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Micrite Crusts on Ladinian Foreslopes of the Dolomites Seen in the Light of a Modern Scenario from the Red Sea

By THOMAS C. BRACHERT & WOLF-CHRISTIAN DULLO*)

With 3 Text-Figures and 3 Plates

Italien
Dolomiten
Rotes Meer
Riff
Vorriff
„Ledge rock"
Spongiostromate Krusten
Meeresspiegelschwankungen

Contents

Mikritkrusten auf Ladinischen Riffhängen der Dolomiten im Lichte moderner Szenarien im Roten Meer

Zusammenfassung

Im Gegensatz zu flachmarinen Karbonatmilieus werden tiefe Vorriffbereiche gemeinhin als Stätten geringer Karbonatproduktion in situ angesehen. In dieser Arbeit stellen wir zwei Beispiele vor, in denen Bildung von Karbonat unterhalb der euphotischen Zone stattgefunden hat: Vorriffhänge und Riffblöcke aus der Mittel-Trias der Dolomiten und aus dem Quartär des Roten Meeres. Aus diesem Grunde mag Karbonatproduktion im tiefen Wasser bedeutsamer sein, als bisher angenommen.

In beiden Fällen ist die Akkretion von Karbonatgestein an steile Oberflächen gebunden, die sich über den umgebenden Meeresboden erheben und auf diese Weise vor starker Sedimentüberdeckung geschützt sind – etwa submarine Kliffs oder allochthone Riffblöcke. Die Akkretion von Karbonat erfolgt dort in horizontaler Richtung, weil dünne Sedimentbedeckungen die Besiedelung von Oberseiten behindern. Auf diese Weise entstehen unregelmäßige Vorsprünge mit ebenen Oberseiten, die an schneebedeckte Tannenbäume erinnern und die wir „ledge rock" genannt haben. Obwohl die Mikrogefüge im Material aus dem Roten Meer und den Dolomiten sehr ähnlich sind, bestehen doch deutliche Unterschiede hinsichtlich der beteiligten Partikel und dem Ausmaß der Zerbohrung. Triassischer ledge rock der Dolomiten ist durch lockere Gefüge spongiostromater Krusten mit wenigen Gerüstbildnern, wie Kalkschwämmen, Korallen oder *Tubiphytes* gekennzeichnet. Im Roten Meer ist das Gestein das Ergebnis eines komplexen Wechselspiels biogener Inkrustation durch Serpuliden und Korallen mit Bohrorganismen und frühen Zementationsprozessen. Laminare Mikritkrusten finden sich nur auf den Oberseiten dieser komplexen Gerüste. Beiden Beispielen gemeinsam ist eine intensive Zementation durch botryoidalen Aragonit.

Absolutdatierungen und Sauerstoffisotopie der Krusten belegen eine Entstehung der Krusten des Roten Meeres während der höchsten Anstiegsrate des holozänen Meeresspiegels. In diesem Zeitraum war der Sedimentexport aus dem Flachwasser reduziert. Weil die Gegenwart einer Sedimentbedekkung auf den Krusten der wesentliche Kontrollfaktor für die Bildung von ledge rock darstellt, schlagen wir vor, daß für die triassischen Krusten ein ähnlicher Mechanismus gegolten haben könnte. Entsprechende Bedingungen sind während Tiefständen des Meeresspiegels oder dem transgressive systems tract der seismischen Stratigraphie anzunehmen.

*) Anschrift der Verfasser: Dr. THOMAS C. BRACHERT, Institut für Geowissenschaften, Saarstrasse 21, D-55099 Mainz; Prof. Dr. WOLF-CHRISTIAN DULLO, GEOMAR, Wischhofstrasse 1–3, 24148 Kiel.

Abstract

Shallow water carbonate environments are characterized by high rates of microbial carbonate production, whereas deeper forereef environments are commonly interpreted to be dominated by low rates of in situ carbonate production. In this paper we document two examples of in situ carbonate formation below the euphotic zone: middle Triassic clinoforms and reef blocks of the Dolomites and the Quarternary record of the Red Sea. Thus, in situ production in fore reef settings may be more important than previously recognized.

In both cases carbonate accretion is restricted to steep surfaces being elevated from the surrounding sea floor – such as submarine cliffs or allochthonous reef blocks – and being thus protected from burial by sediment. Carbonate accretion is mainly horizontal resulting in ledges protruding from the slope, because a cover of shallow water derived sediment inhibits upward growth. Although microfabrics in general are very similar, distinctions due to varying ratios of constituents and bioerosion exist. Triassic ledge rock from the Dolomites is characterized by loose fabrics of spongiostromate crusts with minor contributions by framebuilders such as calcisponges, corals or Tubiphytes. In the Red Sea the framework is the result of competitive incrustation by serpulids or solitary corals and biodestruction by various borers. Laminar micrite crusts are found only on top of this framework. Common to both examples is extensive cementation by botryoidal aragonite.

Radiocarbon dating and oxygen isotope signatures suggest that the Red Sea crusts formed during the highest rate of Holocene rise of sea level associated with low rates of sediment exportation. Because the presence of an extensive sediment cover seems to represent the major controlling factor on ledge development, we propose that the Triassic crusts formed during phases of minimum export of shallow water carbonate sediment particles, such as the lowstand or transgressive systems tract of seismic stratigraphy.

1. Introduction

Micritic crusts are important constituents in forming reef rock through geologic time. Since the stromatolithic bioherms of the Precambrian time, these complex biological associations have evolved in various settings and their frequency has changed in time drastically. They are apparently more frequent in Paleozoic and early Mesozoic reefs. However, their occurrence seems to be overestimated as they play an important role in Miocene (DABRIO et al., 1981; RIDING et al., 1991) and recent reefs (LAND & GOREAU, 1970; GINSBURG & JAMES, 1973; MOORE et al., 197; JAMES & GINSBURG, 1979; LAND & MOORE, 1980; BRACHERT & DULLO, 1991). These examples focus more on the deeper foreslope environment. MARSHALL (1983), JONES & HUNTER (1991), REID & MCINTYRE (1992) and MONTAGGIONI & CAMOIN (1993) have shown that these crusts occur even in the shallow water reef environment and are important as in the geologic past.

Comparisons between modern and ancient crusts are faced with the problem of studying material of different environments. This paper describes sedimentary processes in an environment below the present day occurrence of living zooxanthellate scleractinians, which is bathymetrically the zone between 120 m and at least 200 m waterdepth. In this bathymetric range of the modern Red Sea environment slowly accreting laminar micrite crusts form on horizontal ledges on the steep and sometimes vertical forereef slopes of atolls and barrier reefs as well as on patches of in situ lithified fringing-reef slope sediments. Similar ledges with laminar micrite crusts (GINSBURG & JAMES, 1973) are known from the walls of the deeper forereef from Jamaica and Belize (MOORE et al., 1976; JAMES & GINSBURG, 1979; LAND & MOORE, 1980). In the Ladinian reef world of the Dolomites (FOIS & GAETANI, 1980; GAETANI et al., 1981) steep clinoforms merge with basinal deposits. Micritic crusts are found to occur "on the middle slope" (GAETANI et al., 1981) as well as on allochthonous blocks. Thus the two examples selected seem to represent comparable depositional environments. Although a time gap of almost 200 Ma exists, macroscopic and microscopic textures including the surface morphology of hard substrata are strinkingly similar in the Triassic and Holocene samples.

2. Ladinian Foreslopes

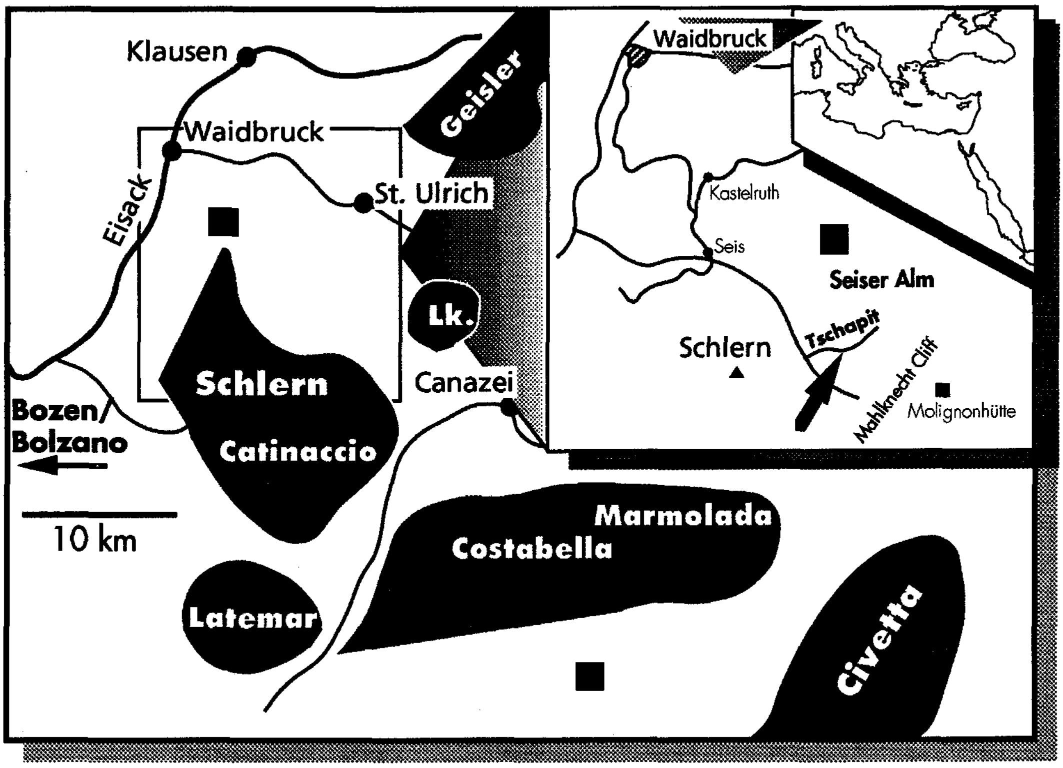
Middle to Late Triassic carbonate build-ups exposed in the Dolomites of northern Italy provide an excellent area where original facies geometries are well recorded (BOSELLINI, 1991). Thus, this region was investigated to test sequence stratigraphic models in the field (BOSELLINI, 1984; BOSELLINI & DOGLIONI, 1988; YOSE, 1991). Our studies focus on the well known base of slope sections of the Tschapit valley northwest of the Sciliar platform (Text-Fig. 1). Here, a remarkably thick wedge of volcaniclastics mixed with carbonate blocks is exposed, similar to the spectacular exposure at the Mahlknecht Cliff, described by BRANDNER et al. (1991).

The carbonate sequence of the Middle Triassic shows two major build-up sequences named Schlern Dolomite 1 (SD_1) and Schlern Dolomite 2 (SD_2). They were formed during 3rd order high stands of sea level. SD_1 and SD_2 are separated by volcanics of the lower Wengen Group. According to the nomenclature of BRANDNER (1991) the discussed outcrops of the Tschapit valley and the Mahlknecht Cliff belong stratigraphically to the upper Wengen Group and are part of the Marmolada Conglomerate (Text-Fig. 2). Similar sections are exposed at the Sella Pass (BOSELLINI, 1984) and the northern margin of the Civetta build-up (FOIS & GAETANI, 1980).

2.1. Sediments of the Forereef Slope

Late Ladinian and Carnian carbonate platforms did not develop a substantial interior lagoonal facies. Typical toplap relationships are developed as seen impressively all around the Sella platform (BOSELLINI, 1984). Therefore, these platforms and buildups prograded over their coeval basinal facies for a few kilometers. In this context, gravity displaced blocks occur in distinct horizons on the lower part and at the base of the clinoforms. The inclination of the clinoforms vary between 15° and 35° depending on the site of the slope and the age of formation (KENTER, 1990). The slope angles of the prograding clinoforms in the Sella buildup show a decrease in inclination as the basin fills and the slope height decreases. Although a complete insight into the overall geometry of the Sciliar buildup is not given, we argue for the same change in slope angle.

The Tschapit valley section exhibits the Wengen Group, which overlay the volcanics and fill their depositional relief (Text-Fig. 2). The lower part of the Wengen Group above the volcanics (8 m) is composed of bioturbated biomicrites intercalated within pelagically influenced marls with few ammonites and bivalves. Then, a series of graded channelized calciturbidites of 8 m thickness follows. They



Text-Fig. 1.
Locality map of the Tschapit Valley section within the pattern of Ladinian carbonate platforms in the Dolomites.

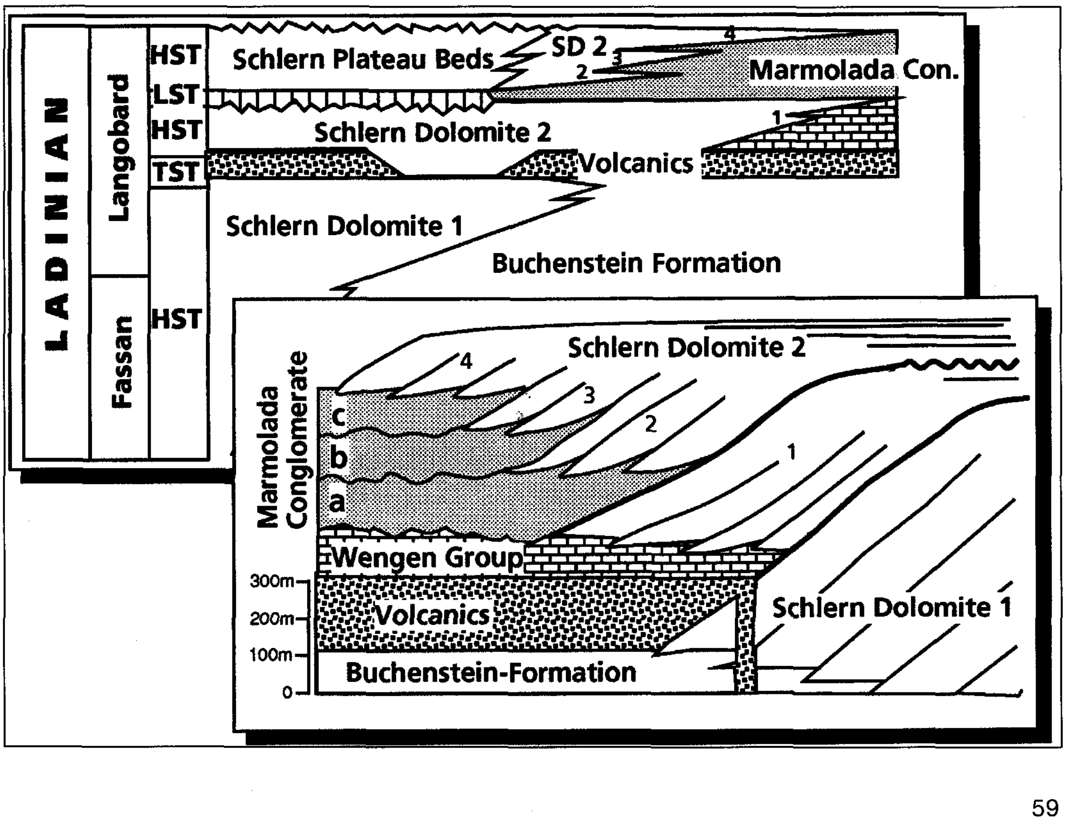
are overlain by debris flow deposits with a sharp erosive contact at their base. These debrites contain the giant Cipit boulders (Tschapit = Italian: Cipit) as well as volcanic conglomerates.

The Cipit boulders (Pl. 1/2) were originally known to bear unaltered reef builders, sometimes even being partly preserved in their primary mineralogy (SCHERER, 1977). This was important to reconstruct the Ladinian reef community because in the Schlern dolomite there is only little information about the original biotic composition. From a systematic analysis of the microfacies comprising the Cipit boulders, however, BRANDNER et al. (1991) deduced that the blocks derived from the upper to middle slope of the reefs and were not eroded from the platform margin or the platform interior.

The original shape and surface morphology of the Cipit boulders is well preserved, because they are embedded in soft marls and volcaniclastics. This surface morphology has been restored by present day weathering and is characterized by numerous ledges. The balkony shaped ledges protrude few cm perpendicular from the surface and resemble flowstones (Pl. 1/3). They are 10 to 15 cm wide and exhibit a sharp and even upper side caused by a narrow sill which encloses a small basin or cavern. The lower sides show undulating surfaces which closely resemble speleothemic dripstone and fuse with the roof of a deeper ledge structure. The individual ledges occur on various levels of the original very steep to vertical gross morphology of the blocks.

2.2. Macroscopic and Microscopic Fabric

The ledges are characterized by an internal macrolaminated fabric seen in fresh fractures (Pl 1/4). Between the irregularly spaced laminae, numerous pockets and sediment traps are developed filled with peloidal grainstones.



Text-Fig. 2.
Sequence stratigraphical and chronostratigraphical framework of the Schlern/Seiser Alm region, combined after BRANDNER (1991).

This may indicate that the even upper surfaces of the ledges had temporal covers of sediment. In thin-section, a large part of the ledges is formed by cavernous, laminar micrite crusts.

The primary biogenic fabric of these crusts consists of few *Tubiphytes*, spongiostromate crusts, sessile nubecularиid foraminifers and inozoan sponges of uncertain taxonomic affinity (*Calicia vesiculifera*). These few and tiny framebuilders are loosely bound together by stromatolithic, cavernous crusts of varying thickness (Pl. 2/1). These crusts show distinct parallel and divergent laminations (Taf. 3/1). Single laminae are not persistent laterally. They are composed of micropellets arranged in a chain-like pattern (Pl. 3/3,5). The biota together with the crusts form macroscopically and microscopically a loosely bound fabric (Pl. 1/3, 2/1) in which a peloidal sediment with subordinate grapestones is trapped and cemented by microspar.

The remaining porosity of this ledge fabric is filled with silt-sized volcaniclastic material. On the other hand small scaled bothryoidal aragonite cements are developed which still can be detected due to relict structures within the present-day granular calcite mineralogy (Pl. 2/3,5). This kind of cement is also precipitated within the inozoan sponges and has grown between the laminae of the crusts.

Borings are rare, however, clearly seen due to the truncation of both aragonite cement and lithified sediment (Pl. 2/3). The borings are 2–3 mm thick and have irregular outlines, similar to traces of eunicid polychaete worms (MACINTYRE, 1984). Multiple borings typical for modern shallow and deep water carbonates (BRACHERT et al., 1987; BRACHERT & DULLO, 1991) are missing.

3. Red Sea Foreslopes

Red Sea coral reefs are represented by fringing and barrier reefs as well as shelf atolls (MERGNER & SCHUHMACHER, 1974; ANGELUCCI et al., 1975; MONTAGGIONI et al., 1986). We studied reef sections offshore Sudan, extending from Port Sudan in the south to the Ras Hadarba area in the north, where all major reef types are developed (Text-Fig. 3).

3.1. Topography of Forereef Slopes

Atolls and barrier reefs exhibit steeply inclined or even vertical slopes (Text-Fig. 2). Windward margins exhibit a prominent terrace from –70 m to –95 m; below –95 m, due to differential tectonics. Leeward margins, however, exhibit a number of small terrace steps, each covered with sand. Below –120 m, the surface of the vertical walls is ragged resulting from numerous ledges, which are only a few cm thick and protrude about 25 cm horizontally from the cliffs (Pl. 1/5,6). Light, pale carbonate sediments accumulate on these ledges. Living macroorganisms are rare along these cliffs. Yellow boring sponges and rare ahermatypic scleratinians occur locally below overhangs. Where the wall has small ledges, which resemble Christmas trees, numerous serpulids, various bryozoans, and thecideid brachiopods settle on the underside of the "branches". The outcropping ledgerock as well as parts of the fauna are covered by black Fe-coatings or crusts.

Fringing reef slopes have inclinations of around 40 and less, and are covered by carbonate mud and sand. Carbonate blocks occur on these sand slopes, which obviously derive from a shallow water environment like the fossil Cipit bolders. These blocks (up to 2 m wide and 1 m high) are sparsely covered by deep water corals (*Madracis, Dendrophyllia*). Besides Cipit bolders, blocks of in situ lithified sediment occur, as well (BRACHERT & DULLO, 1991). Both kinds of blocks have steeply inclined and vertical walls on which overhanging ledges are developed (Pl. 1/1). They are similar with respect to morphology and facies to the ledges of cliffed slopes.

3.1. Macroscopic and Microscopic Fabric

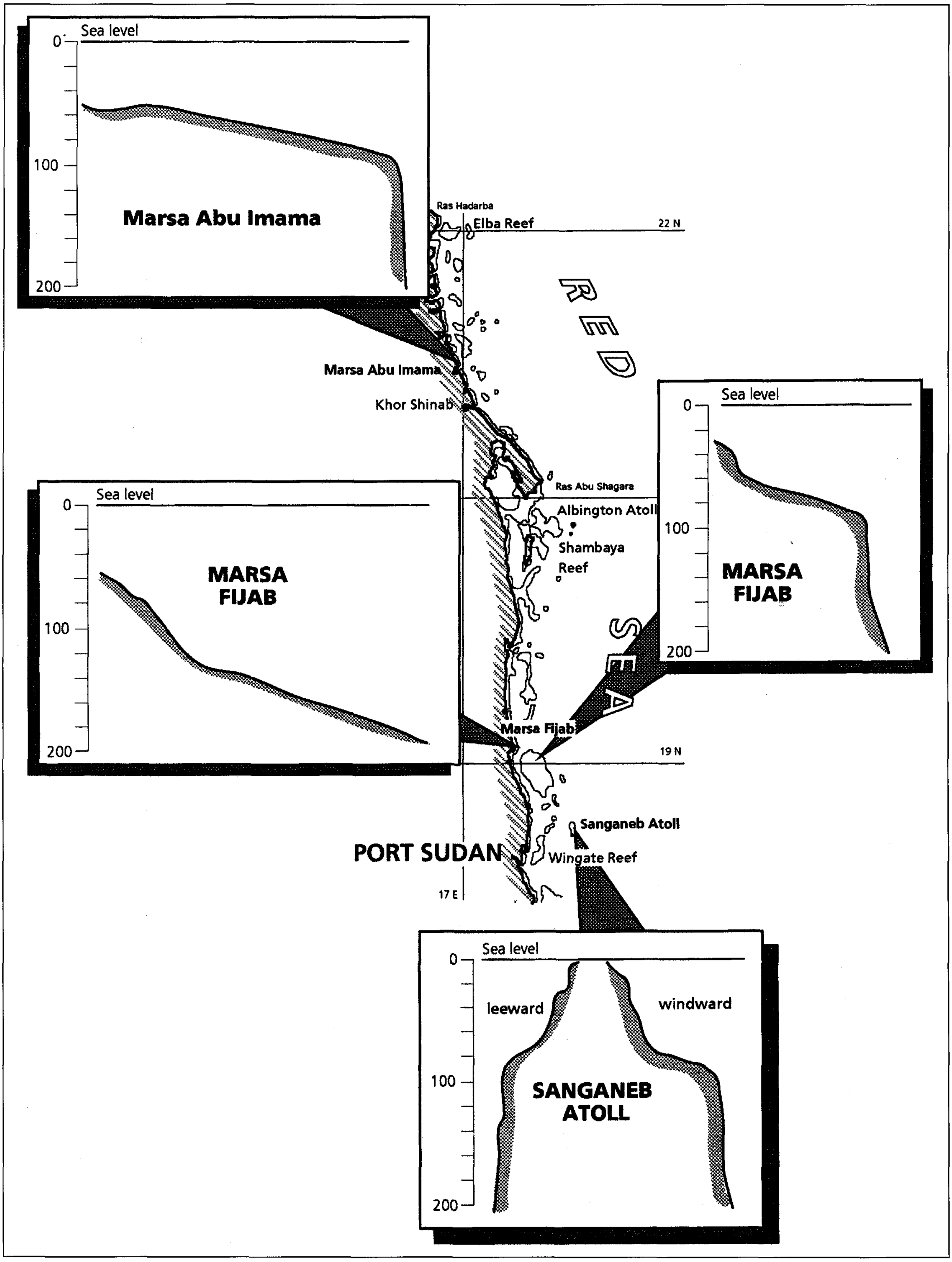
All ledge samples of the atoll and barrier reef sites exhibit three types of major carbonate fabrics. In most cases the ledges have an organic nucleus, which consists of bryozoans, frequent ahermatypic corals, and coralline algae. The latter can be found as in situ relics within the core of many ledges. This primary fabric has determined the overall shape of the ledges. The second fabric is represented by multiple borings which have disintegrated the primary biota and in most of the cases even completely obscured any preceeding rock texture. The lithified fillings of these borings consist of mechanically formed micritic bioclasts, like *Cliona* chips and cryptocrystalline cements. Lithification of filling sediment may be completed within one year (LAND & GOREAU, 1970). In the following we will refer to this micrite as boring micrite. Remaining pore space is either sealed by botryoidal aragonite cement or rays of high Mg-calcite cement (Pl. 2/2,4).

On top of this boring micrite, micrite crusts are developed, which form isopachous fringes. Single laminae have little lateral persistence and are often accentuated by iron staining (Pl. 2/2) but never truncate protruding skeletal particles. Lamination is caused by rhythmic changes of light-grey layers rich in bioclasts (0.5 mm thick) and smooth coatings of dark grey, weakly fluorescent micrite (Pl. 3/2,4). In so far, lamination is portrayed by the number of bioclasts involved and variations in organic content. This type of laminar micrite seems to be organically induced and may thus be assigned to "crypt algal fabrics" (MONTY, 1976).

The ledges on the blocks of gently inclined fringing reef slopes consist partly of grainstones (Pl. 2/4) which are mainly composed of micritic intraclasts, grapestones and micritic agglutinated tubes (20–200 m in diameter). Bioclasts occur as well, derived from the shallow water environment (*Operculina, Heterostegina*, fragments of crustose and articulate coralline algae, and *Halimeda*). Only few admixed planktonics are present. This fabric may also be characterized by multiple borings and be finally overlain by laminar micritic crusts, which do not differ in any respect to those seen on the steep cliffs of barrier reefs and atolls.

4. Discussion and Conclusion

A scenario of crust formation in the Red Sea was discussed in detail by BRACHERT & DULLO (1990, 1991), using both deep-sea data sets as well as stable isotopes and absolute ages from the ledges. According to our previous results, mainly based on ^{18}O values which show a very distinct shift from heavy to light values over time, ledge formation started during the transition of glacial to interglacial. The laminar micrite crusts were formed during a time of most rapidly rising sea level.



Text-Fig. 3.
Selected foreslope profiles along the Sudanese Red Sea coast.

Both ledge rock examples from the Triassic as well as from the Red Sea occur on steep walls in the foreslope environment. Low rates of net sedimentation are crucial for the settlement of deep water benthic communities such as azooxanthellate corals or siliceous sponges. Steep walls of forereef slopes and cliffs of allochthonous blocks are therefore prone to incrustation by slow growing communities including micritic crusts. Their surface morphology is strikingly similar (Pl. 1). Furthermore, in both examples there are peloidal grapestones, boring patterns, and similar marine cements among which the small-scaled botryoids are the most prominent ones. In both cases, however, the crusts play a different role in the generation of the rock framework as reflected by the percentage of crusts within the ledge rocks and their spatial distribution. In contrast to the Red Sea material, in the Triassic examples, biogenic crusts play a dominant role being responsible for a conspicuous macrolaminated fabric (Pl. 2/4) and for the generation of the rock framework. Other constituents, like sponges or the problematic *Tubiphytes*, contribute only minor both volumetrically and functionally. The Red Sea laminar crusts, however, represent a combination of both biogenic crusts and laminar Fe-impregnation related to hardground formation.

From the growth shape of the crusts resembling flowstone or small sinter terraces, we deduce the presence of a limiting agent of vertical accretion, which is probably represented by a thin sediment cover. It is evident from the crudely horizontal upper surfaces of the ledges. The optimum conditions of particle supply for a slow growing mat to bind and cement particles are therefore on steep or even overhanging faces. Depending on the ratio of sediment supply and growth potential a small elevated marginal rim may form (Pl. 2/3). Accretion is therefore mainly horizontal resulting in a cavernous macrolaminated fabric in cross section and flowstone morphologies on outer surfaces.

In the Red Sea examples, the shape of the ledges is mainly due to a precursor biogenic fabric coated by crusts of 0.5 to 4.5 cm thickness. As shown by BRACHERT & DULLO (1991) polygonal sediment basins of square centimeter size rimmed by micrite crusts occur as well, resulting in morphologies wich resemble tiny sinter terraces as well.

Following the sequence and chronostratigraphic stratigraphic interpretations of BRANDNER (1991), the Cipit boulders outcropping in the Tschapit valley have been deposited during a lowstand, while the deposition of the Marmolada conglomerate in the Mahlknechtkliff has been formed during highstand conditions. The alternative interpretation from BOSELLINI (1991) places the Marmolada conglomerate in a low-stand situation, however, the Cipit boulders at the toe of slope around the Sella were deposited during a highstand.

The formation of laminar micrite crusts on top of exposed surfaces may indirectly represent a solution. During rising sea level, space of accomodation is created in the shallow water environment, reducing sediment export. When sediment is not transported and deposited on the clinoforms, such sensitive microbial films creating the crusts may grow and develop. Radiocarbon dating and stable isotopic evidence suggest growth during rising sea level (BRACHERT & DULLO, 1990). Today's cover of loose sediment on top of the modern ledges in the Red Sea (Pl. 1/4,6) result from ongoing storm and wave-induced export and therefore, crust formation does not occur during the present-day high sea level. From this indirectly induced comparison we conclude that the sedimentary environment seen in the Tschapit valley section represents a lowstand or transgressive systems tract of seismic stratigraphy fitting to BRANDNER's (1991) interpretation.

Acknowledgements

We thank Prof. BRANDNER (Innsbruck) for showing us the interesting outcrops in the Dolomites, for stimulating discussions, and for his critical remarks improving the manuscript. Jürgen SCHAUER has piloted us through the marvellous underwater world of the deep foreslopes in the Red Sea with the submersible GEO, which is gratefully acknowledged. Financial support was provided by the Deutsche Forschungsgemeinschaft.

Plate 1

In situ carbonate formation on forereef slopes.

Underwater views from Red Sea examples and field photographs from the Middle Triassic of the Dolomites.

Fig. 1: **Allochthonous reef block partially covered with unlithified sediment (white).**
Overhanging and vertical surfaces of the rock are pustular due to various encrusters.
Marsa Fijab fringing reef, water depth 185 m.
Width of picture: 1.5 m.

Fig. 2: **Cipit boulder (allochthonous reef block) interbedded with volcaniclastics of the San Cassian Formation.**
Sella Pass.

Fig. 3: **Vertical surface of cipit boulder (allochthonous reef block) covered by carbonate ledges resembling morphologically small sinter terraces or flowstone.**
The ledges have a distinct horizontal rim at the upper surface, which encloses a small basin originally presumably filled with sediment (arrow). The depositional surface was preserved because of preferential weathering of surrounding finegrained volcaniclastics.
Seiser Alm (Tschapit Bach), Wengener Schichten.
Width of picture = 25 cm.

Fig. 4: **Cross section of ledge rock (left) and depositional surface (right) of cipit boulder (allochthonous reef block).**
The lens cover at the limit of both is 5.5 cm in diameter. Note the cavernous macrolaminated fabric of the ledge rock.
Seiser Alm (Tschapit Bach), Wengener Schichten.

Fig. 5: **Underwater view of ledges from present day Red Sea forereefs.**
Massive ledges formed on cliffs with reduced rates of sedimentation.
Sanganeb Reef, water depth 150 m.
Width of picture 0.8 m.

Fig. 6: **Underwater view of irregularly distributed, squamous ledges which formed on cliffs with high sedimentation rates.**
Note white filaments (polychaetes) protruding from the front of the ledges.
Shambaya Reef, water depth 175 m.
Width of picture 0.4 m.

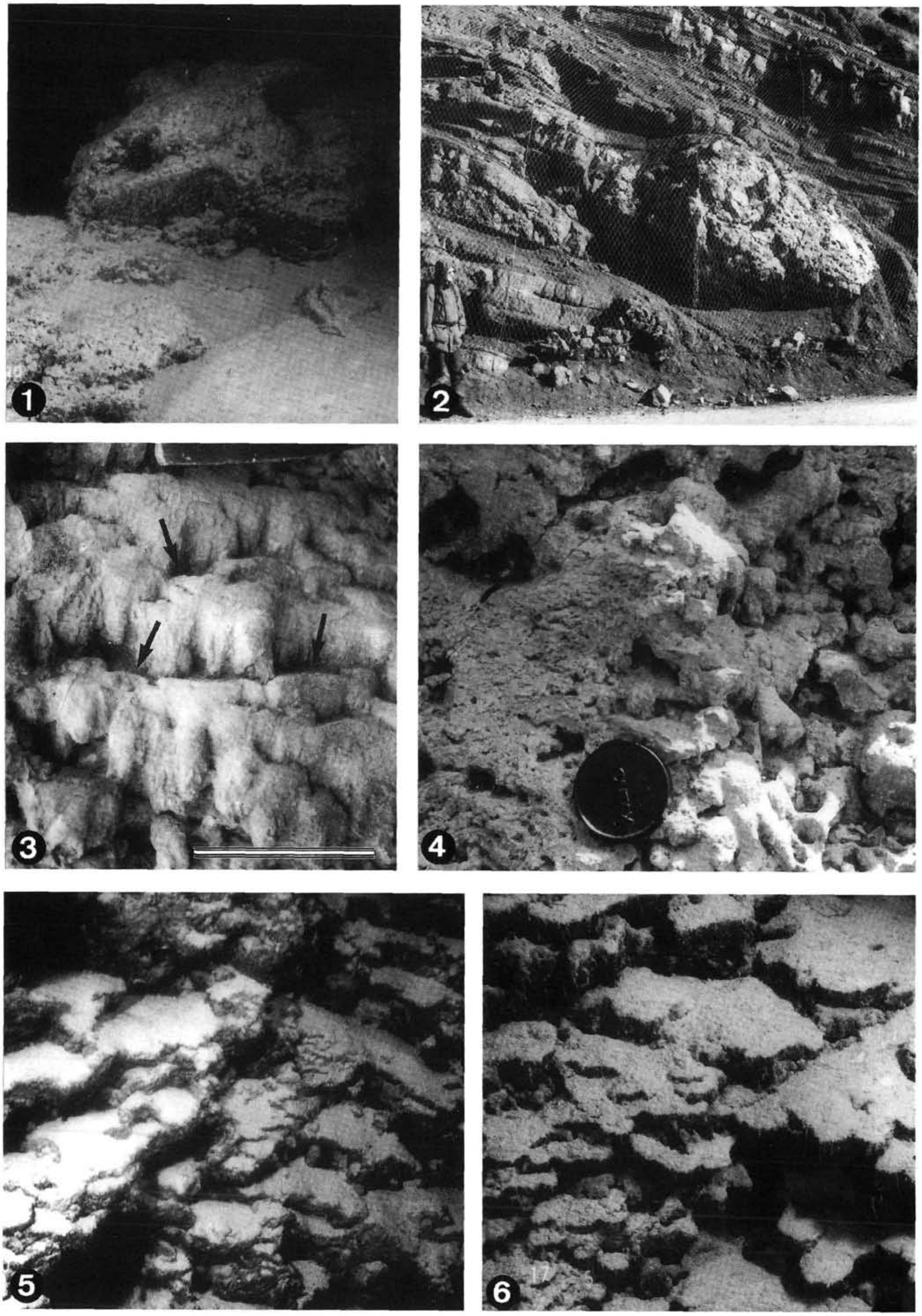

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Plate 2

Microfabrics of forereef carbonates.

The Dolomites (left) and the Red Sea (right).

Fig. 1: **Loosely bound fabric of cavernous spongiostromate crusts**
The origin of large associated void systems sealed with early marine cement is largely unknown. Cavities lacking early marine cement (arrow) may represent boring porosity.
Cipit boulder, Tschapitbach.
Scale bar equals 2 mm.

Fig. 2: **Contact of laminar micrite crust (dark gray) and zone of boring micrite.**
Some of the borings are sealed with fibrous aragonite cement. The micrite crusts consist of laterally discontinuous laminae, which are often accentuated by iron staining.
Khor Shinab, GEO 96, water depth 180 m.
Scale bar equals 2 mm.

Fig. 3: **Loosely bound internal texture of Triassic ledge rock.**
Porosity is cemented by two generations of cement, first stubby cement interpreted to represent primary HMC cement and heterogranular calcite. Some of the pores truncate the first generation of cement and sedimentary fabrics (arrows), interpreted to indicate early cementation and bioerosion.
Cipit boulder, Tschapitbach.
Scale bar equals 1 mm.

Fig. 4: **Pore systems not infilled with cryptocrystalline sediments and precipitates are sealed with fans of botryoidal aragonite and splays of high Mg-calcite cement.**
Sanganeb Reef, GEO 34, water depth 190 m.
Scale bar equals 1 mm.

Fig. 5: **Ghost structures of botryoidal aragonite cement preserved in granular calcite.**
Cipit boulder, Tschapitbach.
Scale bar equals 2 mm.

Fig. 6: **Bands of botryoidal aragonite cement (light gray).**
Note changing thickness and irregular distribution within the pore.
Dahab Reef, water depth 135 m.
Scale bar equals 2 mm.

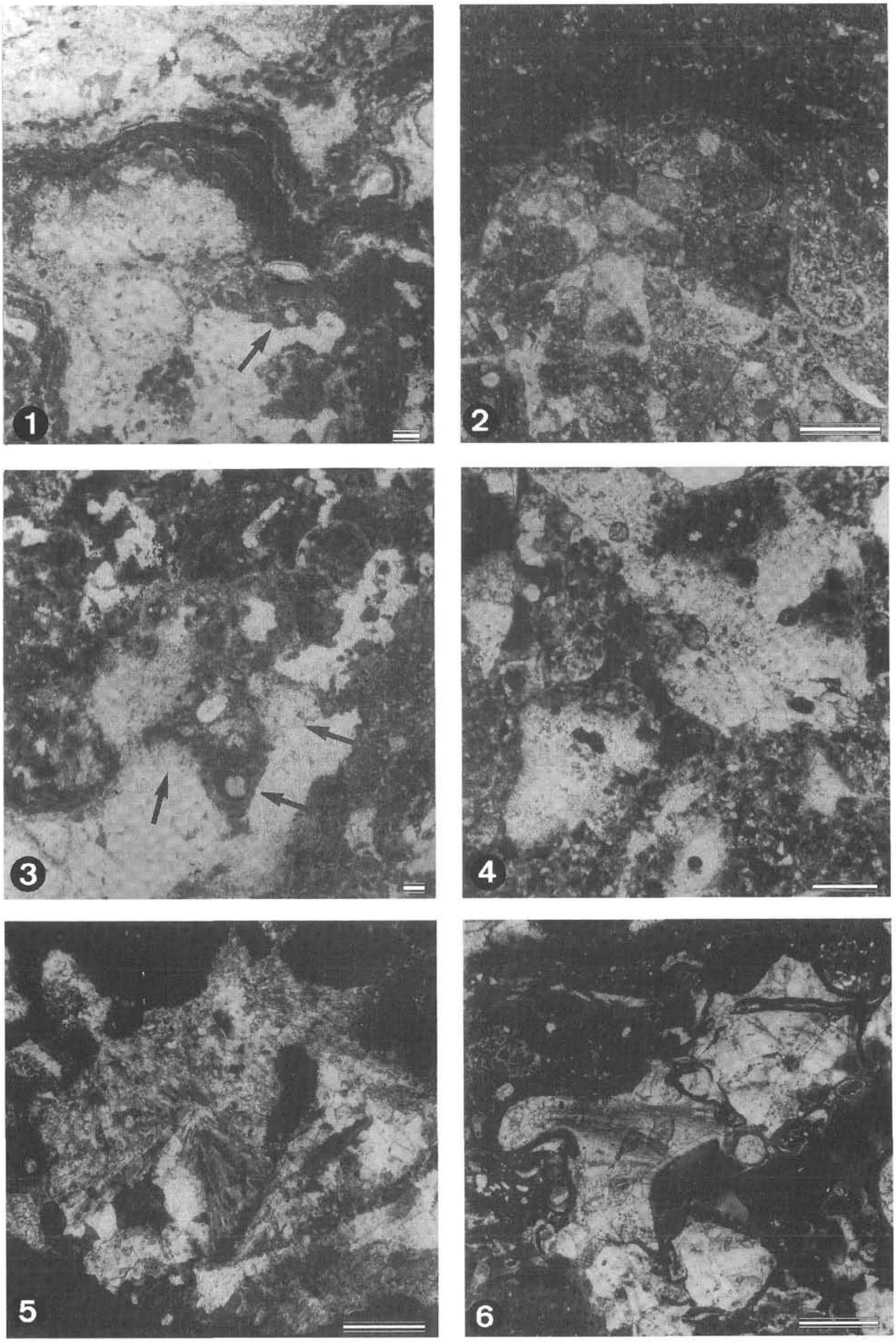
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Plate 3

Microfabrics of spongiostromate crusts.

Fig. 1: **Spongiostromate crust consisting of parallel and divergent laminations.**
Note rare intergrowth with foraminifers (arrow).
Cipit boulder, Tschapitbach.
Scale bar equals 1 mm.

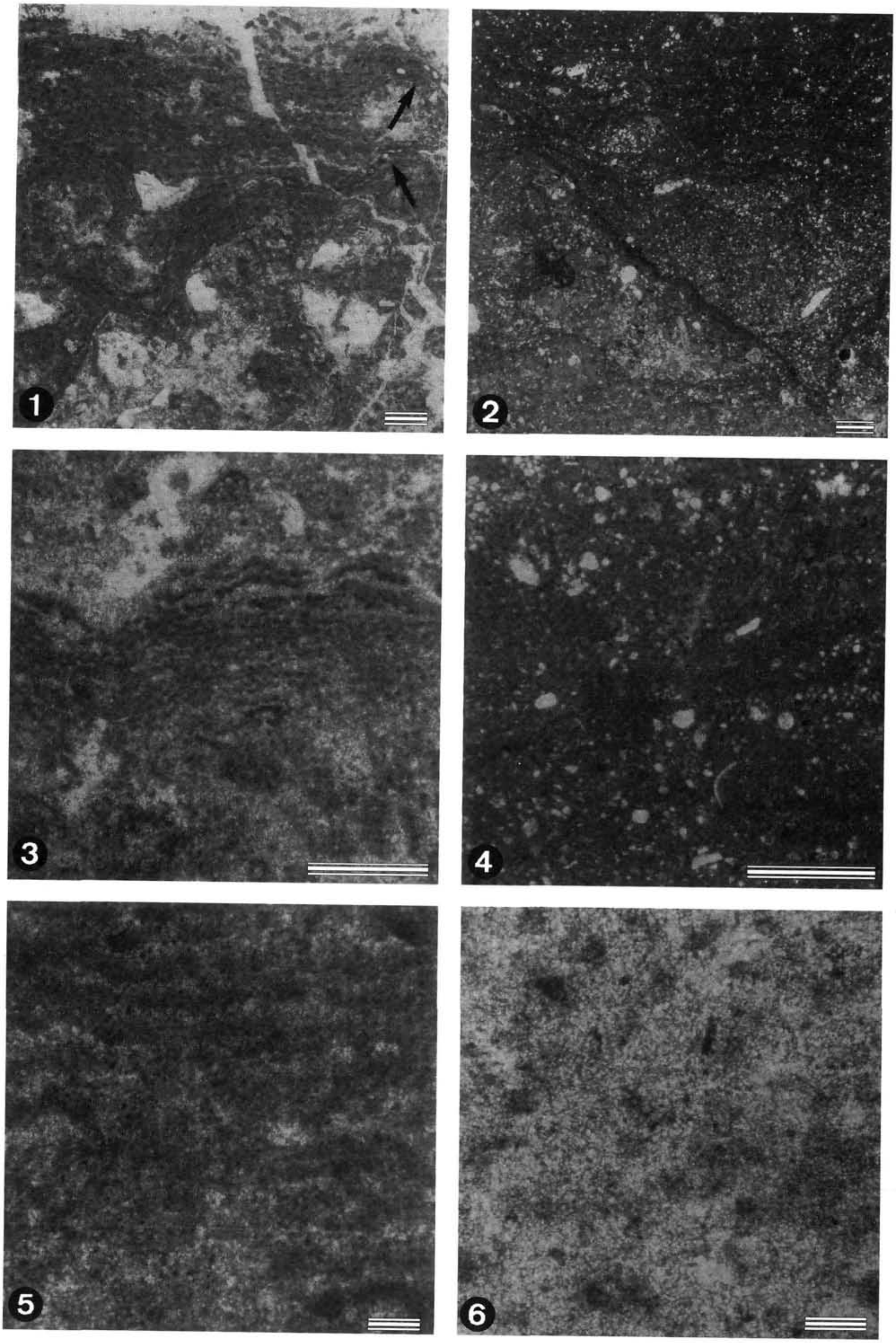
Fig. 2: **Laminar micrite crust from Red Sea forereef consisting of anastomosing parallel and divergent laminae.**
Lamination is caused by rhythmic changes of light gray layers rich in microbioclasts and smooth coatings of dark gray micrite.
Khor Shinab, GEO 94, water depth 200 m.
Scale bar equals 1 mm.

Fig. 3: **Individual laminae of spongiostromate crusts consist of micropellets arranged in a chain-like pattern.**
Cipit boulder, Tschapitbach.
Scale bar equals 500 μm.

Fig. 4: **Close up of laminar micrite crust showing light gray microbioclastic layers and anastomosing seams of dark gray micrite which is weakly fluorescent under UV light.**
Khor Shinab, GEO 94, water depth 200 m.
Scale bar equals 500 μm.

Fig. 5: **Close-up from Fig. 3 showing micropelleted structure of the crusts.**
Cipit boulder, Tschapitbach.
Scale bar equals 100 μm.

Fig. 6: **Clotted structure filling voids within the "zone of multiple boring".**
Khor Shinab, GEO 96, water depth 180 m.
Scale bar equals 100 μm.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