimes under a variety of crystallographic shapes which may show rounded angles according to the site of precipitation; this latter factor also influences the crystal size which passes from one micron or less in the algal sheaths to 2—8 microns in the interstitial mucilages. The resultant stromatolite will accordingly be characterized by a micritic laminated texture zoned with brownish organic layers and showing bundles of nicely calcified filaments; the latter strongly contrast with the matrix as a result of the smaller grain size of their constitutive crystals. The ordonnance and the continuity of the tubes becomes much poorer in the lower part of the structures because of the general compaction and collapse of the individual layers (dead laminae are no more supported by the positive pressure of metabolical gases, nor by the abundantly produced and water laden mucilages which characterize the living ones; eventual dessication furthermore enhances the contraction of individual layers); except in cases of very favorable conditions of preservation, only fragments of tubes will hence be preserved by fossilization. Finally, as described in MONTY (1965 b, p. 199, 201; 1967, p. 73, pl. 8), internally formed pellets due to bacterial action and calcification of colonies of unicells will somewhat disturb the monotonous lamination of micritic and thin organic layers.

Although BLACK noted (1933, p. 176) that "in the widespread algal deposits of the interior of Northern Andros Id., no trace of mechanical lamination was discernible and the sediment is extremely fine in texture" he nevertheless thought that the fine-grained calcitic particles were supplied to the mats by a process of flooding which supposedly took place in two different ways (*id.*, p. 177):

(a) by heavy rainfall, the transportation of sediment consists in "a slight

⁶⁾ Though locally it may contain up to 8 mole % MgCO_3 in lakes close to tidal creeks.

washing of material from the lands into the lakes and creeks"; he added "there is possibly also a little transference of sediment from the lake floors onto submerged parts of the algal flats, when the bottom deposits are stirred up by waves and drifted by wind-blown surface currents onto flooded areas bordering the lakes". I however believe with BLACK that during such heavy rains "the solution effects are probably more important". I do not think that washing of material from the land into the lakes is significant, for there is almost no soil on Andros and the very karstic nature of the Island prevents any runoff.

When the lakes are wide enough to present a significant residual central pond floored with fine grained calcite, there may be some transfer of material into the algal flats as stated by BLACK. I nevertheless believe that the process is very limited for (1) the floor of many inland residual lakelets is covered with sub-continuous algal mats (2) if not, the carbonate has a clotty texture due to aggregation of calcite crystals by *Schizothrix* or unicells and diatoms; such flocs cannot account for the diversified and very particular features of the carbonate within the mats (3) during the 3 months observation period, calcification of mats kept on proceeding although no washing of fine grained material from the central residual lakelet onto the algal flat was observed (4) I found no significant differences between the microstructure of the algal heads I described from small isolated and well circumscribed sinkholes (MONTY, 1965 b, 1967) and that of the deposits reported here

(b) the second type of flooding invoked by BLACK, to account for the calcite found in mats, occurs on a grand scale during hurricanes: "... vast quantities of sea water are piled up on the shoals, and are swept over the low lying parts on Andros as a result of violent westerly winds. During such storms, the water of the banks is laden with churned up sediments and the whole of the flooded area is liable to be smothered under a film of fine white mud, which is left behind when the flood retreats" (p. 177); he adds (id.). "The sediment brought into the center of the island by such flood water is extremely fine-grained, since all the coarser constituents are deposited before the water has travelled far in from the West coast. This uniformity of grain size prevents any mechanical lamination or any noticeable difference in the size between the particles agglutinated round the mucilage of the algae and these particles which settled out under gravity". This process is incompatible with the carbonate found in mats — a low magnesian calcite — as such catastrophic flood would bring in almost pure aragonitic mud which has never been detected here; these X-ray results are confirmed by the striking difference which exists between the morphology of the microcrystals composing the aragonitic muds of the Western banks (needles) and that of the calcite found in fresh water lakes as revealed by the Electron microscope (NEWELL and RIGBY, 1957, pl. XVI, Figs. 1, 2). Furthermore such huge floods that would cross the island from West to East and find their way" ... through the Eastern creeks into the lagoon behind the barrier reef — a cross-country journey of some forty miles" (ibid. p. 177) are really exceptional at the scale of the decade and their frequency cannot account for the observed constant mineralization of the reported stromatolites. Such a process is only effective on the supratidal flats of the Western coast where it originates the well known algal laminated sediments.

Finally, the microstructure and the characteristics relationships between the



Fig. 22



Fig. 24



Fig. 21

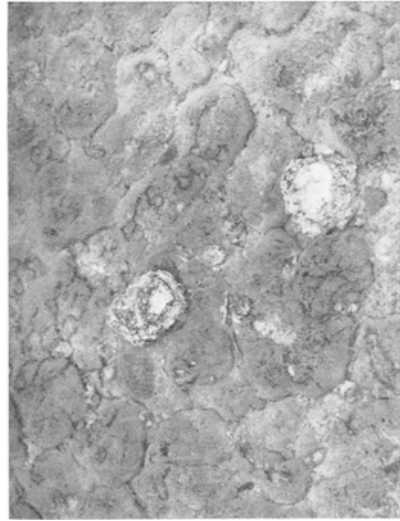


Fig. 23

fine grained calcite and the algal material (filaments, mucilages, colonies of unicells) as has been lengthily described in MONTY (1965 b, 1967) show clearly enough that the two processes invoked by BLACK cannot account for the bulk of the observed mineralization of the biostromal deposits reported in this paper.

Alteration and reworking of the stromatolite deposit

a) Physical factors

They include stormy rains which may disrupt the marginal fragile domes resting on algal grit, or destroy the algal columns when the water level drops.

Prolonged drought is the most important factor which completely alters the stromatolites at the periphery of the flat where the mats shrink, crack and may become brittle or very contorted. The action is less drastic in the lower eulittoral zone; the algal dome becomes more compact, some surficial layers, which are about 1 cm. thick during full growth period, shrink to about 1 mm.; however the moisture of the underlying substrate and the formation of tough watertight algal cover makes it possible for these domes to survive.

b) Metabolical factors

Small scale peeling: Active internal growth of long slender filaments, protected from noxious radiations by a brownish calcified and watertight film of *Schizothrix* and *Scytonema*, originates the accumulation of gaz bubbles in between the fragile filaments; this weak zone is easily disrupted under the pressure of gases and the upper layer peels off (Figs. 21, 22). The peeled fragments float away and/or accumulate in the depressions separating the domes.

Large scale peeling: During the full growth period, complete mats or algal domes may become buoyant. At that time the surficial lamina, covered by a thin film of *Schizothrix*, expands up to 1 or 2 cm. (Fig. 29) and is loaded with gaz bubbles trapped in the overall mucilage. As a result of the strong positive buoyancy, whole algal mats peel off the substrate (Fig. 25) and float away, leaving sorts of big scars in the stromatolitic deposit (Fig. 26). Similarly, whole sets of buoyant algal domes detach from the substrate (Fig. 27) move around, and resediment when the bloom is over; they will be reincorporated into complex and irregular deposits by further overgrowths (Fig. 28). Some individual dome may float over for some distance before being redeposited right side up or upside down on the stromatolitic bed (Fig. 23); they will also be overgrown by seasonal mats to originate compound structures (Fig. 24).

Discussion and final comments

Comparisons

This natural history of significant non marine blue-green algal flats revealed the formation of stromatolitic deposits reminiscent of many occurrences in the geological column; it also gives us an interesting counterpart of the abundant algal

Fig. 21. Small scale peeling in stromatolites from upper mid eulittoral zone; peeling is due to accumulation of gaz underneath the upper fragile lamina (see Fig. 22) where a weak zone progressively forms and originates the disruption of the uppermost layer.

Fig. 22. Belt of smooth stromatolites, mid eulittoral zone. Vertical section through a stromatolitic dome about 10 cm in diameter; note prominent lamination which extends in the underlying mud represented on Fig. 13. Blooming and development of gaz vacuoles in the upper laminae originates a weak zone and the peeling of top layer (cfr. Fig. 21).

Fig. 23. Two algal domes that peeled of their substrate, drifted away and have been redeposited upside down over the stromatolitic bed, at the end of their bloom; the diameter of the domes is about 10 cm.

Fig. 24. Vertical section through a complex stromatolite; a drifted and upside down resedimented algal dome (such illustrated on Fig. 23) overlies another in life position; both of them have been later overgrown by seasonal mat. This figure illustrates the way in which they situation shown on Fig. 23 will evolve.



Fig. 26

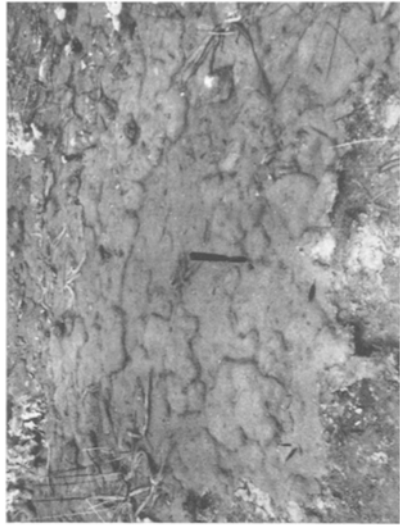


Fig. 28



Fig. 25

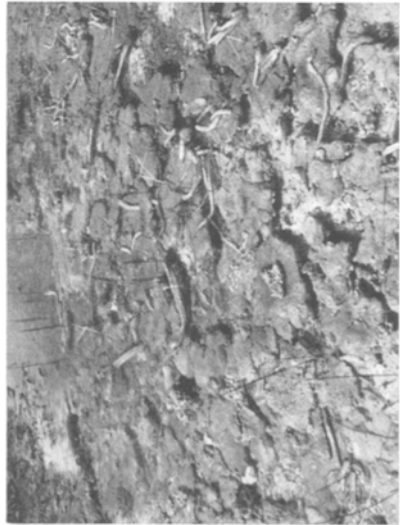


Fig. 27

mats or laminated sediments reported from saline or hypersaline waters of inter- to supratidal settings (GINSBURG et al., 1954; DAVIES, 1969; KENDAL et al., 1968, etc.). The presently reported formations differ strongly from algal laminated sediments by their mode of formation, their microstructure, their mineralogy and associated fauna.

(1) The Wilmo Lake stromatolites are entirely controlled by algae; their overall features do not primarily result from the periodic influx of clastic grains over algal films or mats, but from the seasonal or environmental differentiation of an algal coenose which originate most of the mineralization of the resulting structures.

(2) They show no mechanically deposited graded-bedded layers (like in BLACK's type A, 1933) nor storm layers (like in SHINN et al., 1969).

(3) There is no differentiation of grain sizes into distinct laminae (inter-beddings of silts and muds a.s.o.) and no variation in the granularity of the particles from the proximal to the distal end of the flat, all features which are typical of inter-to supratidal algal laminated sediments as listed in GINSBURG et al. (1954, p. 30—31) and in DAVIES (1969, p. 201—202).

(4) The carbonate grains are the same across the flat and from base to the top of the stromatolite; when structural or dimensionnal modifications occur, they are generally bound to algal or bacterial activity, which accounts for the differences between the crystals of the sheaths and the crystals of the interstitial mucilages, for the formation of pellets in colonies of bacteria or of unicells, etc.

(5) The structure and mineralogy of the finely but thoroughly calcified filaments looks very different from what is commonly found in mats from intertidal settings where molds filaments are more frequent (MONTY, 1965 b, pl. 58; DAVIES, 1969, Figs. A, B.)⁷).

(6) The carbonate mineralogy — a low to very low magnesian calcite — is very indicative of the geochemical environment and would favor a rather simple diagenetic history as opposed to what is found in association with inter-supratidal mats of Western Andros Id., the Persian Gulf, Shark Bay, etc.

(7) The Wilmo Lake stromatolites of course do not include any fragments of marine organisms (there may be some limited contamination in the deposits bordering important tidal creeks though) and the associated preservable fauna is very poor: fresh water gastropods, ostracods, thekamoebeans, etc.

Such fine-grained and homogeneously laminated stromatolites permeated by remnants or fragments of calcified algal filaments, associated with a very poor fauna dominated by gastropods, forming laterally linked or spaced domes

⁷ See however SHINN et al., 1969, Fig. 12 where calcified filaments have apparently be found in supratidal marsh sediments.

Fig. 25. Large scale peeling in the lower eu littoral zone. Active algal growth and accumulation of gas in blooming algal mats (see Fig. 29) endow them with a strong positive buoyancy; the whole mat peels of the substrate and gets disrupted; the resultant fragments then drift and float away. Thickness of mat 4 cm. Depth of water, about 15 cm.

Fig. 26. "Scars" left in the continuous stromatolitic deposit of the lower eu littoral zone after peeling of large fragments of mats. Note how the remaining mat floats over the substrate at the periphery of the scar and opens the way to further peeling. Depth of water: about 15 cm.

Fig. 27. Large scale peeling in the lower eu littoral zone. Floating algal domes during period of bloom; when the phenomenon occurs in region exposed to the trade winds, the whole set of detached domes will drift away to pile up some place when the bloom is over. The importance of algal encrustation around the reeds can be appreciated from comparing the vertical young reeds with the dead encrusted ones lying flat over the domes.

Fig. 28. "Resedimented" domes that have been gathered into a complex deposit by seasonal overgrowth. The result of the processes illustrated in the Fig. 27 may yield a type of biohermal accumulations due to flotation, drift and local piling up of the structures rather than to plain constructional phenomenon.

capped or not with various knobs or columns, are undoubtedly features which we are used to meet in the geological column.

BLACK (1933) described algal heads from the flats of lake Forsyth and Stafford Lake (North Andros); he did not however analyze the algal zonation of the flat which he reported as a surface where the development of mats was constantly opposed by dessication of the substrate; that is why the heads he rapidly described (BLACK's type C) form individual discs standing well apart from each other (BLACK, id. Figs. 19—20) whereas the lamination is concave upward (id. Fig. 8, p. 183); this originates an internal structure very different from the one shown here on Figs. 10, 11, 22, 32 where the lamination is constantly convex upward, a typical feature of encrusting communities. The descriptions that BLACK gives of his type C heads and of their internal structure suggests however that he studied them in a pretty dessicated stage, which shows up on his photographs, by the very dark colour of the mats. Anyhow, these two "facies" or "phases" (BLACK's and ours) of fresh water algal deposits built by an identical coenose are pretty good replicates of some pre-cenozoic stromatolites.

Lack of significant lithification

One may wonder why these algal formations do not originate hard lithified structures instead of unconsolidated earthy deposits; the problem was already felt by BLACK when, comparing his Andros stromatolites with other Recent cyanophycean structures, he wrote that the Bahamian algal deposits "stand apart from all other recorded examples in being completely unlithified" (p. 184); he probably had in mind here the many concretions found in fresh water lakes or streams and the famous "Biscuit Flat" (South Australia) where MAWSON (1929) had found important accumulations of lithified algal biscuits growing on temporarily submerged flats. In fact such a type of question — how come androsian stromatolites do not get lithified? — is always a dangerous one that may have no answer that our reason can understand (*how come* some chlorophytes secrete an internal aragonitic framework, while other remain uncalcified?); we may however try to sort out some elements to think about:

(1) Androsian mats (such as BLACK's type C, D, MONTY, 1967, types 1, 2, 3, pp. 68—76; and the deposits reported here), thriving at very shallow depths and having to stand eventual periods of severe exposure, are dominated by a fresh water alga well adapted to the harsh conditions of subaerial life: *Scytonema myochrous*; its individual filaments are surrounded by a thick lamellated sheath, which generally becomes deeply stained with protective pigments and which encases itself into a thin and brittle encrustation of small calcitic crystals (MONTY, 1967, pl. 6); pure cultures of *Sc. myochrous* never go any further than this stage of calcification of the individual sheaths, as is confirmed by KANN (1941 b); so that no hard calcareous object can result.

(2) In the reported mats, *Scytonema* is accompanied by the tiny blue-green *Schizothrix calcicola* (MONTY *ibid.*, BLACK, *ibid.*) which, in fresh waters originates strongly lithified structures. As exposed in MONTY (1965 b, 1967), *Sch. calcicola* is a subaquatic alga which consolidates and thickens the mats, during the phases of submergence or of increased subtratal humidity, by stretching calcified films between the *Scytonema* filaments or by binding bundles of *Scytonema* together; however being given the interference of many other algae which

somewhat disturb the framework (*Plectonema*, *Entophysalis*, *Johannobaptista*, diatoms, etc.), the abundance of released mucilage, the rather slow rate or precipitation of calcium carbonate and the difficulty of ionic migration (due to density of mucilage, eventual complexation, etc.), *Schizothrix* can originate but loose calcified structures and not the hard calcareous objects like the ones found in the lake of Constance or the tufa illustrated by IRION and MÜLLER (1968, Figs. 6, 7).

(3) Other environmental chemical factors may also interfere: these shallow warm waters are much less aggressive with respect to the karstic substrate than the waters of our temperate and cold lakes or streams; hence the ratio $\text{CO}_2/\text{Ca}(\text{HCO}_3)_2$ is rather different. Furthermore, the sudden escape of the eventual excess of CO_2 , which in our European calcareous lakes and streams considerably enhances the carbonate precipitation, is very limited in the protected settings characterizing many Androsian lakes. During windy days, when the surface turbulence facilitates the release of the CO_2 trapped in the water lens, the author has however observed local conspicuous whittings in residual ponds. The process is however too slow and unfrequent to add significant amount of carbonate to the algal structures.

General features of stromatolites vs. environment

The description of fresh water blue-green algal flats, reported here in very general terms, illustrated some aspect of the differentiation of one given stromatolitic community in response to very small variations of environmental conditions. As is the case with most studies on algal flats we are left with the impression that the algae themselves have little to do in the overall morphology of the resulting structures, but that the environmental conditions are the ruling factors in the shaping of heads and associated structures; we can indeed summarize the observations as follows:

(1) The stability and location of the final water level during the dry season originates two main ecological and morphological zones: on the one hand, these wide flats liable to be exposed to drought and characterized by pure stromatolitic deposits (Figs. 7, 18); on the other, the distal portion of the flats, or the eventual ponding areas, where stromatolites are invaded by competitive plants (Fig. 20).

(2) The eventuality of a more or less complete dessication, as well as its duration, segregates three main belts: that of thin, cracked, poorly laminated polygons, that of various algal heads and that of subcontinuous mats.

(3) The length of underwater growth is a factor of differentiation of the morphology of heads and separates smooth domes, domes with pinnacles, domes with columns (Figs. 10, 14, 18).

(4) The intervention of dynamic environmental factors may alter the deposit: the action of the trade winds intervene in the modeling of original pinnacles into striking lineations (Fig. 19), whereas heavy rains may destroy algal columns and leave residual knobs on top of the stromatolites (Fig. 16).

(5) If the nature of the substrate, hence its moisture retention, has a fundamental influence on the algal growth when the water level drops, its morphological features may directly influence the overall shape of the stromatolites, be



Fig. 29

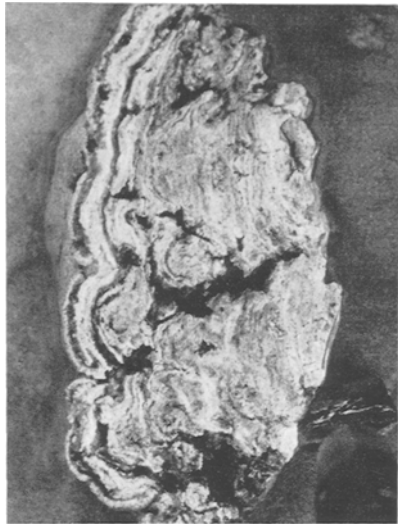


Fig. 30

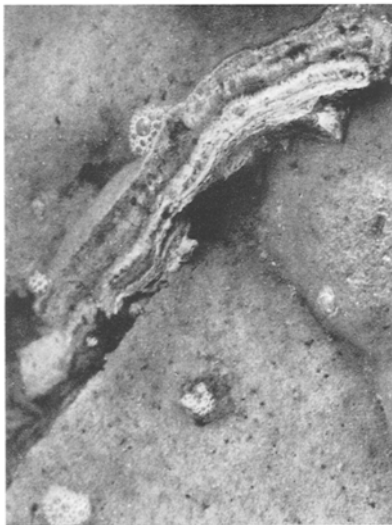


Fig. 31

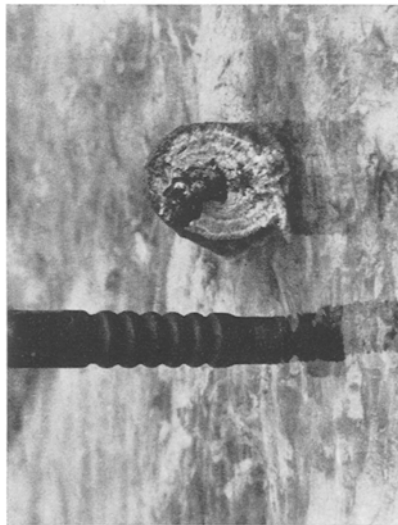


Fig. 32

Fig. 29. Cross section through a peeling mat of the lower eulittoral zone; the upper layer (about 2 cm thick) is fully expanded as a result of algal bloom and accumulation of gaz bubbles in between the filaments.

Fig. 30. Cross section through stromatolitic deposit overgrowing the pitted Pleistocene substrate; the apparent "domes" formed here by the blue green algal mat are imposed by the presence of rocky projections which appear beneath the mat.

Fig. 31. Piece of wood encrusted by stromatolitic algae; successive encrustations originate a laminated sheath encasing the branch. Diameter of cross section is about 5 cm.

Fig. 32. Vertical section through a complex algal dome; the irregularities of the surface are here dictated by the presence of underlying discrete domes that were later overgrown.

it in the case of protruding substratal rocks (Fig. 30), of former stromatolites (Fig. 32) or even of pieces of wood (Fig. 31).

Before stating that blue-green algae are always passive agents building up structures which are primarily shaped by environmental conditions, I would like to try to frame the problem properly by enlarging the field of discussion. To this purpose let us rapidly oppose the zonation of blue-green algal crusts in the eulittoral zone of two main types of lakes, i. e. the oligotrophic and the eutrophic lakes. In the oligotrophic lakes, where the waters are generally deeper and clearer than in eutrophic ones, the shores are quite often steep and therefore narrow; among other things, this steepness of the eulittoral zone originates a set of successive and well delineated habitats, each of which closely fits the ecological requirements of a given algal coenose that consequently will become the dominant one in a given belt; the algal cover of the eulittoral zone will not consequently be uniform, but will distribute itself into successive well individualized belts leading for instance to the succession downshore of a *Tolypothrix* zone, *Rivularia* zone, *Schizothrix* zone, etc. This originates, in the same direction, a typical series of very different types of crusts or mats, each one showing its individual characteristics and growth form. Accordingly in the case of rather steep shores, the environmental pressure favors a distinct and rather brutal distribution of particular algal coenoses which in their turn originate a clear distribution of *proper growth forms* (see KANN, 1941 b).

The situation is quite different in eutrophic lakes which are generally bordered by wide and flat benches. In this case, the greater part of the subhorizontal and drying up shores constitute a rather uniform habitat characterized all over by important but similar yearly environmental changes. This will favor the establishment of one complex basic community whose range of adaptation and tolerance comprizes the general set of environmental and seasonal conditions; accordingly the eulittoral zone will be invaded by an almost uniform algal cover, and the fundamental type of mat or crust will tend to be the same over the greatest part of the flat. The adaptational properties of the association will generally cope with environmental pressure along to main pathways:

(1) Physically induced morphological changes: resulting in the formation of thin algal polygons upshore (when growth is very intermittent), of nice and healthy domes downflat, of oriented structures in equilibrium with the local dynamic agents, etc.

(2) Morphological changes due to variations in the respective abundance of participating algae. As opposed to the various structures distributed down the steep shores and which are built each by a definite alga, accompanied or not by a very small number of by-goers, the associations found on subhorizontal flats, submitted to rather important and continuous environmental changes, are generally complex and include a great number of participating algae⁸⁾; among these, are generally two or three basic ones adapted to the seasonal extreme conditions to be endured by the community so that the mat can keep on growing whatever be the conditions. This organisation confers a great plasticity

⁸⁾ It is however evident that when seasonal changes include extremely hard conditions, such as concentration of brines, the algal association will be restricted to one or perhaps two algae, i. e. the more resistant ones (case of *Lyngbya stratum*; see p. 775).

to the mat and opens the way to an easy differentiation both in time and in space; *in time* because the basic algae will lead each in its turn according to seasonal changes, originating that way a conspicuous laminated structure but also an ever changing external aspect of the stromatolite; differentiation *in space*, because small lateral variation in the environment (with respect to tolerance of the coenose, not to our appreciation) will favor such or such alga of the community; the balance of the participating algae will be changed, hence the properties and features of the mat; this is for instance the case for the mats described by GINSBURG et al., 1954: their types I and II are built by the same basic community but with different proportion of participating algae.

Accordingly, if in the first case (illustrated by the steep shores of oligotrophic lakes) we end up with different mats, specifically built by the different algae in different specific habitats, the second (illustrated by the flat shores of eutrophic lakes) shows different stromatolitic morphologies built by an identical but highly flexible basic algal community that copes with environmental pressure; as the latter case sums up conditions which are generally found on tidal flats where most geological studies are carried on algal mats, it is not surprising that the "concept of passivity" of blue-green algal structures shaped by nothing else than environmental conditions opened the way to a general but misleading theory.

In view of what precedes, we may however have a better understanding yet of the significance of these algal flats and of their stromatolitic cover. Indeed, we should always keep in mind that these wide and monotonous flats are but a mixed and intermediate habitat, accordingly colonized by a mixed and intermediate blue-green algal association (an equivalent intermediate belt can never take any significant development around oligotrophic lakes where the shores are much too steep). The resulting stromatolites and mats are then generally built up — beside many ubiquitous forms — by a collection of various specific blue greens whose ecological ranges overlap on the flats; the resulting structures appears thus as a compromise. However, when we trace this association towards the specific biotopes of each of the leading component alga, we generally end up with rather pure cultures of them, showing each its specific growth form. For instance: tracing landward the stromatolitic deposits of Wilmo Lake, we finally reach structures built by pure growths of *Sc. myochrous* (type 1 MONTY, 1967, p. 70, Fig. 5, pl. 5), while tracing them seaward we find the pure stromatolitic domes built by *Schizothrix calcicola* (MONTY, 1965 a, 1967, p. 89—92, pls. 16-3, 17-3, 18, 19). In such wide scope, algae have surely something to do with the general features of the resulting stromatolites, and undoubtedly much more than the local hydrodynamical agents.

Competition and individualization of stromatolitic flats

When surveying marine and non marine environments, one is stricken by the fact that the most important and successful blue-green algal colonization is found on periodically exposed flats i. e. the inter to supratidal zone in the first case, the eulittoral zone of lakes in the second one; in both instances, there is of course a similarity in the type of habitat, were it not for a factor time: the frequency of exposure and submergence is indeed daily in the case of intertidal

flats, whereas it is seasonal in the case of supratidal flats and of the eulittoral zone of lakes.

It has been shown elsewhere (MONTY, 1972) that inter- and supratidal flats are but one of the many settings that stromatolites did colonize during their long geological history and that they had finally been confined there as a result of the strong ecological pressures developed by competitive subtidal communities. If we consider the situation in Wilmo Lake and match it with what has been reported from European lakes we find that similar competitive relationships between stromatolitic blue-green algae and other plant communities are also found in non marine settings. KANN (1941 b) discussed the problem in the case of eutrophic lakes; the abundance of nutrients found in these lakes results in a great development of all algal groups (greens, browns, diatoms, reds) as well as of various phanerogames in the upper layers of the lakes (such a situation may be analogous to the one that characterized Paleozoic and surely Mesozoic shallow seas). The settling of such a rich and varied colonization originates strong competition for space and nutrients between the different algal groups and it appears that benthic blue-green algae are poor competitors with respect to more powerful ones like the *Cladophora*. Algal mats that might form will be loose unlaminate structures in which *Cyanophyta* grow interspersed with various types of other disturbing algae. However, says KANN (id.), if the water level varies greatly in such a way that important portions of the benches become seasonally exposed to drought and intense radiation, a new habitat is created, habitat that only one algal group — the blue-greens — will be able to colonize uncompeted, because of its various morphological, cytological, physiological properties (MONTY, 1971); KANN (ibid.) concludes that this is the main reason why blue-green algal crusts most characteristically colonize a well defined portion of the lakes, i. e. their eulittoral zone. WOROCHIN (1936) described similar situations in the case of highly alkaline lakes saturated with Na_2SO_4 and containing significant amounts of iodine and bromide; for instance, the Great Tambukan lake (a shallow lake of Western Caucasus) is colonized at depths of 0.5 to 1m. by a thick growth of the filamentous green alga *Rhizoclonium hieroglyphum* (a genus close to *Cladophora*) associated with some outnumbered blue greens. As the chances of drought and exposure increase shoreward, the *Rhizoclonium* community recesses while the bottom is floored with an almost continuous layer of *Cyanophyta* (*Chroococcus*, *Lyngbya*, *Phormidium*, *Oscillatroya*, etc.) which passes, near the desiccated upper shore, to leathery mats composed of an almost pure culture of *Lyngbya aesturii*. In the case of lakes which, flooded in Spring and Fall, dry up completely during the Summer (WOROCHIN, id.) *Rhizoclonium* forms but scattered patches while blue-green algal mats, dominated by *Lyngbya*, colonize most of the flat; as WOROCHIN states it (ibid.) the periodical dessication of the lake maintain the purity of the *Lyngbya* stratum.

All these trends agree with what has been reported here from Wilmo Lake: pure stromatolitic deposits and heads develop on the periodically exposed flats; downflat, that is toward sites that remain submerged a longer and longer period of time, the mats become invaded by a variety of green algae and phanerogames (such as *Elodea*) which not only compete for space and nutrients with blue-green algae, but overgrow them and disrupt the stromatolitic structure.

All these examples illustrated a well known ecological "law" of population

dynamics, i. e. the passage from communities with rather high diversity and low dominance in (relatively) favorable habitats, to communities with very low diversity but very high dominance in very particular or severe habitats. As has been discussed in MONTY (1972) the present status of Cyanophyta results from a long history of competition between blue-green algae and various marine encrusting communities and the confinement of significant algal mats or stromatolites on periodically exposed flats, where they can grow undisturbed and unimpeded.

One might think that predation, the intervention of boring animals, etc. . . . may prevent blue-green algae from growing successfully or stromatolitic structures from forming outside of these periodically exposed flats. Such a view has recently been developed by GARRETT (1970). I do not think that such a type of non competitive relationship can account for the poor development of stromatolites in the sea (MONTY, 1972). Blue-green algal mats provide a habitat to many microorganisms (worms, ostracodes, crustaceans, gastropods, etc. . . . BATHURST, 1968; NEUMAN et al., 1970) which they feed together with higher animals (fishes etc. MONTY, 1965, p. 285, Fig. 32 a, 1967, p. 81, DAVIES, 1969, Fig. 18 a etc. . . .) This does not prevent algal laminated sediment to form (DAVIES, id.) nor stromatolitic domes to grow (MONTY, id. "mats and crust built by *Scytonema crustaceum*"). Feeding on rock-building blue-green algae is also known in fresh water structures, the building up of which does not seem to be hindered by the burrowing or browsing organisms: this is illustrated by the larvae of chironomids which built feeding and living burrows in Oscillatoracea-tufa and feed on the algae (see STIRN, 1964; IRION & MÜLLER, 1968, etc. . . .); furthermore, most fresh water blue-green algal deposits, be they mats, crusts or tufa are generally associated with a great number of gastropods belonging to a small number of species and feeding on the growing algal crusts; when the animal dies, its shell becomes readily incrustated by successive calcareous laminae to be incorporated into the algal crust, or to form the well known fresh water oncolites or "Schneckeliasand" (BAUMAN, 1911; RUTTE, 1953, pl. 14, Fig. 4, etc. . . .). In the latter case, the predators do not eliminate blue-green algae but on the contrary, favor the formation of oncolites by providing a hard substrate for encrusting algal communities to grow.

So, projecting the data into the marine realm and in the fossil record, I believe that the observed abundance of stromatolitic deposits on periodically exposed flats is not primarily a matter of predation but before all a matter of direct intercommunity competition in which the competitive weakness of blue-green algae has driven them to settle in habitats where their competitors could not grow (see complete statements and restrictions in MONTY, 1972).

Floating colonies

Floating colonies such as reported from Wilmo Lake, are not a unique phenomenon but have been described from other fresh water settings (PHILLIPS, 1958, etc. . . .) as well as from marine environments (PHILLIPS, 1963). In all cases, the phenomenon is associated with the period of algal bloom and occurs at very shallow depths (1—3 feet). Once formed, these floating aggregates originate a new habitat and the whole structure of the mat is liable to suffer some

important transformations. PHILLIPS (1958) observed that the process starts by a vigorous multiplication of blue-green algae [*Arthrospira*, *Spirula*, *Oscillatoria*⁹⁾, etc. . . .] on the muddy bottom of the pond. An abundant mucilage is secreted during the growth so that the top layer becomes air tight, while the lower filaments progressively permeate the mud and bind the particles. The abundant oxygen resulting from active photosynthesis during the Summer months remains trapped in the algal film above the mud and inflates it; the mat and the adhering mud finally tear away and are buoyed up at the water surface where the algae of the top layer multiply prodigiously. Following the first two phases of blooming and peeling, the third one, that of floating originates further alteration in the mat *sensu lato*: first of all, the surficial layer forms now a sort of outer integument where the filaments grow parallel to the horizontal plane of the floating mass; secondly, in older colonies, the underlying mud acquires a stratified pattern in which three main laminae can be recognized; the original mud just beneath the mat, an underlying black layer rich in bacteria and reduced organic constituents (namely of algal origin) and finally a gray layer resulting from the re-oxygenation of the lowermost part of the black layer suddenly carried into oxidizing environments after peeling.

The process stops after a few weeks or less when the algal bloom fades away; at that moment, fragments of mats and adhering mud sink and pile up on the bottom of the lake or lagoon.

When the peeling process affects large algal mats, it is most probably enhanced by the accumulation of bacterial CO₂ and/or H₂S beneath the mat; indeed, the underlying mud looks definitely black (cfr. Fig. 26); it is crowded with bacteria and releases a strong odor of sulfur. Experiments conducted by PHILLIPS (1963) show that the pH at this level and in the released bubbles is around 7 or less, whereas that of the overlying water is around 8. Such chemical conditions account for significant solution of calcium carbonate beneath the mat (and the relative enrichment of the substratal mud in organic matter) while important precipitation keeps on around the top filaments and in the mat itself¹⁰⁾. There is accordingly a recycling of the carbonate in the environment, process which somewhat inhibits the rapid formation of important deposits; solution and bacterial action destroys the buried structures and prevents the preservation of laminated deposits that would result from the piling up of successive seasonal mats; flotation and disruption of continuous mats acts in the same way.

Such chemical processes seem to be most active under subcontinuous mats growing in shallow standing waters, but not on the algal flat proper, at least there where the algal heads do grow; the discontinuity between the domes probably favors a better circulation of the lake water bathing the stromatolites and their muddy basement; furthermore, if black layers would form they would probably be reoxygenated during the dry season when the algal structures suffers some shrinking.

⁹⁾ These are replaced by *Lyngbya* and/or *Spirulina* in marine settings, the former in salinities greater than 27‰, the latter favoring salinities between 20–25‰ (PHILLIPS, 1963).

¹⁰⁾ These simultaneous phenomena are very similar to the ones described by GOLUBIČ (1962) to account for the formation of "Fürchensteine" or pitted rocks under algal crusts in the Yugoslavian Karst.

This accounts for the fact, that although at given places the stromatolitic domes rest on a brownish black mud, most of the deposit overlies a white very fine calcitic mud in which the lamination extends.

The peeling of blooming mats and the associated phenomena reveal fundamental processes that should be kept in mind in paleoecological and morphological studies of stromatolites. These processes, operating in very quiet environments under the control of plain organic activity may completely disrupt stromatolitic deposits and induce various modifications in the algal structures. The consequences of the peeling and fragmentation of subcontinuous mats are at least threefold:

(1) Big "scars", that would surely appear as erosional traces in the fossil record, are left in the "mother deposit" when important portions of mat tear away (Fig. 26).

(2) The resulting floating aggregates, when sinking to the bottom after the period of bloom, originate a chaotic piling up of "clasts" ranging in size from a few centimeters to a few decimeters; such deposits would probably be interpreted in the fossil record as resulting from important mechanical action of waves or tides, and a very different set of environmental conditions would be erroneously reconstructed.

(3) As previously said, floating aggregates acquire a new internal structure and/or lamination resulting from the new life and biochemical conditions into which the algal mat and its adhering substrate are suddenly carried; these modifications will of course increase with the duration of surficial drift. Accordingly, the formation of floating aggregates does not only disrupt and "recombine" a stromatolitic deposit but may induce a proper differentiation of the mats which is not typical of the bottom conditions where the aggregates come from or will sink.

As far as the individual heads crowding the algal flat are concerned, we have seen that small scale peeling (Fig. 21) could also originate conspicuous scars at the surface of the stromatolite; these scars will be fossilized by discordant overgrowths of forthcoming seasonal layers. The frequency of these features joined to the presence of upsidedown resedimented domes (Fig. 24) would undoubtedly lead, in the fossil record, to an erroneous reconstruction of turbulent settings.

Finally, individual algal heads, when sinking after the bloom, may pile up against any irregularity of the lake floor or on previously sunk domes: this results in the building up of small mounds that might be interpreted as biohermal, i. e. constructional, instead of "detrital" accumulations.

The facts and hypotheses reported in this note were meant (1) to describe fresh water blue-green algal biostromes in process of formation, and to frame them in the subcontinuous series of algal deposits found across Andros Island and adjacent marine platforms. (2) To widen the scope at the light of the processes known in both marine and fresh water settings so that a sort of philosophy concerning the ecological, distributional and morphological interpretation of stromatolites and mats could be tentatively proposed; these concepts will be developed elsewhere. An attempt was made, in the discussions and comments, to show the tremendous importance of life processes in the intimate organization, shaping, distribution and alteration of stromatolitic deposits and to balance these processes with environmental physical ones.

All the small-scale processes and factors responsible for the given features and behaviour of a stromatolitic flat, as well as the complex flow of biological, social, chemical . . . phenomena within a simple algal dome or mat have always frightened me when I consider the simple (too simple!) resulting laminated structures that the paleontologist has to study; I wonder then how much of the natural history of a stromatolite is left in the thin compacted residual laminae found at the base of a Recent deposit (Figs. 13, 22); how much then in a fossil stromatolite? Well, very little most probably. But we shall miss or misunderstand this "very little message" if we do not know the rules of the game, if we do not know where the message might well come from, if we do not analyze it in full detail, if we do not sharpen our concepts. To this purpose, the Present may be a key to the Past provided:

(1) we have a good critical knowledge of the present processes at every single level of organization

(2) we dig out from the right present the right key to the right, analogous or homologous Past.

Bibliography

- BAAS-BECKING, L. G. M., KAPLAN, I. R., MOORE, D.: Limits of the natural environments in terms of p_H and oxydo-reduction potentials. — *Journ. of Geology*, **68**, No. 3, 243—284, 1960.
- BATHURST, R. G. C.: Subtidal gelatinous mat, sand stabilizer and food, Great Bahama Bank. — *Journ. Geology*, **75**, 736—738, 1967.
- BAUMAN, E.: Die Vegetation des Untersees (Bodensee). *Archiv Hydrobiol. und Planktonkunde Suppl.-Bd. I*, 26—48, 1911.
- BLACK, M.: The algal sediments of Andros Island, Bahamas. — *Royal Soc. London Philos. Trans. Ser. B*, **222**, 165—192, 1933.
- BLUM, J. L.: The ecology of River algae. — *Bot. Review*, **22**, 291—341, 1956.
- : Algal population in flowing waters. — In: "The ecology of algae" Sp. publ. No. 2, Pymatuning Lab. of Field Biology. Univ. of Pittsburg, 11—21, 1960.
- BRADLEY, W. H.: Fresh water algae from the Green River formation of Colorado. — *Torrey Bot. Club*, **56**, p. 421—428, 1929.
- : Algal reefs and oolites of the Green River formation. — *U.S.G.S. Prof. pap.*, **154 C**, 203—223, 1929.
- BREHM, V., & RUTTNER, F.: Die Biozönosen der Lunzer Gewässer. — *Int. Rev. d. ges. Hydrogr. und Hydrob.*, **16**, 1935.
- CAYEUX, L.: Roches carbonatées. — Masson ED., Paris 1935.
- CERDERGEN, G. R.: Reofilia eller det rinnande vattnets algsamnällers. — *Svensk Bot. Tidskr.*, **32**, 362—373, 1938.
- CLARKE, J. M.: The water biscuits of Squaw Island, Canandaigua lake, N.Y. — *Bull. N.Y. State Mus.*, **8**, No. 39, 195—198, 1900.
- CHODAT, R.: Communication préliminaire sur les algues incrustantes et perforantes. — *Arch. Sc. Phys. et Nat. Genève*, **512**, 1897.
- COLOM, G.: La paléocéologie des lacs du Ludien-Stampien inférieur de l'île de Majorque. — *Revue de Micropaléontologie*, **4**, **1**, 17—29, 1961.
- DAVIES, G. R.: Algal-laminated sediments, Gladstone Embayment, Shark Bay, Western Australia. — In: Carbonate sedimentation and environment, Shark Bay, Western Australia. A.A.P.G. Memoir, **13**, Tulsa, Oklahoma, 169—205, 1970.
- DECKSBACH, N. K.: Zur Kenntnis einiger sub- und elitoraler Algen Assoziationen rüsicher Gewässer. — *Arch. f. Hydrobiol.*, **17**, **3**, 492—500, 1926.

- DESKACHARY, T. V.: Cyanophyta. — Indian Council of Agricultural Research. New Delhi, 1959.
- DONALDSON, J. A.: Stromatolites in the Denault formation Marion Lake, coast of Labrador, Newfoundland. — Geological Survey of Canada. Dpt. of Mines and Technical Surveys. Bulletin, **102**, 28 p., 2 figs., 7 pls. 1963.
- DROUET, F.: Ecophenes of *Schizothrix calcicola*. — Proceeding of the Acad. Nat. Sc. of Philadelphia, **115**, No. 9, 261—281, 1963.
- EGGLETON, F. E.: Limnology of a meromictic interglacial Plunge-basin lake. — Amer. Microsc. Soc. Transact., **75**, 334—378, 1956.
- ECHLIN, P.: The Blue-Green Algae. — Scientific American, **214**, No. 6, 74—81, 1966.
- FOREL, F. A.: Le Léman. — Monographie limnologique, 3, Lausanne — F. Rouge Edit., 1902.
- FREYET, P., & PLAZIAT, J.-C.: Importance des constructions algaires dues à des Cyanophycées dans les formations continentales du Crétacé supérieur et de l'Eocène du Languedoc. — Bull. Soc. Géol. de France (7), VII, 679—694, 1965.
- FRITSCH, F. E.: The encrusting algal communities of certain fast flowing streams. — New Phytol., **28**, 3, 165—196, 1929.
- : The lime encrusted Phormidium community of British streams. — Int. Verein für theor. und angewandte Limnologie, Verhandlungen, **10**, 141—144, 1949.
- : Algae and calcareous rocks. — The advancement of Sci., **7**, 25, 57—62, 1950.
- FRITSCH, F. E., & PANTIN, C. F. A.: Calcareous concretions in a Cambridgeshire stream. — Nature, **156**, No. 3987, 397—398, 1946.
- GARRETT, P.: Phanerozoic stromatolithes: Noncompetitive ecologic restriction by grazing and burrowing animals. — Science, **169**, 171—173, 1970.
- GEITLER, L.: Cyanophyceae (Blaualgen) Deutschlands, Österreichs und der Schweiz mit Berücksichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiete. — Rabenhorst's Kryptogamen — Flora — XIV. Band. Akademische Verlagsgesellschaft m. b. H., Leipzig.
- GEBELEIN, C. D.: Distribution, morphology and accretion rate of recent subtidal algal stromatolites. — Bermuda. Jour. Sedim. Petr., **39**, 32—49, 1969.
- GLAZEK, J.: Recent oncolites in streams of North Vietnam and of the polish Tatra Mounts. — Ann. Soc. Geol. Pol., **35**, 2, 221—242, 4 pls., 3 figs., 1965.
- GINSBURG, R. N.: Ancient analogues of recent stromatolites. — Int. Geol. Congress. XXI Session, Norden, Part XXII, 26—35, 1960.
- GINSBURG, R. N., ISHAM, L. B., BEIN, S. J., & KUPFERBERG, J.: Laminated algal sediments of South Florida and their recognition in the fossil record. — The marine laboratory, University of Miami (unpublished) 1954.
- GOLUBIĆ, S.: Zur Kenntnis der Kalkinkrustation und Kalkkorrosion im See Litoral. — Schweiz. Zeitschr. f. Hydrol., **24**, 2, 229—243, 1962.
- : Algenvegetation der Felsen. — Die Binnengewässer. Bd. XXIII. — E. Schweizerbart'sche Verlagsbuchhandlung (Nägeller und Obermiller) Stuttgart, 183 p., 1967.
- GRUNINGER, W.: Recent Kalktuffbildung im Bereich der Uracher Wasserfälle. — Abh. Karst- u. Höhlenk. — München, Reihe E (Bot), **2**, 113 S., 1965.
- HOWE, M. A.: The geologic importance of the lime secreting algae. — U.S.G.S. Professionnal Paper, **170**, 57—64, 1931.
- HURTER, E.: Beobachtungen an Litoralalgen des Vierwaldstätter Sees. — Mitt. a. d. Hydrobiol. Lab. Kaataneienbaum b. Luzern, X. Heft, 1928.
- IRION, G., & MÜLLER, G.: Mineralogy, Petrology and chemical composition of some calcareous Tufa from the Schwäbische Alb, Germany. — In: "Carbonate sedimentation in Central Europe", Müller, G., and Friedman, G. M. Ed., Berlin, Heidelberg, New-York (Springer), 157—171, 1968.
- ILLING, L. V.: Bahama calcareous sands. — Am. Ass. Petrol. Geol. Bull., **38**, 1—95, 1954.

- JOHNSON, J. H.: Algae as rocks builders with notes on some algal limestones from Colorado. — Univ. of Colorado Studies, **23**, No. 3, Colorado (Boulder) 1936.
- : Algae and algal limestone from the Oligocene of South Park, Colorado. — Bull. of the Geol. Soc. of America, **48**, 1227—1236, 2 pls., 1 fig., 1937.
- KANN, E.: Zur Ökologie des litoralen Algenaufwuchses im Lunzer Untersee. — Int. Rev. d. ges. Hydrogr. Hydrobiologie, **28**, 1933.
- : Ökologische Untersuchungen an Litoralgen ostholsteinischer Seen. — Arch. f. Hydrobiol., **37**, 2, 178—269, 1940.
- : Cyanophyceenkrusten aus einem Teich bei Abisko (Swedisch Lappland). — Arch. Hydrobiol., **37**, 4, 495—503, 1941 a.
- : Krustensteine in Seen. — Arch. f. Hydrobiol., **37**, 4, 504—532, 1941 b.
- KENDAL, C. G. St. C., & SKIPWITH, Sir PATRICK A. d'E. Bt.: Recent algal mats of a Persian Gulf Lagoon. — Journ. of Sedim. Petrol., **38**, 4, 1040—1058, 1968.
- KORDE, N. V.: Deposits of Blue-Green algae in sapropel lakes. — Dokladi Akad. Nauk. SSSR, **58**, 1947.
- : Blue-green algae as sources of sapropel deposits. Pt. 1: Blue-green algae in sediments of Transural Lakes. — Trudy Lab. Sapropel. Otlozhenii, 1950.
- : Biostratification and classification of Russian sapropels. — Izdatel'stvo Akademiya Nauk. SSSR. Moscow 1960.
- LAUTERBORN, R.: Die Kalksinterbildungen an den unterseeischen Felswänden des Bodensees und ihre Biologie. — Mih. Bad. Landesver. Naturk. u. Naturschutz in Freiburg, **1**, H. 8, 1922.
- MAWSON, D.: Some South Australian algal limestones in process of formation. — Quart. Jour. Geol. Soc. London, **85**, 4, 613—620, 1929.
- MONTY, C. L.: Biostromes stromatolithiques dans le Viséen moyen de la Belgique. — C. R. Acad. Sc., **256**, 5603—5606, 1 fig., 1963.
- : Recent algal stromatolites in the Windward Lagoon, Andros Island, Bahama. — Ann. Soc. Géol. Belgique, Bull., **88**, 6, B, 269—276, 1965 a.
- : Geological and environmental significance of Cyanophyta. — Ph. D. Thesis, 429 p., 89 pls., 42 figs. Princeton University, N.J., USA, Microfilm No. 66 — 5003 Univ. Microfilm Inc. Ann Arbor, Michigan 1965 b.
- : Distribution and structure of recent stromatolitic algal mats, Eastern Andros Island, Bahama. — Ann. Soc. Géol. Belgique, **90**, 3, 55—100, 19 pls., 13 figs., 1967.
- : An autoecological approach of intertidal and deep water stromatolites. — Ann. Soc. Géol. Belgique, **94**, 265—276, 4 figs., 1971.
- : The Phanerozoic history of stromatolite communities. — Ann. Soc. Géol. Belgique, 1972 (in press).
- MÜLLER, G.: Exceptionally high strontium concentrations in fresh water onkolites and mollusk shells of Lake Constance. — In: "Carbonate sedimentology in Central Europe. — Müller, G., and Friedman, G. M., Ed., Berlin, Heidelberg, New York (Springer) 1968, 116—127.
- MURRAY, G.: Calcareous pebbles formed by algae. — Phycological Memoirs, pt. III, 73—77, London 1895.
- NAUMAN, E.: Untersuchungen über einige sub- und elitorale Algen-Assoziationen unserer Seen. — Archiv f. Botanik, **19**, 16, 1—30, 1925.
- NEUMANN, A. C., GEBELEIN, C. D., & SCOFFIN, T. P.: The Composition, structure, and erodability of subtidal mats, Abaco, Bahamas. — Journ. of Sedim. Petrol., **40**, 1, 274—297, figs. 1—8, 1970.
- NEWELL, N. D., & RIGBY, J. K.: Geological studies on the Great Bahama Banks. — p. 15—73 in: Le Blanc, R. S., and Breeding, J. G., eds., Regional aspects of carbonate sedimentation. Soc. Econ. Paleontologists Mineralogists, Spec. Pub. 5, 178 p., 1957.

Aufsätze

- OBERDORFER, E.: Lichtverhältnisse und Algenberiedlung im Bodensee. — ZS. Bot., **20**, 10/11, 1928.
- PHILLIPS, R. C.: Floating communities of algae in a North Carolina pond. — Ecol. **49**, 465—766, 1958.
- : Ecology of floating algal communities in Florida. — Quart. Jour. Flor. Acad. Sces., **26**, 4, 329—334, 1963.
- PIA, J.: Pflanzen als Gesteinsbildner. — 355 S., Berlin (Gebrüder Bornträger) 1926.
- : Die rezenten Kalksteine. — Z. f. Krist. Mineral. u. Petrol. Mitteil. Ergänzungsbd. Abt. B, 420 S., 1933.
- POLLOCK, J. B.: Blue-green algae as agent of deposition of Marl in Michigan Lakes. — Michigan Academy of Sciences XXth report, 247—260, 1918.
- PURDY, E.: Recent calcium carbonate facies of the Great Bahama Bank. 1. Petrography and reaction groups. — J. of Geol., **71**, 3, 334—355, 1963 a.
- : Recent calcium carbonate facies of the Great Bahama Bank. 2. Sedimentary Facies. — J. of Geol., **71**, 4, 472—497, 1963 b.
- RODDY, H. J.: Concretions in streams formed by the agency of Blue-green algae and related plants. — Proc. Amer. Phil. Soc., **54**, 246—258, Philadelphia 1917.
- RUTTE, E.: Die Algenkalke aus dem Miozän von Engelwies in Baden. — Neues Jb. Geol. u. Paläontol., Abh., **98**, 2, 149—174, 1953.
- SCHMIDLE, W.: Postglaziale Ablagerungen im nordwestlichen Bodenseegebiet. — Neues Jb. Mineral., **II**, 104—122, 1910.
- SCHOLL, D. W., & TAFT, W. H.: Algal contributors to the formation of calcareous Tufa, Mono Lake, California. — Journ. Sed. Petr., **34**, 2, 309—319, 1964.
- SCHÖTTLE, M.: Die Sedimente des Gnadensees. Ein Beitrag zur Sedimentbildung im Bodensee. — 104 p., Diss., Heidelberg.
- SCHÖTTLE, M., & MÜLLER, G.: Recent carbonate sedimentation in the Gnadensee (Lake Constance), Germany. — In: "Carbonate sedimentology in Central Europe". Müller, G., and Friedman, G. M., Ed., Berlin-Heidelberg-New York (Springer) 1968, 148—156.
- SCOFFIN, T. P.: The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. — Journ. of Sedim. Petrol., **40**, 249—273, figs. 1—28, 1970.
- SEWARD, A. C.: Fossil plant. — (Quoted by Cayeux, 1935.)
- SHINN, E. A., LLOYD, R. M., & GINSBURG, R. M.: Anatomy of a modern carbonate tidal-flat, Andros Island Bahamas. — Journ. of Sedim. Petrol., **39**, 3, 1202—1228, figs. 1—37, 1969.
- STIRN, A.: Kalktuffvorkommen und Kalktufftypen der Schwäbischen Alb. — Abh. Karst- u. Höhlenk., München, Reihe E (Bot.), **1**, 92 p., 1964.
- SYMOENS, J. J.: Note sur des formations de tuf calcaire dans le bois d'Hautmont (Wauthier-Braine). — Bull. Soc. Roy. Bot. Belgique, **82**, 81—95, 1949.
- SYMOENS, J. J., DUVIGNEAUD, P., VAN DEN BERGEN, C.: Aperçu sur la végétation des tufs calcaires de la Belgique. — Bull. Soc. Roy. Bot. Belgique, **83**, 329—352, 1951.
- SYMOENS, J. J., & MALAISSE, F.: Sur la formation de tuf calcaire observée sur le versant Est du plateau des Kundlungu. — Acad. Roy. des Sces d'Outre-Mer. des Séances, 1967-6, p. 1148—1151, 1967.
- TILDEN, J. H.: Some new species of Minnesota algae which live in a calcareous or siliceous matrix. — Bot. gaz., **23**, 7—9, 95—104, 1897.
- ULRICH, FR.: Über die Wachstumsform des organogenen abgeschiedenen Kalkspates und ihre Beeinflussung durch das Kristallisationsmedium. — Z. f. Kristallographie, **66**, 513—514, 1927.
- WALCOTT, C. D.: Pre-Cambrian algonkian algal flora. — Smithsonian Misc. Coll., **64**, 77—156, pls. 4—23, 1914.

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- WALLNER, J.: Zur Kenntnis des unter pflanzlichem Einfluß gebildeten Kalkspates. — *Planta Archiv f. Wissenschaft. Botanik*, **23**, 51—55, 1934.
- : Zur Kenntnis der Kalkbildung in der Gattung *Rivularia*. — *Beih. z. Bot. Zbl.*, **54**, Abt. A, 1935.
- WOROCHIN, N. N.: Zur Biologie der bittersalzigen Seen in der Umgebung von Pjatigorsk (nördl. Kaukasus). — *Arch. f. Hydr., Hydrobiol.*, **17**, 628—643, 1926.