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## THALLOPHYTE BORING AND MICRITIZATION WITHIN SKELETAL SANDS FROM CONNEMARA, WESTERN IRELAND<sup>1</sup>

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**ABSTRACT:** Carbonate grains from the skeletal sands off the western Irish coast of Connemara (53°N latitude) are extensively bored by thallophytes, yet the borings, unlike those in warm-sea sediments, are not associated with cryptocrystalline carbonate (micrite). On the other hand, *living Lithothamnium* colonies and *Lithothamnium* fragments frequently have their cell cavities filled by high Mg-calcite micrite and, less commonly, parts of the algal skeleton may be micritized. In living colonies, the micrite is often confined to certain growth lamellae of the red alga.

The presence of micrite as a void filler or as a replacement of preexisting carbonates is indicative of environments capable of precipitating metastable cements. The environments of precipitation may be depositional or post-depositional. All available evidence favors a biochemical precipitation mechanism in the micritization of the red algal skeletons, brought about essentially by the life activities of the organism. In the light of the present study, the significance of micritized grains within carbonate sediments is re-examined.

### INTRODUCTION

The occurrence of cryptocrystalline carbonate micrite within skeletal and non-skeletal grains of Recent carbonate sediments and their ancient equivalents is widespread (Bathurst, 1966, 1971; Land, 1967; Winland, 1968; Fuchtbauer, 1969; Bricker, 1971; Ginsburg, *et al.*, 1971, and Alexandersson, 1969, 1972, 1974). It is noticeable, however, that almost all records of this phenomenon within Recent carbonate sediments are from tropical or warm temperate environments. The only exception is a study by Alexandersson (1974), who described cementation processes in coralline algal nodules from the Skagerrak, North Sea, where biochemical precipitation occurs in undersaturated waters.

The micrite may be restricted to the outermost rims of grains, thus creating the familiar micrite envelopes (Bathurst, 1966), or it may replace the whole grain. The formation of rounded and homogeneous carbonate grains ("peloids") by a combination of abrasion and micritization has been demonstrated by many authors who have described the transitions occurring between this grain type and many types of unaltered grains (Illing, 1954; Purdy, 1968; Kendall and Skipwith, 1969).

The micrite is commonly associated with algal

bores. Bathurst (1966) has suggested a mechanism to account for the micrite envelopes which involves repeated boring of grains by algae and the filling of the empty bores by micrite. The widespread association between algal boring and micritization has commonly been interpreted as a cause and effect phenomenon, despite Bathurst's (1966) statement that the processes by which empty algal bores are filled is unknown. Alexandersson (1972) believes that no organisms take part directly in the precipitation within the voids and the micritization process is regarded as a form of marine cementation. Also, where the level of carbonate saturation is low the borings remain empty.

Micritized grains are common and widely distributed within tropical and warm temperate carbonate environments, and record an equally widespread diagenetic phenomenon, probably the most important diagenetic phenomenon that occurs in shallow water carbonate sediments. The mechanisms leading to the formation of cryptocrystalline carbonates in skeletal carbonate sediments off Connemara will be described in this paper, thus recording this phenomenon from an area of cold temperate *supersaturated* seawaters. A supersaturation state approaching almost 300% with respect to CaCO<sub>3</sub> needs to be emphasized especially in view of some recent work tending towards the view that, even in tropical shallow waters the level is somewhat lower than this (Bathurst, pers. comm.).

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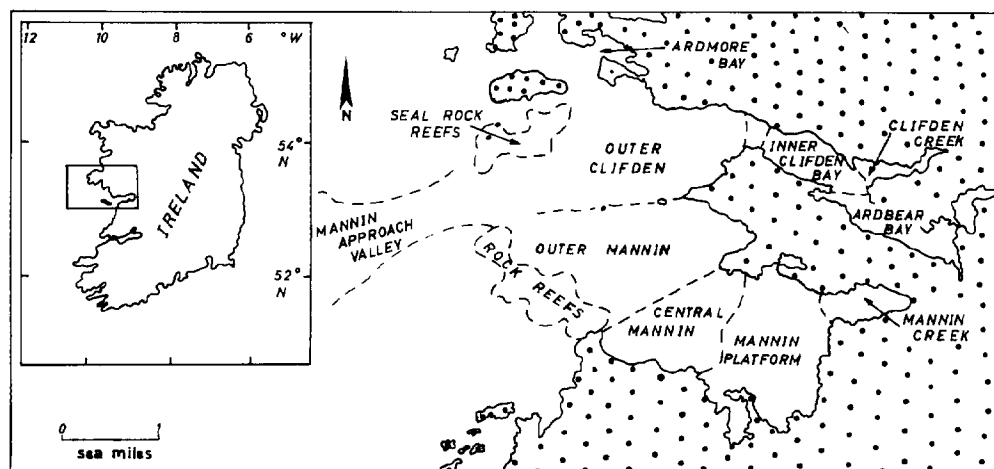


FIG. 1.—Location of study area in western Ireland. The dashed lines represent facies boundaries and depth zones.

#### MATERIALS AND METHODS

The sediment samples were collected either with a Van Veen type grab sampler or by SCUBA diving. The samples were thoroughly washed until free of chloride, dried and embedded in a slow setting epoxy resin in a vacuum desiccator. Thin sections were made for microscopic examination and for staining in the identification of carbonate minerals and organic matter.

The composition of the unaltered and micritized skeletal materials were determined by standard X-ray diffraction methods (Gunatilaka, 1975). Several successive and serial microtome sections were made of the red algal colonies and the mineralogy of each section was separately determined. Some of these sections passed through the micritized growth lamellae of the alga. The magnesium content of the high Mg-calcites was also accurately determined by atomic absorption analysis and confirmed the values obtained by X-ray methods.

The seawater was collected by using a NIO sampler which also simultaneously recorded the sea floor water temperature. Salinity was determined by silver nitrate titration and the alkalinity and supersaturation states were calculated according to the method outlined by Strickland and Parsons (1965). The salinity varied from 34.39‰ to 34.79‰ and the water temperature from 11°C to 14°C for the warmest months. The seawater was found to be supersaturated with respect to  $\text{CaCO}_3$  by almost 300%. Comparison of saturation states between different carbonate regions and environments

is somewhat problematical because of the non-standardization of measurement techniques and calculation procedures. Even allowing for such uncertainties, the Connemara seawaters were surprisingly in a state of supersaturation.

#### SETTING AND GENERAL FEATURES OF THE CONNEMARA SEDIMENTS

The location of the study area is shown in Fig. 1. The skeletal sediments, all sands and gravels were collected from water depths of 0–54 m. No major rivers enter the bays and the carbonate sediments are largely skeletal material derived from within the basin of deposition. The region is a cold temperate environment, situated at about 53°N latitude.

Gravels and sands composed largely of *Lithothamnium calcareum* fragments are forming upon a platform situated within the more sheltered parts of Mannin Bay. This platform is commonly covered by a dense growth of the seagrass *Zostera*. Farther offshore, the *Lithothamnium* fragments give way to molluscan and other skeletal sands or gravels.

The sediments have been studied from two main aspects: (1) the occurrence of thallophtye borings in calcareous grains, and (2) the occurrence of micrite fillings in *Lithothamnium* grains.

#### THALLOPHYTE BORING WITHIN SKELETAL GRAINS

In the present study more than 100 sediment samples have been examined and all contained bored grains. The skeletal grains are mainly

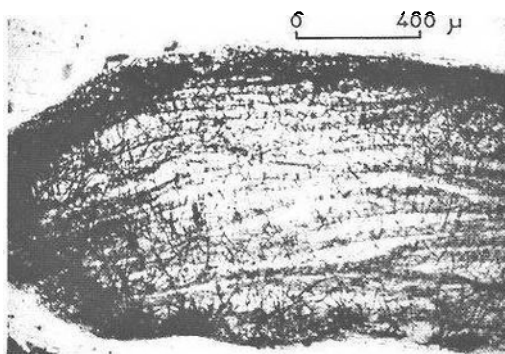


FIG. 2A.—Exclusively fungal borings in a molluscan shell fragment, collected from a water depth of 41 m.

derived from mollusca, barnacles, red algae, foraminifera, bryozoa, ostracods, echinoderms, and their spines. Almost all coarse sand samples have all grain types bored, but within fine sand samples many of the grains lack borings. The borings within fine sand grains originate from a single grain surface, and other surfaces may truncate or lie along the borings. Fine sand or silt grains bored on all surfaces are uncommon or absent in most samples. It is concluded that these fine-sized grains are not attacked by borers, and those borings that do occur within them were constructed within coarser grains, which were subsequently broken into finer fragments. It appears that the activities of the boring organisms were a major contributory factor in the weakening of the skeletons and thus, indirectly, to the production of fine sand grains. The importance of this process was studied in detail by Ginsburg (1956), in a pioneering study from the Florida Bay region. This points to the important fact that de-

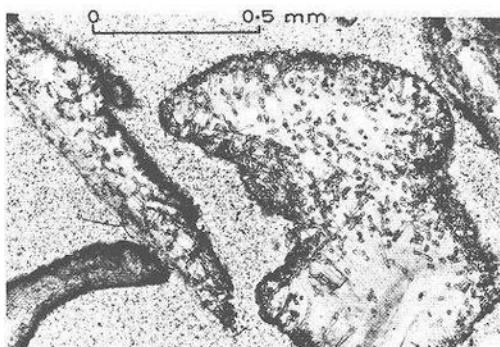


FIG. 2B.—Exclusively algal borings in molluscan shell fragments collected from a water depth of 2 m.

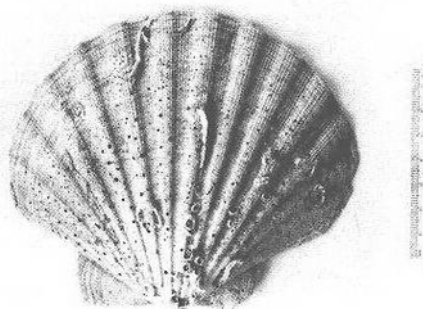


FIG. 2C.—Large bores made by sponges, annelids or bryozoa. Scale = 7.5 cm.

spite regional differences, biological breakdown can result in similar end products.

Four main types of borings may be distinguished in the Connemara sediments (see Bathurst, 1971, page 382 for identification criteria).

- (1) *Fungal* (Fig. 2A). Slender, thread-like bores, up to 5  $\mu$ m in diameter which branch dichotomously or irregularly.
- (2) *Algal* (Fig. 2B). Sinuous finger-like bores which commonly diverge from a single opening. About 10  $\mu$ m in diameter.
- (3) *Possibly Algal*. Similar to (2), but the bores tend to be parallel with the grain surface and when abraded may resemble cup-like depressions. About 15–20  $\mu$ m in diameter.
- (4) *Large Irregular Bores* (Fig. 2C). Up to 1 mm in diameter, possibly constructed by clionid sponges, polydroid annelids or bryozoa and similar to those reported by Fütterer (1974).

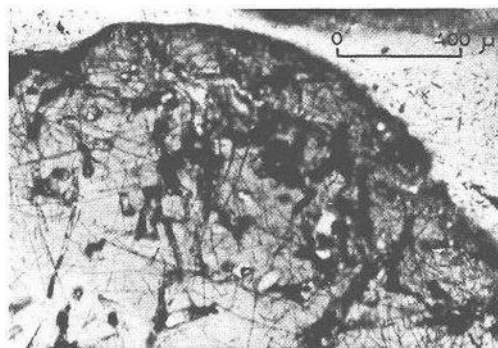


FIG. 2D.—Large algal, and fungal borings occurring together in a molluscan fragment, collected from a water depth of 13 m.

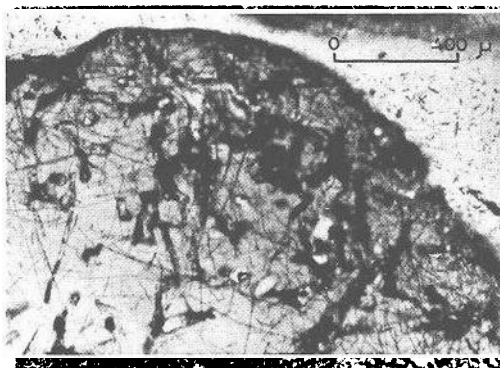


FIG. 2E.—A large, empty algal boring within a *Lithothamnium* fragment. The area to the left of the boring has been heavily micritized and altered with parts of the original red-algal skeleton still visible through the micrite. The area to the right of the boring remains unaltered and still retains the mosaic pattern of the compartments. Collected from a water depth of 1 m.

Type (1) often infests types (2) and (3) as shown in Fig. 2D. Only type (4) and the largest algal borings (15–20  $\mu\text{m}$ ) occur within the red-algal grains, as shown in Fig. 2E. The fungal and smaller algal borings are presumably excluded by the algal skeleton. Echinoderm grains, in contrast, are bored chiefly by the fungi and the borings are confined to the more massive parts of the spines (Fig. 2F).

It has not been possible to detect a systematic decrease in the extent of grain borings with increasing water depth, but within samples collected from water depths greater than 25–30 m, algal bores are considerably decreased and the fungal bores become predominant (Fig. 2A). This is in agreement with the observations of Perkins and Halsey (1971).

The borings are sometimes exclusively concentrated around the grain periphery, giving the appearance of an envelope (Fig. 3A). They have, however, never been found to contain micrite. They may be (i) empty, (ii) filled with organic matter, or (iii) lined by black coatings of unknown composition. Similar, heavy black coatings are frequently found within *Lithothamnium* cavities (Fig. 3B). The organic fills are resistant to attack by mild acids, but completely disappear on treatment with oxidizing agents. Commonly, the organic fills of bores are contiguous with the organic coats that envelope the grains. These grains appear identical with those reported from the sediment grains in the Persian Gulf region (Kendall and Skipwith, 1969).

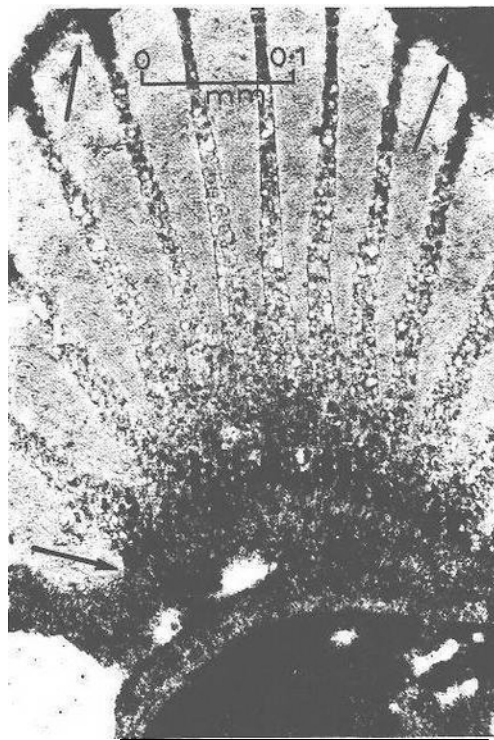


FIG. 2F.—Fungal borings (arrows) in the massive parts of an echinoid spine. The micrite is confined mainly to the stereom (central parts). Note that the borings are not present at all in the micritized area. Thin section of a presently forming and lithified *Lithothamnium* sand.

#### MICRITE WITHIN LITHOTHAMNIUM GRAINS

The characters of red-algal grains are variable, both within samples and within grains. In some grains the algal skeleton appears unaltered, and is transparent in thin section. The cellular cavities occur in the same states as the thallophyte borings, that is, (i) they may be empty, (ii) occupied by brownish organic material, and (iii) lined with dense black organic coatings (Fig. 3B). In other grains the cell cavities are filled with a high Mg-calcite micrite containing 11–13 mole percent  $\text{MgCO}_3$ , often giving the appearance of a mosaic (Fig. 2E).

The tissue of coralline algae is differentiated into two basic skeletal layers: the hypothallium made of elongated cells or compartments that initially grow horizontally and the perithallium composed of vertically elongated cells. Several of these hypothallium-perithallium layers are seen in a mm thick algal crust. Commonly, the skeletal compartments filled with micrite occur

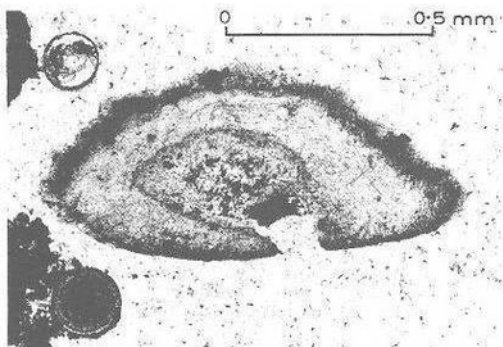


FIG. 3A.—Unfilled thallophyte borings confined to the periphery of a shell fragment, giving the appearance of an envelope. 16 m water depth.

in distinct layers within the skeleton (Fig. 3C). Under high magnifications it is apparent that only the smaller compartments are generally filled. The average size of such compartments is about 25–50  $\mu\text{m}$ . The micrite cement is particularly common just below the hypothallial layers and in the earlier formed layers of perithallium. Because cementation is considered to be a growth phenomenon and the micrite is distributed between successive skeletal laminae, the term *growth lamellae* is proposed for the micritized layers.

In some grains, the micrite occurs in randomly distributed regions, each 10–15 compartments across. In rare cases, the micrite fills almost all the cells with the exception of the outer 2–3 growth layers. In grains where a large part of the skeleton has micrite filled cavities, the entire skeleton appears brownish and cryptocrystalline, and indistinguishable from the compartment

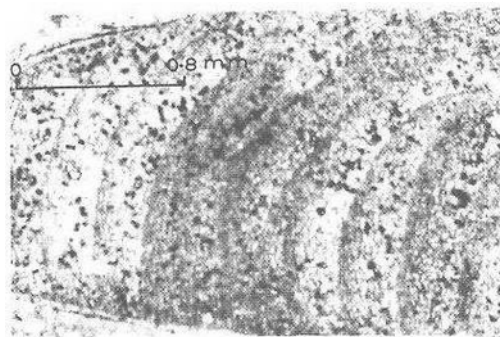


FIG. 3B.—*Lithothamnium* compartments filled with a dark colored organic material, collected from a water depth of 1 m in a reducing zone in the inner parts of Mannin Creek.

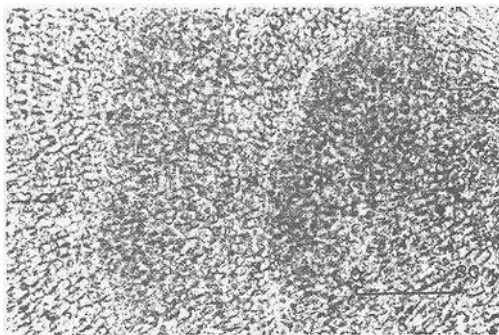


FIG. 3C.—Compartments containing micrite (darker areas) are confined mainly to the growth lamellae of the red alga. The alternating lighter areas are devoid of any micrite. Section from a *Lithothamnium* colony collected in growth position from Mannin Platform.

fills. In extreme cases, the skeletal microstructure is no longer discernible and the grain area is converted to a randomly orientated aggregate of brownish micrite crystals (Fig. 2E). It is apparent that two distinct types of cryptocrystalline carbonate occur within these red-algal skeletons; one a void filler, the other a skeletal replacement.

#### DISCUSSION

Within the Connemara sediments, the occurrence of micrite is markedly grain selective and is confined to the *Lithothamnium* skeletons. The absence of micrite fillings within extensively bored skeletal grains in general, and its occurrence within *Lithothamnium* grains where it is not associated with borings, suggests that boring organisms do not take part in this form of micritization. This conclusion, that the removal of algal filaments from bores is not necessarily connected with their later infilling by carbonate, agrees with the recent observations of Alexandersson (1972, 1974).

It has been suggested that the micrite might be precipitated as a byproduct of the metabolic activities of certain bacteria (Bathurst, 1966; Purdy, 1968; Kendall and Skipwith, 1969). In this context, it is still difficult to explain why the bores within the Connemara sediments have not been filled with micrite (remembering that the Connemara seawaters are supersaturated with respect to calcium carbonate).

It is significant that most records of micritization are from environments where the seawater appears to be supersaturated with  $\text{CaCO}_3$ . This association suggests that both void filling

and replacive types of cryptocrystalline carbonate are cements, and that their presence is indicative of environments in which carbonate precipitation is possible.

That the void filling micrite in general is a cement has been demonstrated several times (Ginsburg, *et al.*, 1971; Alexandersson, 1972, 1974, and Schröder, 1972). In this special case it is thought that the restriction of micrite to red-algal grains, the common occurrence of micrite along the growth lamellae of the red algae, and its absence from compartments adjacent to actively growing surfaces, are evidence that micritization occurred while the red algae was living, and is the product of its metabolic activities. In this explanation, micrite is precipitated within the dead central portions of its skeleton from water whose chemistry has been markedly affected by the life activities of the living outermost layers of the *Lithothamnium*, thus emphasizing the importance of the micro-environment in the micritization process. The process is very similar to red-algal cementation of *Lithophyllum corniche* in the Mediterranean (Alexandersson, 1969). The idea of internal biochemical precipitation has been advanced by Gunatilaka (1972) and Alexandersson (1974) and is also supported by the data of Eutsler (in prep.) and the experimental investigations of Towe and Malone (1970). From the Connemara and Skagerrak examples it appears that: (i) irrespective of the state of saturation of the seawater, a biochemical "triggering effect" is probably operative in this form of micritization within the red algae, and (ii) in supersaturated and undersaturated seawaters of cold temperate regions, boring and micritization are unrelated processes.

It is interesting to note that the micrite cement and the substrate (host skeleton) have apparently the same mineralogy and about the same Mg content. Alexandersson (1972) reports that the mineralogy of intergranular secondary carbonate is predominantly host controlled in warm seawaters supersaturated with  $\text{CaCO}_3$ , and in the absence of host control, the mineral form is predominantly aragonite micrite. Similar conditions occur in the *Lithothamnium* rhodoliths in the Skagerrak (Alexandersson, 1974). Mg-calcite cements were also detected within the red-algal species *Goniolithon* collected in growth positions from the Bahamas (Glover and Pray, 1971). Here too, the cement and substrate apparently had the same Mg content in the high Mg-calcite, again confirming the host control of the secondary carbonate.

In Connemara, the micrite within the red-

algae is either a void filling cement and/or a replacement. The origin of void filling cement can be explained as one of precipitation, probably caused by certain biochemical activities in the living red algae. The "replacement micritization" seems to represent an entirely different mechanism which must involve either removal-precipitation, or recrystallization. To confirm which of these two processes dominate in the Connemara environment, further studies are required using techniques of better resolution and reliability than was available for the present study.

The red-algal bank in Connemara is growing on a very shallow platform where there is good tidal exchange and circulation with seawater of normal oceanic composition. The sediment is permeable enough and the wave and current activity sufficiently intense that the composition of the water on the platform is not markedly different from that of the open ocean. Therefore, this type of cementation may not require a major compositional modification of normal oceanic waters. Frame building organisms are responsible not only for the construction of their own organic framework, but also for a good part of its internal cement. In addition, the processes of carbonate cementation in most shallow water environments show a definite preference for the living framework. As is known now, this could be true of all known environments wherein this type of cementation occurs on the sea floor. In geological terms they must represent examples of penecontemporaneous cementation.

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#### REFERENCES

- ALEXANDERSSON, E. T., 1969, Recent littoral and sub-littoral high Mg-calcite lithification in the Mediterranean: *Sedimentology*, v. 12, p. 47-61.  
 ———, 1972, Micritization of carbonate particles: processes of precipitation and dissolution in modern shallow marine sediments: *Geol. Inst. Univ. Uppsala Bull., N.S.*, v. 3, p. 201-236.  
 ———, 1974, Carbonate cementation in coralline algal nodules in the Skagerrak, North Sea: *Biochemi-*

- cal precipitation in undersaturated waters: *Jour. Sed. Petrology*, v. 44, p. 7-26.
- BATHURST, R. G. C., 1966, Boring algae, micrite envelopes, and lithification of molluscan biosparites: *Geol. Jour.*, v. 5, p. 15-32.
- , 1971, Carbonate sediments and their diagenesis: *Developments in Sedimentology 12*: Elsevier, Amsterdam, 620 p.
- BRICKER, O. P. (ed.), 1971, Carbonate Cements: Johns Hopkins Univ. Studies Geology No. 19, 376 p.
- FUCHTBAUER, H. (ed.), 1969, Lithification of carbonate sediments: *Sedimentology*, v. 12.
- FUTTERER, D., 1974, Significance of the boring sponge *Cliona* for the origin of fine grained material of carbonate sediments: *Jour. Sed. Petrology*, v. 44, p. 79-84.
- GINSBURG, R. N., 1956, Environmental relationships of grain size and constituent particles in some South Florida carbonate sediments: *Bull. Am. Assoc. Petroleum Geologists*, v. 40, p. 2384-2427.
- , D. S. MARSZALEK, AND N. SCHNEIDERMAN, 1971, Ultrastructure of carbonate cements in a Holocene algal reef of Bermuda: *Jour. Sed. Petrology*, v. 41, p. 472-482.
- GLOVER, E. D., AND L. C. PRAY, 1971, High-magnesium calcite and aragonite cementation within modern subtidal carbonate sediment grains: in Bricker, O. P. (ed.), Carbonate Cements: Johns Hopkins University Studies Geology No. 19, p. 80-87.
- GUNATILAKA, H. A., 1972, A survey of the geochemistry and diagenesis of Recent carbonate sediments from Connemara, Western Eire: Unpubl. Thesis, Reading University, U. K., 122 p.
- , 1975, The chemical composition of some carbonate secreting marine organisms from Connemara, Ireland: *Proc. Royal Irish Acad.*, v. 75, Section B, p. 543-557.
- ILLING, L. V., 1954, Bahaman calcareous sands: *Bull. Am. Assoc. Petroleum Geologists*, v. 38, p. 1-95.
- KENDALL, C. G. ST. C., AND P. A. D'E. SKIPWITH, 1969, Holocene shallow-water carbonate and evaporite sediments of Khor al Bazam, Abu Dhabi, Southwest Persian Gulf: *Am. Assoc. Petroleum Geologists Bull.*, v. 53, p. 841-869.
- LAND, L. S., 1967, Diagenesis of skeletal carbonates: *Jour. Sed. Petrology*, v. 37, p. 914-939.
- PERKINS, R. D., AND S. D. HALSEY, 1971, Geological significance of microboring fungi and algae in Carolina shelf sediments: *Jour. Sed. Petrology*, v. 41, p. 843-853.
- PURDY, E. G., 1968, Carbonate diagenesis: an environmental survey: *Geologica Romania*, v. 7, p. 183-228.
- SCHRÖEDER, J. H., 1972, Fabrics and sequences of submarine carbonate cements in Holocene Bermuda cup reefs: *Geol. Rundschau*, v. 61, p. 708-730.
- STRICKLAND, J., AND T. R. PARSONS, 1965, A manual of seawater analysis: Bulletin No. 125, Fisheries Research Board of Canada, 311 p.
- TOWE, K. M., AND P. G. MALONE, 1970, Precipitation of metastable carbonate phases from seawater: *Nature*, v. 226, p. 348-349.
- WINLAND, H. D., 1968, The role of high-Mg calcite in the preservation of micrite envelopes and textural features of aragonitic sediments: *Jour. Sed. Petrology*, v. 38, p. 1320-1325.