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Stromatactis-Mud Mound Formation – A Case Study from the Lower Devonian, Montagne Noire (France)

Stromatactis-Mud Mound Bildung – eine Fallstudie aus dem Unterdevon der Montagne Noire (Frankreich)

by

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Abstract

Mud mounds in the Emsian of the Montagne Noire are built by red biomicrites and white sparitic layers. The latter fall into the category of stromatactis structures. Sponges and bryozoans are dominant in the micrites. The stromatactis structures are interpreted as spar-filled cavity-systems, which originated from microbial mats decaying in the sediment. The bryozoan/sponge community as well as the microbial mat community both contributed to the growth of the mounds. Mound growth was thus primarily biologically controlled, but influenced by sea level changes. Spectral analysis of detailed measurements of quarry sections revealed orbital cycles to be responsible for the sea level changes.

Zusammenfassung

Die Mud Mounds im Emsium der Montagne Noire bestehen aus einer Wechsellagerung von roten Biomikriten und hellen sparitischen Lagen. Letztere entsprechen der Definition von Stromatactis-Strukturen. Die Fauna der Mikrite wird von Bryozoen und Schwämmen dominiert. Die Stromatactis-Strukturen werden als früh- und spätdiagenetisch zementierte Hohlraumsysteme gedeutet, die durch den Abbau grobflächiger Mikrobenmatten im Sediment entstanden sind. Sowohl Bryozoen/Schwamm- als auch Mikroben-Vergesellschaftung trugen im Wechsel zum Aufbau der Mounds bei. Das Moundwachstum war grundsätzlich biologisch gesteuert, aber durch die Auswirkungen von Meerespiegelschwankungen beeinflubt. Als Ursachen für die zyklischen Meeresspiegelschwankungen werden, aufgrund einer Spektralanalyse cm-genauer Profilaufnahmen, Schwankungen der Erdbahnparameter vermutet (Milankovitch-Zyklen).

1. Introduction

Red Devonian stromatactis-bearing mud mound sediments are exposed in a number of quarries in the Montagne Noire (Southern France, Fig. 1). These mounds, up to 70 m high and with a basal diameter of several hundred meters, were deposited during a regressive 3rd order phase in a time span less than one conodont (*serotinus*-) zone (JOHNSON et al., 1985; FLAJS & HÜSSNER, 1993). A time span of far less than one conodont zone is indicated by conodonts indicative of the *Polygnathus laticostatus*-zone (sensu WEDDIGE & ZIEGLER, 1977) just below the mud mounds and the co-occurrence of *Polygnathus serotinus* and *P. inversus* in the upper part of the mounds. The co-occurence of these two conodonts is characteristic for the lowermost *serotinus*-zone (YOLKIN et al., 1994). The mounds are composed of interlayered red biomicrites and white sparite layers and patches (Pl. 1). In the red biomicrites, sponges and bryozoans are the dominant faunal constituents (Pl. 2). Echinoderms, trilobites and rugose corals are of minor importance and commonly occur in layers. Most of the white sparite bands and patches (stromatactis fabrics sensu DUPONT, 1881 and LECOMPTE, 1937) are interpreted as resulting from microbial mats (FLAJS et al., in press). The mats have been covered by sediment and decayed subsequently. The cavities thus formed, have been filled by numerous generations of sparitic cement. The inner part of the cavities was filled by blocky spar. There are also smaller sparite patches which have been completely filled by blocky spar. These are thought to have not resulted from microbial mats, but instead from diagenetic recrystallization, starting out from shelter or larger interparticle pores (FLAJS & HÜSSNER, 1993). Alternative views on the origin of stromatactis structures have been discussed earlier (FLAJS & HÜSSNER, 1993; HÜSSNER, 1994).

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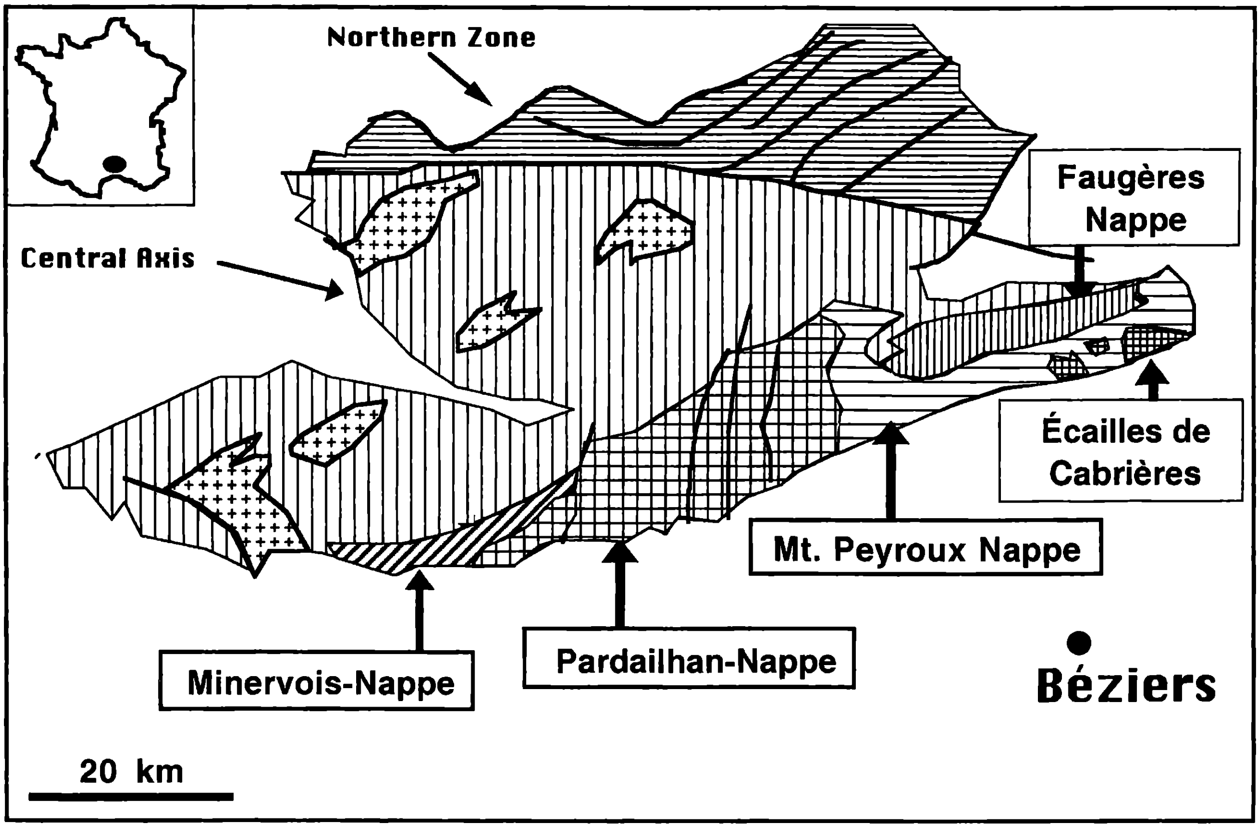

Figure 1: Main structural units of the Montagne Noire. Arrows on labels "Mt. Peyroux Nappe" and "Minervois Nappe" point to working areas (from FLAJS & HÜSSNER, 1993).

Sedimentary features indicate that the mud mounds were formed at water depths between storm- and fair-weather wave base. Most of the mud, we suppose, was imported from a nearby carbonate shelf and has been baffled by the sponge/bryozoan community. Parts of the mud may have formed by microbial activity in place. During times of initial 5th or 6th order sea-level rises, sediment export from the shelf was extremely low, enabling microbial mats to spread over more or less the whole mound. With increasing sediment input the mats digitated upward and finally died. During these times the bryozoan/sponge community replaced the microbial mats. Such changes in sea level, sedimentation rate and composition of the biotic community occurred more than 200 times. The controls of mound formation itself as well as of the cyclicity within the mounds will be discussed below.

2. Material and Methods

The present study is based on several weeks of field work by the authors, including sampling, point counting and counting sections such as those shown in Fig. 4, centimeter by centimeter. More than six hundred thin-sections have been analyzed with classical microfacies methods and about hundred by cathodoluminescence. Point counting of thin sections tends to underestimate the frequency of organisms such as siliceous sponges. By early lithification many sponge spicules and thus sponges have been preserved in life position. Thus most of the original sponges are represented by micrite rather than spicules in the thin sections. If we consider skeletal grains as proxies for the biomass originally present, sponges are heavily underestimated in comparism to organsims such as brachiopods, molluscs and echinoderms. Consequently we estimate the original percentage of the sponge biomass to be three to five times the relative value given in Fig. 3.

Geological mapping by several diploma students provided valuable information as to the spatial distribution of the stromatactis facies. M. Vigener provided useful information from his ongoing research on the diagnesis of the rocks described below. Besides translucent and cathodoluminescence microscopy he made chemical analyses of Fe, Mn, Sr, and Mg as well as isotope studies. Details of his findings will be published after he finishes his PhD Thesis. Time series analysis (using Fourier-transformation) was provided by the Department of Geophysics of the RWTH Aachen.

3. Results

Biostratigraphy, sedimentology and regional sediment distribution indicate, that deposition between the rather closely spaced mounds was very low to absent. The mounds on the other hand attain sedimentation rates of at least 70 B (1 Bubnoff = 1m/my). They have basal diameters of several hundred meters and heights of up to seventy

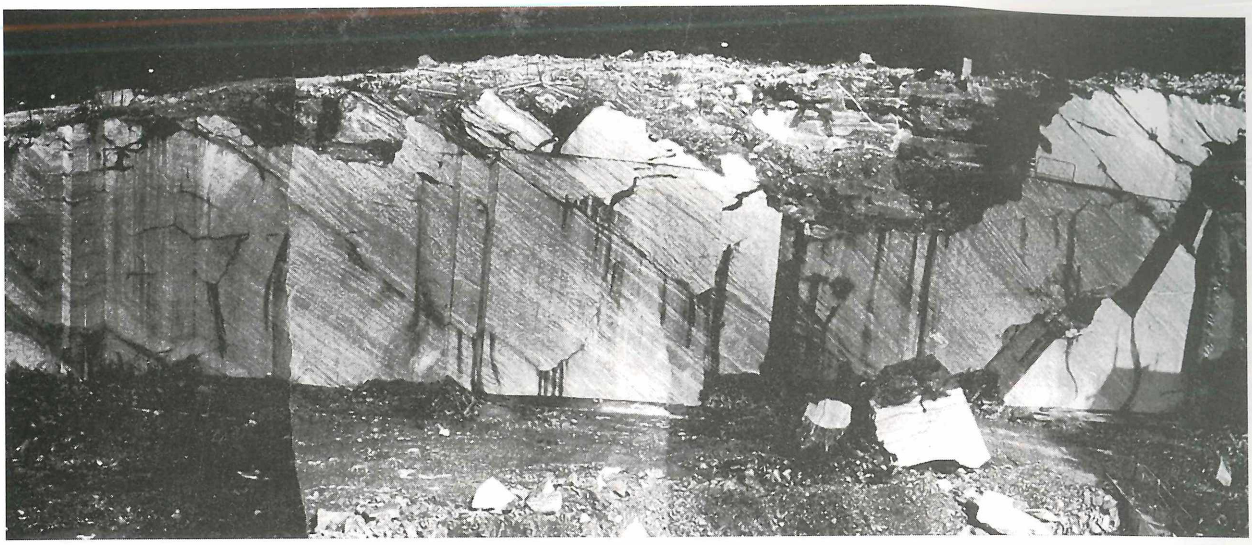

Figure 2: Northern wall of the Rocamat Quarry NE of the village of Caunes/Minervois. Photograph taken in spring 1992. Note alternations of red biomicrite and white stromatactis structures. Stromatactis layers are arranged in bundles. Length of quarry wall is approx. 50 m.

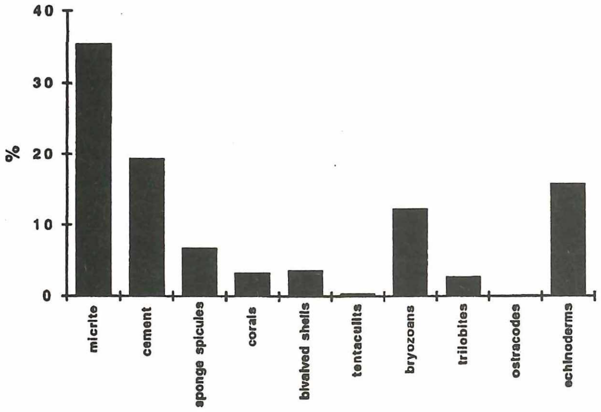

Figure 3: Average faunal and lithological composition of red biomicrites, based on point counting of thin sections.

meters. Dips of the flanks are about 20° and thus considerably lower than at contemporaneous mounds in Morocco (BRACHERT et al., 1992). Still, the distribution of thickness and facies cannot be explained by physical controls alone. Within the physical framework described above, growth of the mounds was biologically controlled. Despite changes in sediment input, which led to a switch of biotic communities, the mound structure, once sparked, kept growing at previously established places. The deposition of the mound sediments did not follow the physical principle of achieving a state of minimal potential energy, but instead was controlled by the biological principle of gaining ecological advantages above the surroundings.

The interlayering of red biomicrites and stromatactis structures is not equidistant, but the stromatactis layers are grouped into bundles of 10 to 20. This pattern is apparent in the field. To confirm a supposed cyclicity in the mound sediments a section of almost 50 meters has been measured centimeter by centimeter on the largest exposure in the Rocamat quarry (Fig. 3). About 30 meters of this section are shown in Fig. 4. The results of spectral analysis of these data can be seen in Fig. 5. Besides the switch from red biomicrites to stromatactis-structures and back, three recurring sedimentary cycles can be recognized with thicknesses of 3.3 m, 5.7 m and 13.9 m respectively. Assuming a constant rate of sedimentation, sediment thicknesses are proportional to time periods.

4. Discussion and Conclusions

The layered lithofacies of the mound sediments indicate switches in depositional regimes and biotic communities. The fauna of the red biomicrites is composed of approximately equal shares of sponges, bryozoans and echinoderms. The actual contribution of the sponges to the biomass of the bryozoan/sponge community was considerably higher than indicated in Fig. 3, whereas the share of the echinoderms, corals and trilobites was generally lower because they tend to be concentrated in layers and much rarer elsewhere. Shells of brachiopods and bivalves are minor constituents of the fauna and tentaculites and ostracodes are very rare.

The major elements of this community are sessile benthonic animals. Because of the basic needs of benthonic organisms, such as light, nutrients and waste disposal, they find slightly better environmental conditions on elevations of the sea floor as compared to the level bottom (HÜSSNER, 1994). Further growth of the mounds was thus biologically controlled. The microbial community, which spread over the mound during periods of extremely low sedimentation, was benthic sessile as well. Consequently the already existing mounds were the preferential living sites of these organisms too. By living on the mounds they contributed to further growth by trapping and/or precipitating carbonate, and to further stabilization of the

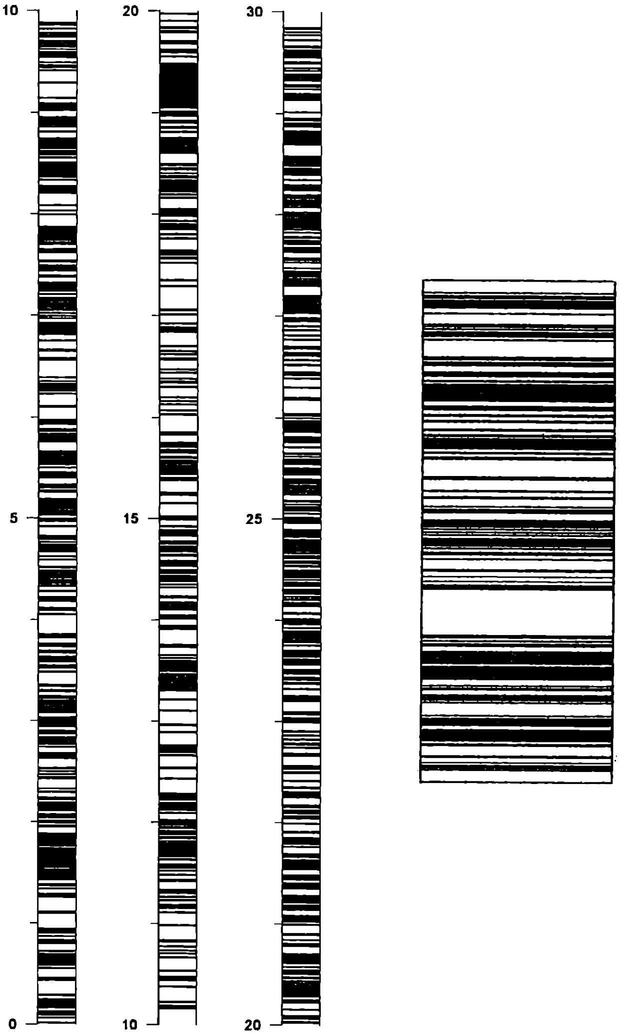

Figure 4: Stromatactis/micrite interlayering in the Rocamat Quarry (cf. Fig. 2), based on cm by cm measurements. Lower frequency cycles are more clearly visible in the compressed section to the right. Numbers refer to thickness in meters.

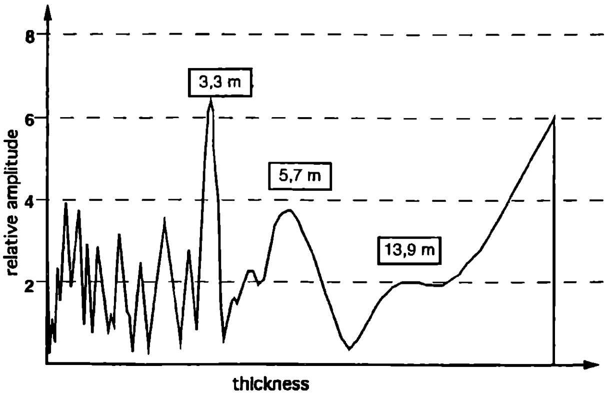

Figure 5: Power spectrum derived by spectral analysis of the section shown in Figs. 2 and 4. The 13.9 m peak is weak because only three cycles were covered in the section.

elevation by their encrusting life-stile. Sedimentation was also controlled biologically during "microbial times" Despite the changes in physical conditions as expressed in sediment import-rates from the shelf, mound growth was primarily controlled by biological programs inherited by the organisms.

So far mound growth has been discussed. In the following we will consider the reason for sedimentation changes and thus the frequent switch between two different biotic communities. In the rock column, the changes in lithology, reflecting different biota, are not randomly distributed, but follow the pattern described above. The ratios of the observed cycles: 1:1.7:4.2 closely resemble the ratios of the 20,000y 40,000y 100,000y orbital cycles of the Pleistocene (LIU, 1993). Despite the fact that the duration of orbital cycles has changed in the Phanerozoic (GOODESS et al., 1992) the ratios of the cycles were fairly constant.

In the measured sections pressure solution was more intense in the red biomicrites than in the stromatactis structures. We are aware that this must have affected sedimentary thicknesses, but the similarity to Milankovitch cycles is still striking. Absolute time spans are difficult to obtain for the Lower Devonian. The stromatactis limestones have been deposited in less than one conodont zone. Although the duration of the *serotinus*-zone may represent more than 1 my, the time span for the formation of the stromatactis limestones should be in the order of several hundred thousand years. This result is in good agreement with the observed three cycles, each representing 100,000 years (geological mapping indicates, that two more cycles are likely to be present but are not exposed).

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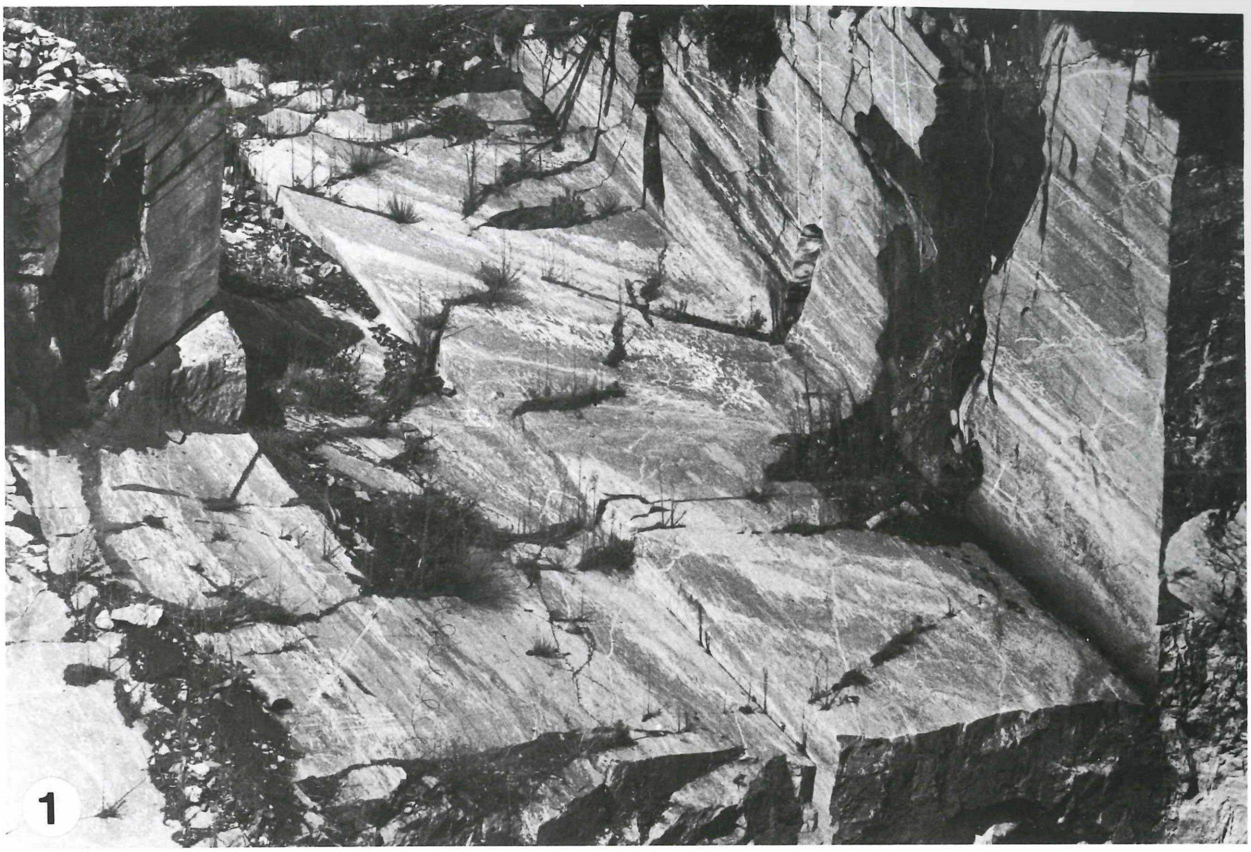
PLATE 1

Fig. 1. Slightly oblique cut of extensive stromatactis layers. Notre Dame de Cros Quarry.

Fig. 2. Close up of stromatactis layers exhibiting flat base, digitated roof and reticulate pattern. Block cut subvertically to bedding. Rocamat Quarry.

PLATE 1



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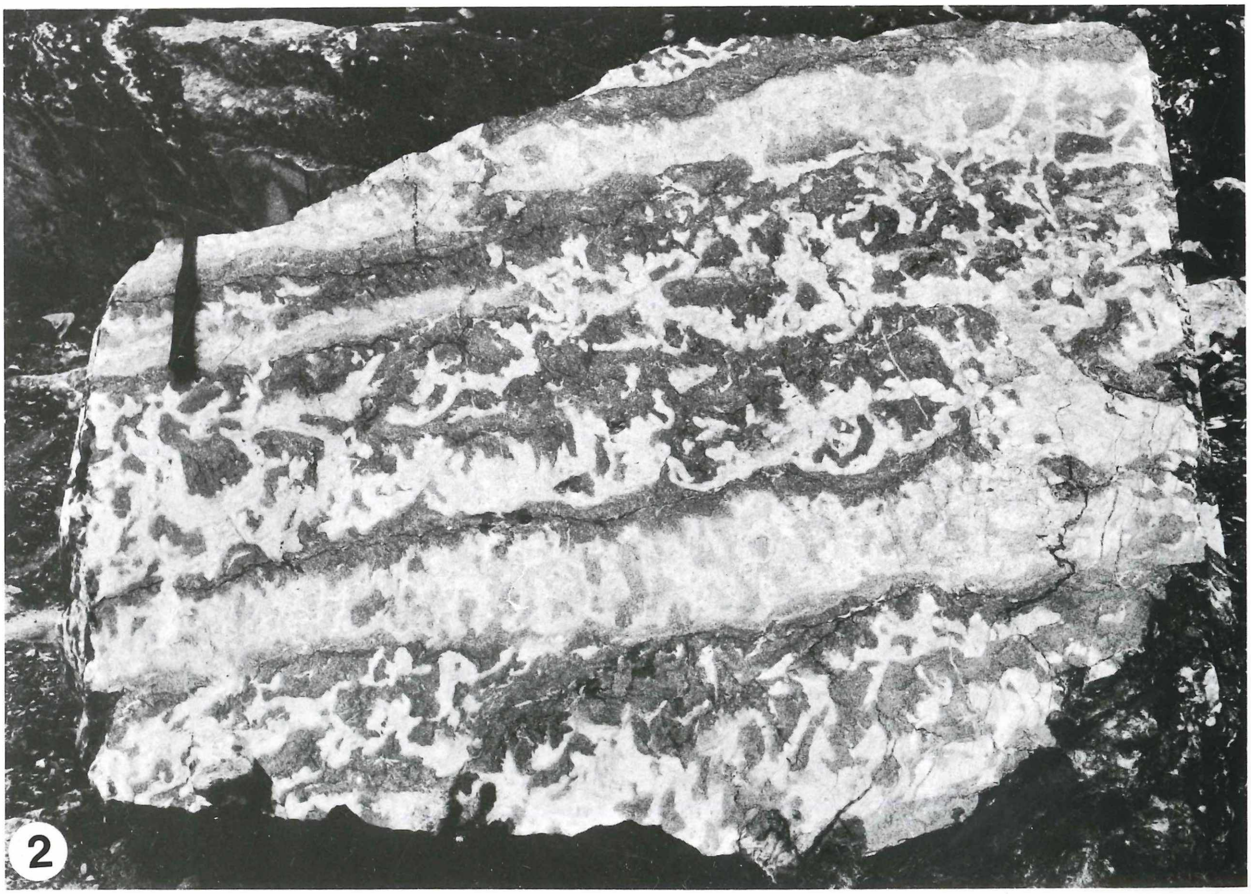

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PLATE 2

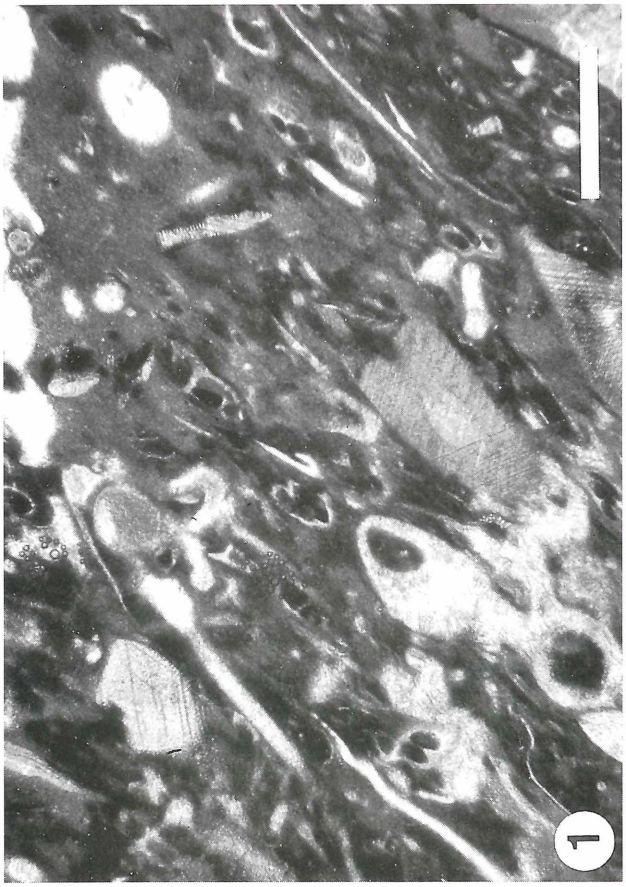
Fig. 1. Bryozoan/sponge/echinoderm wacke- to packstone. Rocamat Quarry; x 10 (scale bar = 2 mm).

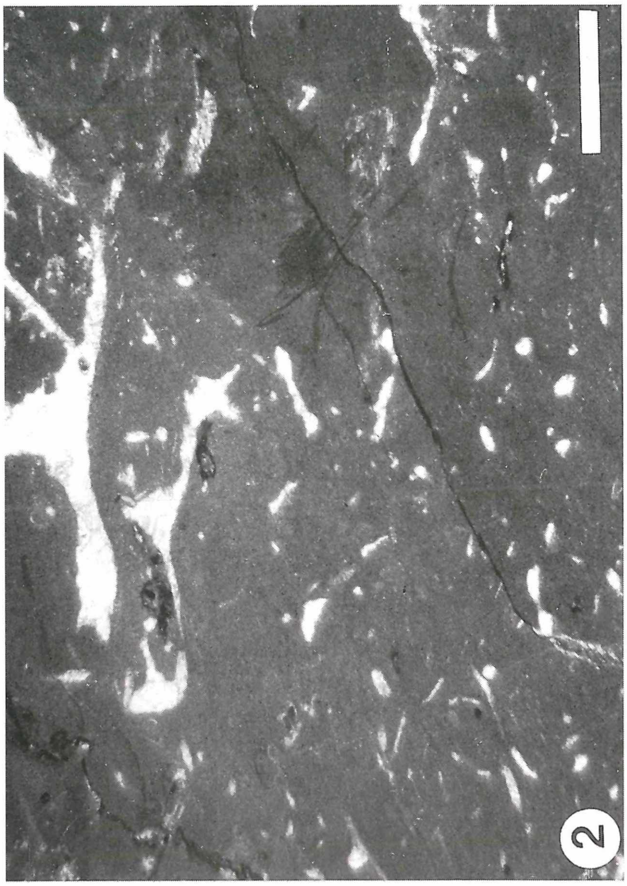
Fig. 2. Sponge mudstone with LF-fabrics. Rocamat Quarry; x 10 (scale bar = 2 mm).

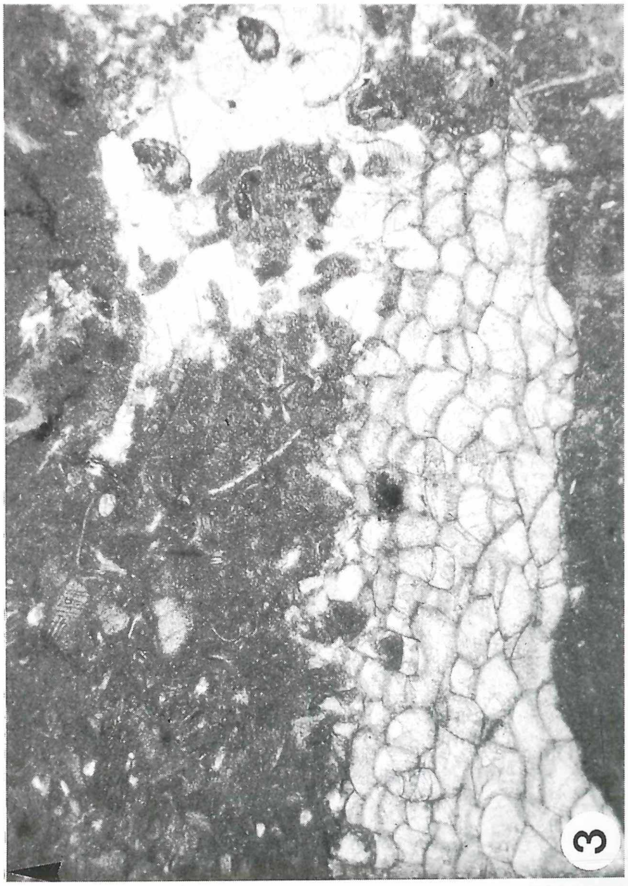
Fig. 3. Encrusting cystoporoid bryozoan colony in life position; intraparticle pores are filled with scalenohedric and blocky cement (not distinguishable at this magnification) connected to small stromatactoid structure (filled with blocky spar) at upper right. Puech de la Suque; x 20.

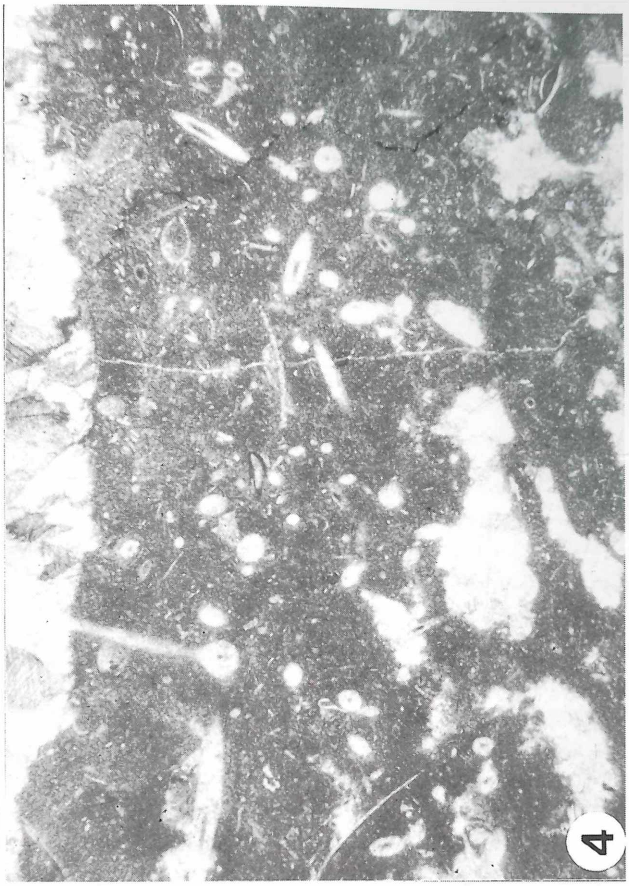
Fig. 4. Sponge with LF-fabric at the base; axial channels are filled with micrite; at the top of the picture base of a stromatactis structure showing large radiaxial-fibrous crystals. Rocamat Quarry; x 14.

PLATE 2









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