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On a Columnar Stromatolite in the Precambrian Bambui Group of Central Brazil

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ABSTRACT

A columnar non-branching algal stromatolite has been discovered in dolomites of the Bambui Group (Late Precambrian, Central Brazil). The columns are up to 4 meters high and their circular or drop-shaped plan outlines are about 35 cm in diameter. Internal structure shows alternation of conically arranged, partly pelleted dark and more or less homogeneous light lamellae. The determination of the subgroup ("species") *Conophyton* cf. *cylindricus* Maslov 1937 emend. Komar 1965 allows us to confirm a Late Precambrian age (lower Middle Riphean) for the Bambui Group. The environmental conditons (high-energy subtidal basin) are discussed.

ZUSAMMENFASSUNG

Im nordwestlichen Teil von Minas Gerais (Zentralbrasilien) wurde in Dolomiten der Bambui-Gruppe (Jungpräkambrium) ein säulenförmiger, unverzweigter Stromatolith-Typ gefunden. Die einzelnen Säulen haben kreisförmigen bis tropfenförmigen Grundriss (∅ bis 35 cm), eine Höhe von bis zu 4 m und setzen sich im Prinzip aus einer Anzahl von ineinandergestellten Kegeln zusammen. Alle durch Erosion und selektive Verwitterung sichtbar gemachten Strukturen lassen sich demnach als Kegelschnitte erklären. Unter dem Mikroskop zeigen die Stromatolithe einen Wechsel von dünnen, teilweise zerbrochenen, dunklen Mikritlagen mit etwas breiteren, feinsparitischen hellen Lagen. Die Bestimmung von *Conophyton* cf. *cylindricus* Maslov 1937 emend. Komar 1965 ergibt nach russischer Auffassung eine Bestätigung für jungpräkambrisches Alter (unteres Mittelriphean). Verschiedene Indizien weisen auf einen stark bewegten Subtidenbereich als ursprüngliches Sedimentationsmilieu hin.

RESUMO

Uma ocorrênçia de um estromatólito en forma de coluna, *Conophyton* cf. *cylindricus* Maslov 1937 emend. Komar 1965, foi descoberta nos dolomítos do Grupo Bambuí, nordeste de Vazante (Estado de Minas Gerais). Uma descriçâo dos organismos é apresentada como uma interpretaçâo do ambiente de sedimentaçâo. Esta ocorrênçia confirma a idade precambriana superior do Grupo Bambuí.

Introduction

For quite some time algal stromatolites of the Collenia type are known in several sequences of Brazil, including the Bambui Group (Cassedanne 1964, 1968).

During a six month reconnaissance survey in the Rio São Francisco basin of northern Minas Gerais, a stromatolitic type so far unknown in South America, *Conophyton* Maslov, was discovered. In this paper a general description of its structure is presented. The function of this stromatolite as an environmental and age indicator for the Bambui Group is discussed.

Acknowledgments

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General Setting

Site (Fig. 1)

Itinerary: coming from Belo Horizonte we leave at Paracatú (514 km) the asphalt road leading to Brasília. Here we turn south towards Vazante on an unpaved road till Guarda-Môr (about 70 km from Paracatú). We then change to the old Vazante trail and follow it for about 25 km till Vaza-Môr where we turn to the east, passing through Fazenda Olho d'agua, to reach the few straw huts of Cabeludo. This trip from Paracatú to the site takes about $2^1/_2$ hours (roads are passable only by truck or jeep during

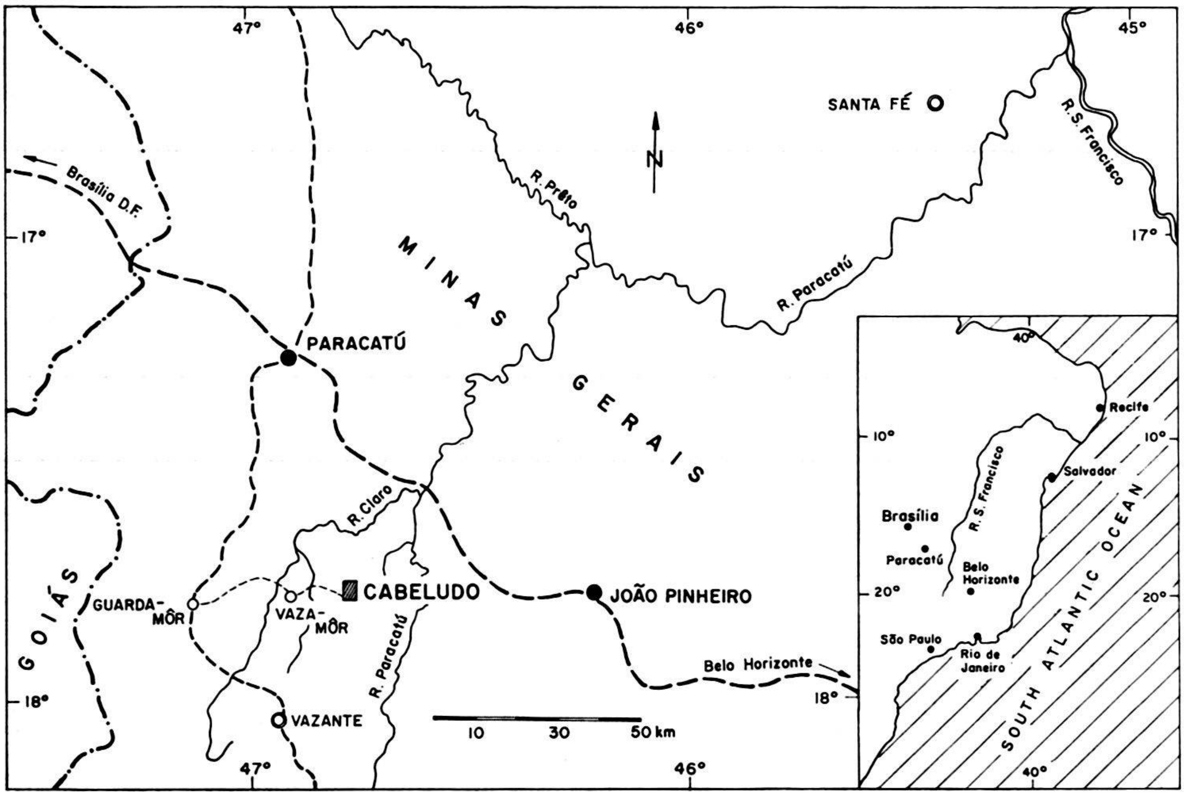

Fig. 1. Map of the area southeast of Brasília, showing access routes to Cabeludo and location of the map indicated on Fig. 2.

dry season). The outcrop is 1 km north of the village within the Fazenda of José Alvis de Oliveira. The rocks are hidden to a great extent by vegetation although they control the morphology: shales are characterized by a dendritic drainage system and are poorly covered by grass and some small bushes. Dolomites are always overgrown by thick tropical forest, whereas Cerrado[1]) vegetation refers to lateritic soil.

Structural and stratigraphical framework (Fig. 2)

The investigated area is part of the southern Bambui basin which covers much of the valley of the upper Rio São Francisco. The Bambui Group (RIMANN 1917), consisting of a monotonous assemblage of shales, carbonates, quartzites, siltstones and sandstones, overlies unconformably a more or less metamorphic crystalline basement. Isotopic age determinations (AMARAL et al. 1968) and some of the stromatolites occurring in the carbonates, indicate a Late Precambrian age.

In the area of Cabeludo, a carbonate basin, filled with subhorizontal dolomites is surrounded by two shaly formations. The one on the eastern side dips steeply below the dolomites. The other shale formation, occurring in the western and southern part of the mapped region, conformably overlies the dolomites, dipping around 30° to SW. These Upper Shales are locally folded and also contain small carbonate units. The dolomites, forming small pinnacles, are cut by joints, along some of which sink-holes generated. Fracture zones may also be recognized by higher concentrations of milky quartz and hematite on the soil or within the wall rocks.

General description of the mapped lithological units:

Dolomites

Massive or poorly stratified, light to dark grey, partly siliceous dolomites with abundant algal structures. Their total thickness, estimated from isolated outcrops, is about 120 meters. Four rock types may be distinguished:

a) *Algal-laminated dolomites:* algal-laminated dolomites with partly broken and sometimes pelleted laminae. Parallel to the laminae there may occur layers of chalcedony which are replaced to some extent by coarsely crystalline dolomitic cement. These siliceous layers are weathered out as brown to grey ribs. Some laminations in the upper part are thought to be Collenias (laterally linked hemispheroids in the sense of LOGAN et al. 1964), whereas the newly described algal stromatolites, which are determined as *Conophyton*, are found only at the base of this strata.

b) *Intrasparitic dolomites:* internally structured, well rounded and sorted intraclasts (∅ 0.2–0.8 mm), embedded in a fine crystalline cement. The abundant interparticle vugs are filled with a coarsely crystalline mosaic of dolomite. The intraclasts are probably of algal origin (see Plate III, Fig. 4). This rock type, with a thickness of few meters is exposed in one small outcrop at the base of the Serra Lajes.

c) *Clotted dolomites:* dark grey to black, massive dolomite. The dark patches represent chalcedony-rich dolomitic micrite, embedded in fine grained sparitic dolomite. They are usually encountered in the upper part of the dolomite unit, e.g. immediately below pt 740 (see Fig. 2).

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[1]) Disseminated, twisted small trees with coriaceous leaves and tufted, dry grass.

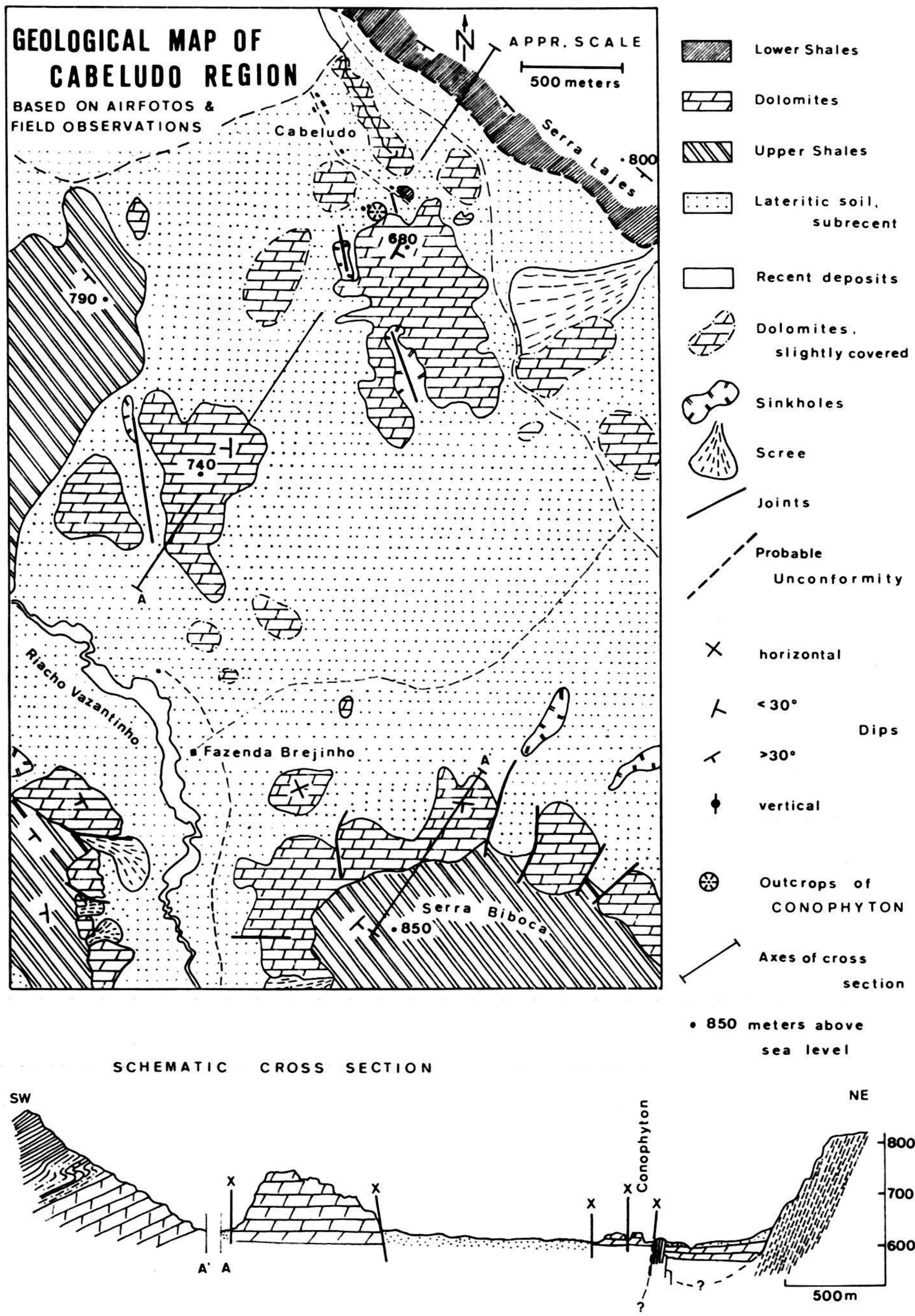

Fig. 2. Geological sketch map of Cabeludo region with a schematic cross section.

d) *Purple sedimentary breccia:* reddish micritic dolomite with angular to slightly rounded components (∅ few mm to 50 cm) of fine grained, siliceous dolomitic sparite and chert fragments. Hematite and pyrite concentrations are observed along fragment boundaries. Best outcrops are found SW of Serra Biboca, forming the top of the dolomite unit.

CASSEDANNE (1964, 1968, 1969) observed slight concentrations of Pb and Zn in stromatolitic dolomites, which would concern our samples 1, 2, 4 and 5. However our investigations reveal no significant anomaly in stromatolitic layers but a rather strong one in our samples 8 and 9, the purple sedimentary breccia (see the Table 1).

Table 1. Partial analyses of some dolomites of Cabeludo

Sample		Dolomite (% $MgCO_3$)	Calcite (% $CaCO_3$)	Dol/Calc	Pb ppm	Zn[2])	Insoluble %
1	BR71/05.020	89.1	2.6	34.3	50	57	6.1
2	05.021	94.4	2.3	41.0	38	14	0.6
3	04.032	93.3	3.4	27.4	41	10	0.3
4	04.034	88.2	3.5	25.2	48	33	4.9
5	04.129	95.8	1.2	80.0	42	14	0.3
6	05.023	94.8	1.7	55.8	40	13	1.1
7	04.107	94.6	1.8	52.6	41	9	1.3
8	04.120	95.0	2.1	45.2	180	10	0.3
9	04.044	64.6	9.6	6.7	360	155	12.4

Carbonates were determined by complexometric titration, Pb- and Zn-contents by atomic absorption in the Min. Petr. Institute, Berne.
The sample numbers correspond to the following rocks:
1 micritic cement between *Conophyton* columns
2 *Conophyton* lamelled dolomite
3 intrasparitic dolomite
4, 5 algal-laminated dolomites with *Collenia*-structures from separate outcrops.
6, 7 algal-laminated dolomites from separate outcrops
8, 9 purple sedimentary breccias from separate outcrops

Upper Shales

Shaly-carbonaceous unit. The shales are argillaceous to silty, some also graphitic and all more or less carbonaceous. They are of red, violet, pale orange and light grey to greenish colour. Intercalations of black, fine-grained dolomites with abundant stratiform silica layers are frequent in the lower part. The carbonate content of the shales decreases from bottom to top, the content of clastic detritus increases. The mineral assemblage[3]) is: illite, quartz, kaolinite, ± chlorite, ± hematite; dolomite, calcite. South of the mapped region thick bedded quartzites and arkoses overlie the shales. The exposed total thickness of this unit in the area of Cabeludo is approximately 250 meters.

[2]) WEDEPOHL (1971) notes a medium Pb-Zn-content in limestones and dolomites of 9 (Pb) and 23 ppm (Zn).

[3]) 17 samples of shales were investigated by the X-ray method. The qualitative mineral content was determined from diffractometer diagrams of airdried samples.

Lower Shales

These are exposed in the northeastern part of the mapped region, covering Serra Lajes and a small outcrop within the Conophyton area, as shown on Fig. 2. The minimum thickness exposed is 300 meters. The shales are of orange to yellowish and grey colour and contain argillaceous as well as silty components. Their mineral assemblage[3]) includes: illite, kaolinite, ± chlorite, ± quartz. Carbonates seem to be absent.

Metamorphism of Upper and Lower Shales

The crystallinity of illite (in the sense of KUBLER 1967) for both, Upper and Lower Shales varies between 2.5 and 4.5 and therefore suggests the grade of metamorphism to be of lower green shist facies (uppermost anchi- and beginning of the epizone). The pink to violet colour of many hematitic shales (upper shaly unit) is also thought to indicate this grade of metamorphism (increasing solid solution of TiO_2 in hematite, FREY 1969).

Columnar stromatolites

Conophyton cf. *cylindricus* MASLOV 1937, emend. KOMAR 1965

Outcrops and Morphology (Fig. 3,4,5)

The stromatolites are exposed in a number of pinnacles of light grey to yellowish weathered dolomite at the base of the dolomite unit. The selective erosion of variously intersected algal colonies allows the growth pattern to be studied in detail:

Columnar stromatolites are of up to 4 meters hight and a medium diameter of 30 cm. The pillars are vertical to slightly inclined without an evidently preferential direction. They can be regarded as a mass of cones, one by one inserted into each other. All structures seen are sections of cones with an apical angle varying from 30 to 40°.

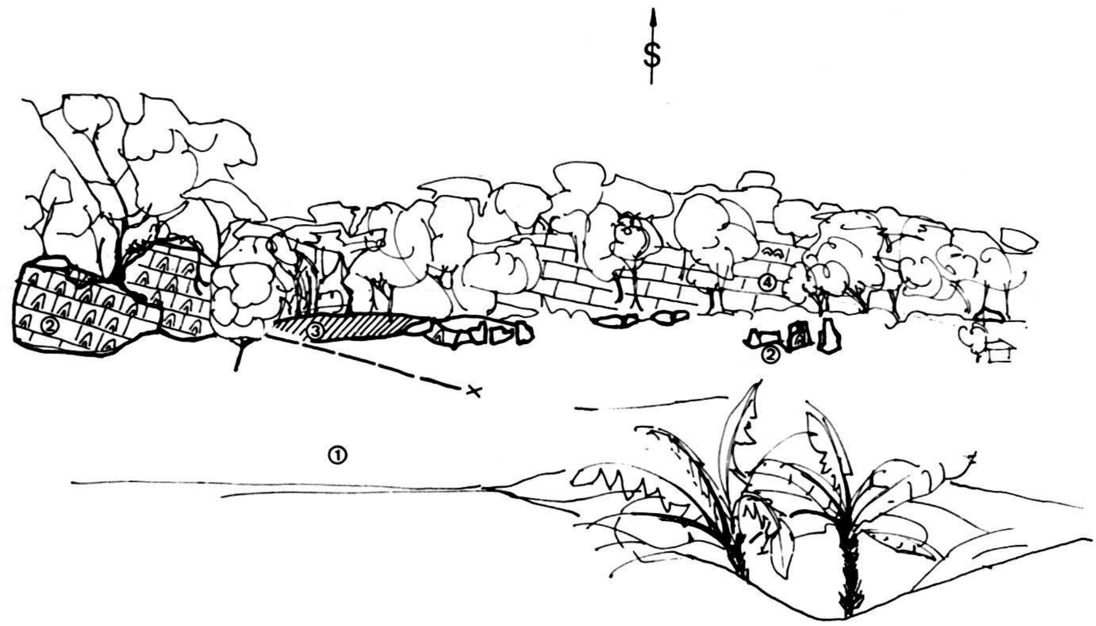

Fig. 3. View of Cabeludo outcrops. The banana-trees in the foreground are situated in a sinkhole (carbonate underground). Explanations see Fig. 4.

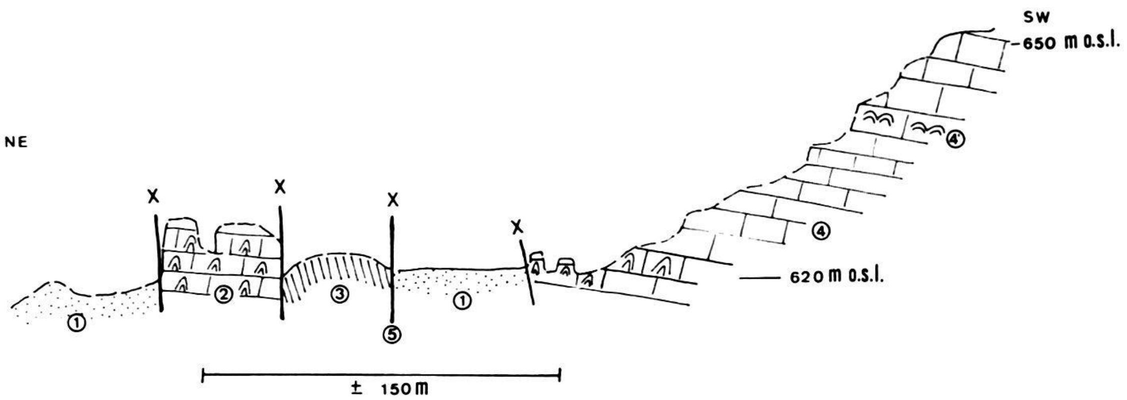

Fig. 4. Schematic cross section of the outcrops (exagerated in vertical scale). Explanations: 1 (lateritic soil), 2 (dolomites with *Conophyton*), 3 (Lower Shales), 4 (algal-laminated dolomites), 4′ (*Collenia* horizon), 5 (fracture zones).

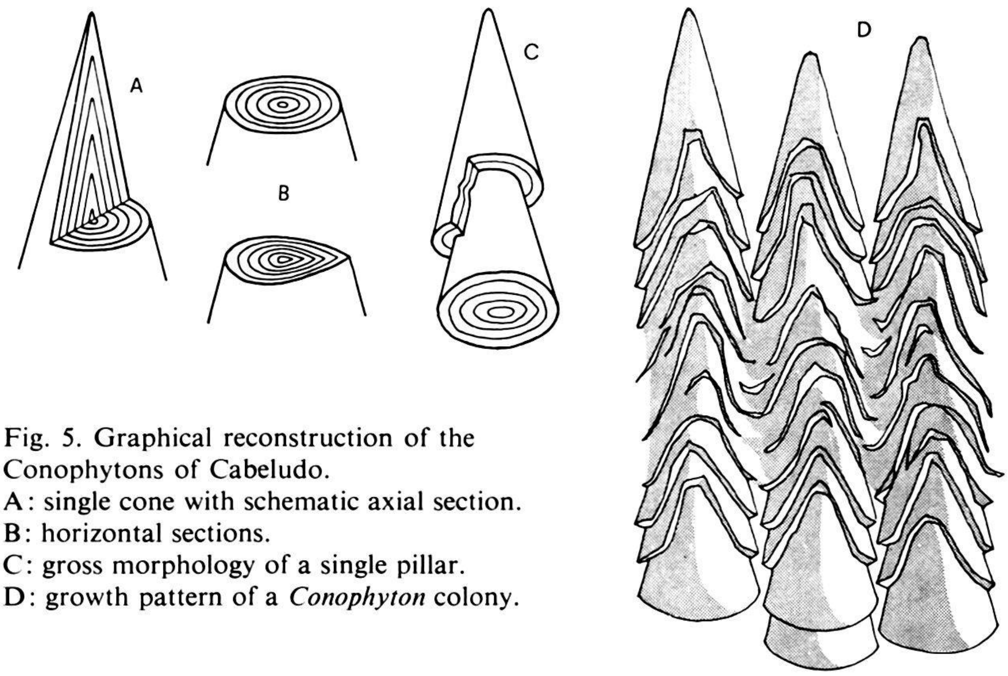

Fig. 5. Graphical reconstruction of the Conophytons of Cabeludo.
A: single cone with schematic axial section.
B: horizontal sections.
C: gross morphology of a single pillar.
D: growth pattern of a *Conophyton* colony.

Plan outlines are sometimes circular (section perpendicular to the axis), but mostly elliptical or drop-shaped. These forms of stream-like sections result from a predominant direction of wave action. Irregularities of sections also depend on the variable space between growing pillars (0.5–10 cm). Closely packed columns rarely show circular plan outlines.

Internal structure (Fig. 6)

The internal structure was studied in thin sections as well as on polished surfaces (see Plates III and IV). Alternation of distinct dark and light lamellae, the main feature of stromatolites, is very well preserved.

a) *Dark lamellae:* these consist of cryptocrystalline dolomitic layers (all thin sections have been stained, EVAMY 1963). These lamellae might originate from algal mats (?), often broken and partly pelleted. They are sometimes accompanied by an internal sediment, consisting of a lighter grey, dolomitic lutite (Fig. 1, 2; Table III).

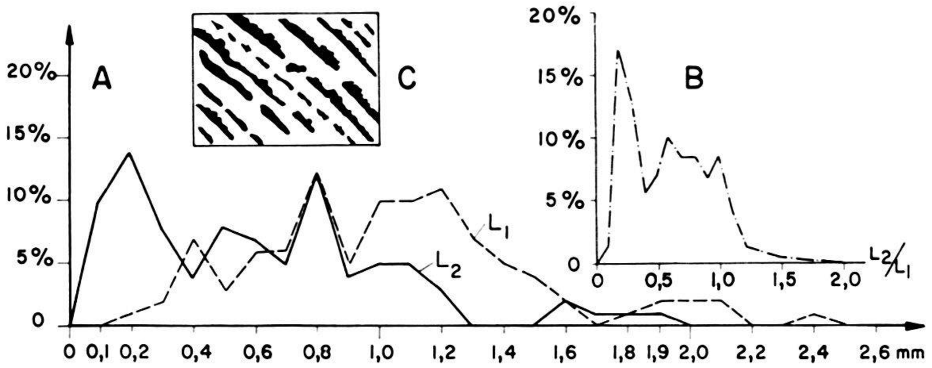

Fig. 6. Internal structure of the Conophytons of Cabeludo (based on 100 measurements in several samples of the Cabeludo locality).
A: thickness of light (L_1) and dark (L_2) laminae.
B: ratio of thickness for each pair of adjacent laminae.
C: schematic texture of microstrata.

The thickness of dark laminae shows a great variation and ranges in our samples from 0.1 to 2.0 mm as shown on Figure 6. Their boundaries are more distinct on the side towards the axis. The lamellae boundaries are sometimes pronounced by stylolites and synsedimentary deposited chalcedony layers.

b) *Light lamellae:* these consist of fibrous and coarsely crystalline, interlocking dolomite (grain size ∅ 15–100 microns), representing probably carbonate mud trapped by the algal mats. Within these layers the grain size increases towards the center. There the dolomite may become rich in iron and some authigenic quartz grains may occur. Fibrous (type A) and drusy (type B) dolomite cement represent two generations of cementation as shown by GRAF and LAMAR (1960). The light lamellae may include thin fragments of dark lamellae. The thickness of the light layers varies between 0.1 and 2.5 mm and is in general only a little broader than the dark ones.

The ratio of thickness of adjacent dark and light lamellae as defined by KOMAR et al. (1965) varies between 0.2 and 1.5 with most samples lying between 0.2 and 1.0.

No continuation of internal laminae from one column to the neighbouring one has been observed.

c) *Axial zone:* the bending of the lamellae in the apex of the cone is accompanied by a thickening of lamellae, which are in some cases broken into fragments (see Plate II, Fig. 4). The diameter of this zone in the sense of KOMAR et al. (1965) varies between 5 and 8 mm.

Classification

Two types of classification of fossil stromatolites are discussed here:

Descriptive nomenclature (LOGAN et al. 1964)

It is based on the assumption that morphology of stromatolites depends on environmental conditions only. The nomenclature, therefore, is purely descriptive and is based upon the geometric form which is directly attributed to the environment as known from recent occurrences. This logical and useful nomenclature has the hemispheroid as the only basic geometric unit. However, this system does not apply to the conically shaped stromatolites. Hence we are forced to use the other, although less significant classification, as applied and described by RAABEN (1964), KOMAR et al. (1965), CLOUD et al. (1969), namely the

Binominal nomenclature

Using such features as gross morphology, manner of ramification and microstructure, the above mentioned authors classify the columnar stromatolites into groups ("genera"). Further subdivision into subgroups ("species") is given by statistical analysis of dimensions of laminae and characteristics of axial and marginal zones. Estimating that stromatolite morphology might be of biological and geochronological value, the Russian geologists succeeded in using their taxa for subdividing the Late Precambrian of the USSR.

The columnar stromatolites of Cabeludo are very similar to the subgroup *Conophyton cylindricus* MASLOV 1937 emend. KOMAR 1965. Features which are similar to the main characteristics of this subgroup include: shape of columns, thickness of laminae, texture of microstrata and dimensions of axial zone. There is only a slight difference from our forms (see Fig. 6) to those of KOMAR et al. 1965 (Fig. 26, p. 62) concerning the ratio of thickness of adjacent lamellae. With regard to this ratio only, ours also show faint similarities to the subgroup *Conophyton garganicus* KOROLJUK 1960.

Environment

No modern analogy of *Conophyton* has been described[4]) so far and only few attempts of environmental interpretations are known to the author (LOGAN 1957, TROMPETTE 1969, BERTRAND-SARFATI 1972). However, macroscopic and microscopic observations may serve as indications for chemical and physical conditions which were active at times of deposition and diagenesis of the Cabeludo Conophytons:
- the considerable height of the described stromatolites requires early lithification and, therefore, a great rate of sedimentation as shown by GEBELEIN (1969) in the Bermudas;
- since there is no obvious sign of dessication in the outcrops there is no reason for accepting intertidal or supratidal conditions;
- elongation of the plan outlines in most columns points to an influence of relatively strong permanent water currents;
- the absence of micritic matrix (see Plate III) also suggests a rather high-energy environment.

These observations point to a highly energetic subtidal basin as the most probable environment during growth-time of the *Conophyton* stromatolites.

The algal laminated dolomites, including a *Collenia* horizon which overlie the *Conophyton* zone (Fig. 4), indicate a later gradual change from offshore to tidal-flat environment. This regressive phase, creating intertidal to supratidal, hypersaline conditions might also explain the observed early diagenetic dolomite and chert (see Plate III, Fig. 1 and 3).

[4]) Discrete stromatolitic columns of up to 1 meter relief which, in our opinion, might be compared with *Conophyton* are mentioned in HOFFMANN et al. (1971). They were found in zones with strong wave action in the hypersaline Shark Bay, Western Australia.

Age

All *Conophyton* stromatolites are restricted to the Proterozoic. This was first shown by Russian authors from occurrences of widely separated regions of the USSR and Spitzbergen (KOMAR et al. 1956, RAABEN 1969 and others) and is now confirmed from North America, Australia and Africa (see CLOUD et al., 1969, p. 1030 ff.).

Conophyton cf. *cylindricus* MASLOV 1937, emend. KOMAR 1965 is a typical lower Middle Riphean stromatolite and indicates an age interval of 1650–950 my. This "species" is known from the lower Middle Riphean of the USSR; Syeh Limestone and Missoula Group in the Belt Series (Montana, USA) and the Mescal Limestone in the Apache Group (Arizona, USA). The new finding of *C.* cf. *cylindricus* in the Bambui Group of Brazil is in accordance with the geological evidence of a Late Precambrian age (EBERT 1956, BEURLEN 1956, CASSEDANNE 1964).

These results apparently contradict the radiometric data obtained by AMARAL et al. (1967) on the Bambui shales of Vazante. The authors give an age of 600 ± 50 my (Rb-Sr whole-rock method) for the Bambui Group. Although there is a minimum age difference of 300 my, compared with the Russian observations, both determinations lie within the Late Precambrian.

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Plate I

Conophyton cf. *cylindricus* MASLOV emend. KOMAR

Fig. 1 — Exposed dolomitic pinnacle with vertical sectioned columnar stromatolites of a total height of 3.50 meters. The columns are closely packed but without visible continuation of lamellae from one pillar to the neighbouring one (see also Fig. 5D). The pillars are light grey, regions in between are yellowish weathering. The apical angle is about 40°.

Fig. 2, 3 — Circular and drop-shaped plan outlines. The orientation of the drop-shaped ones, in accordance with measurements in nearby outcrops, is about SW–NE. Taking this direction as parallel to the runoff tidal waters we can estimate a NW–SE running coast line.

Fig. 4 — Well exposed pillar with visible conic shape and disposition of lamellae.

Fig. 5 — Detail of a pillar with circular plan outlines and smooth surface.

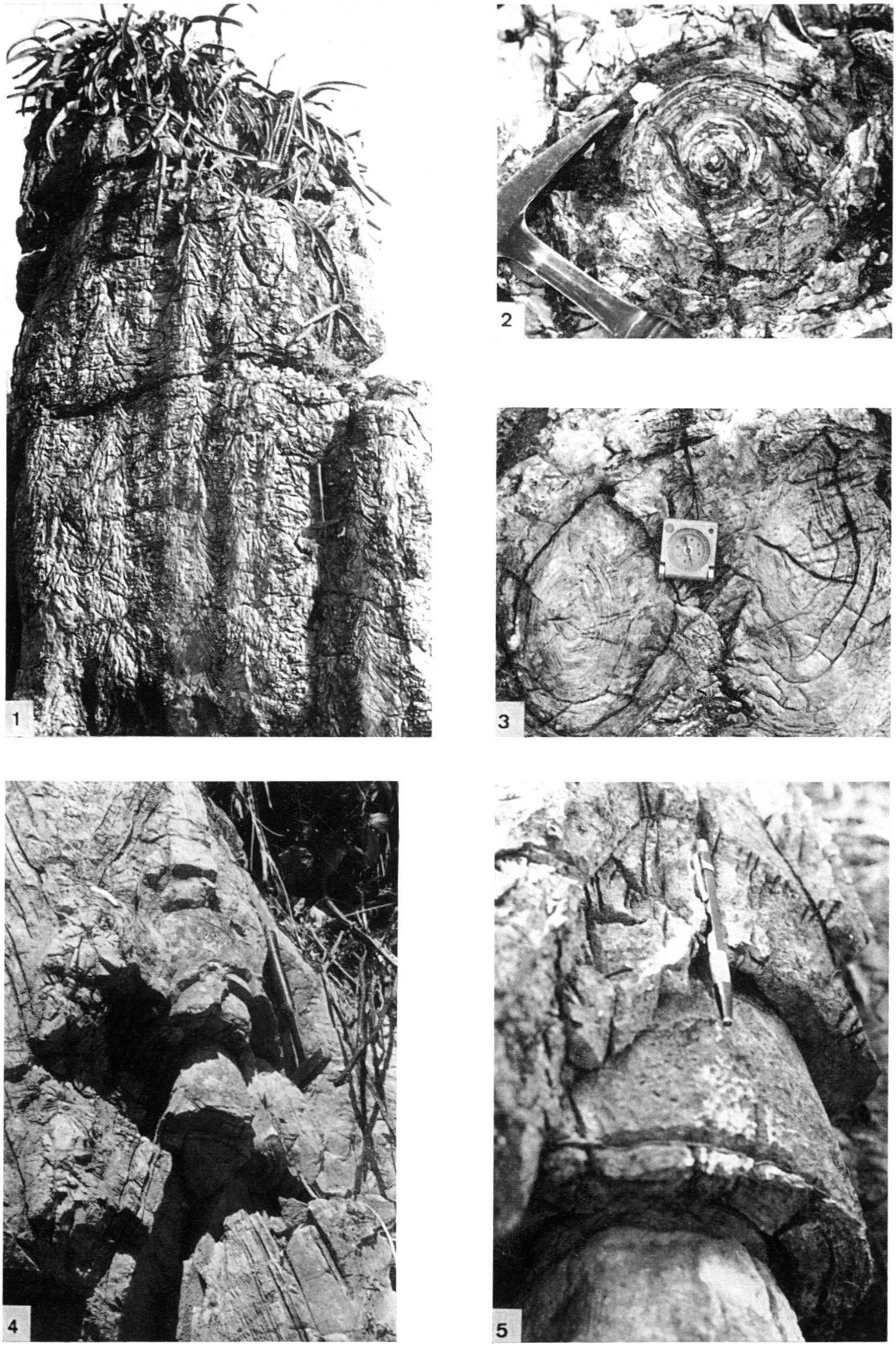

1
2
3
4
5

Plate II

Conophyton cf. *cylindricus* MASLOV emend. KOMAR

Fig. 1 Single cone. Total height 24 cm, diameter 26 cm.

Fig. 2 Polished horizontal section of an elongated cone with internal structure. The dark lamellae are partly broken and sometimes pelleted. The white spots represent coarse crystalline vugs.

Fig. 3 Single weathered cone, vertical section polished.

Fig. 4 Detail of the vertical section shown on Fig. 3 with axial zone of about 5 mm in width.

Fig. 5 Thin section made of same slab as Fig. 2. Texture of microstrata with alternating dark and light lamellae. Centre of the picture with fine fragments of dark lamellae embedded in white ones.

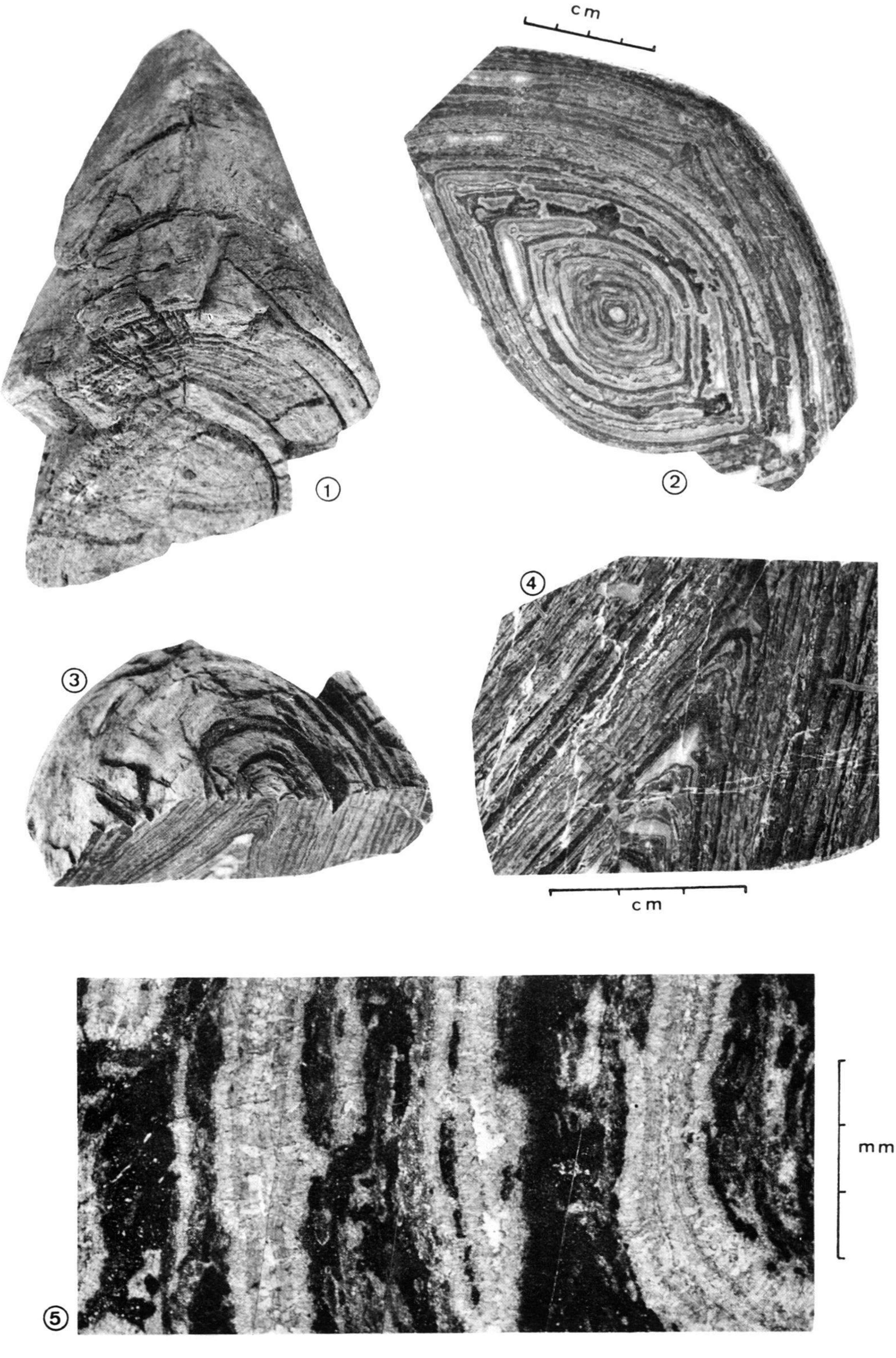

cm
1
2
4
3
cm
mm
5

Plate III

Fig. 1–3 *Conophyton* cf. *cylindricus* MASLOV emend. KOMAR

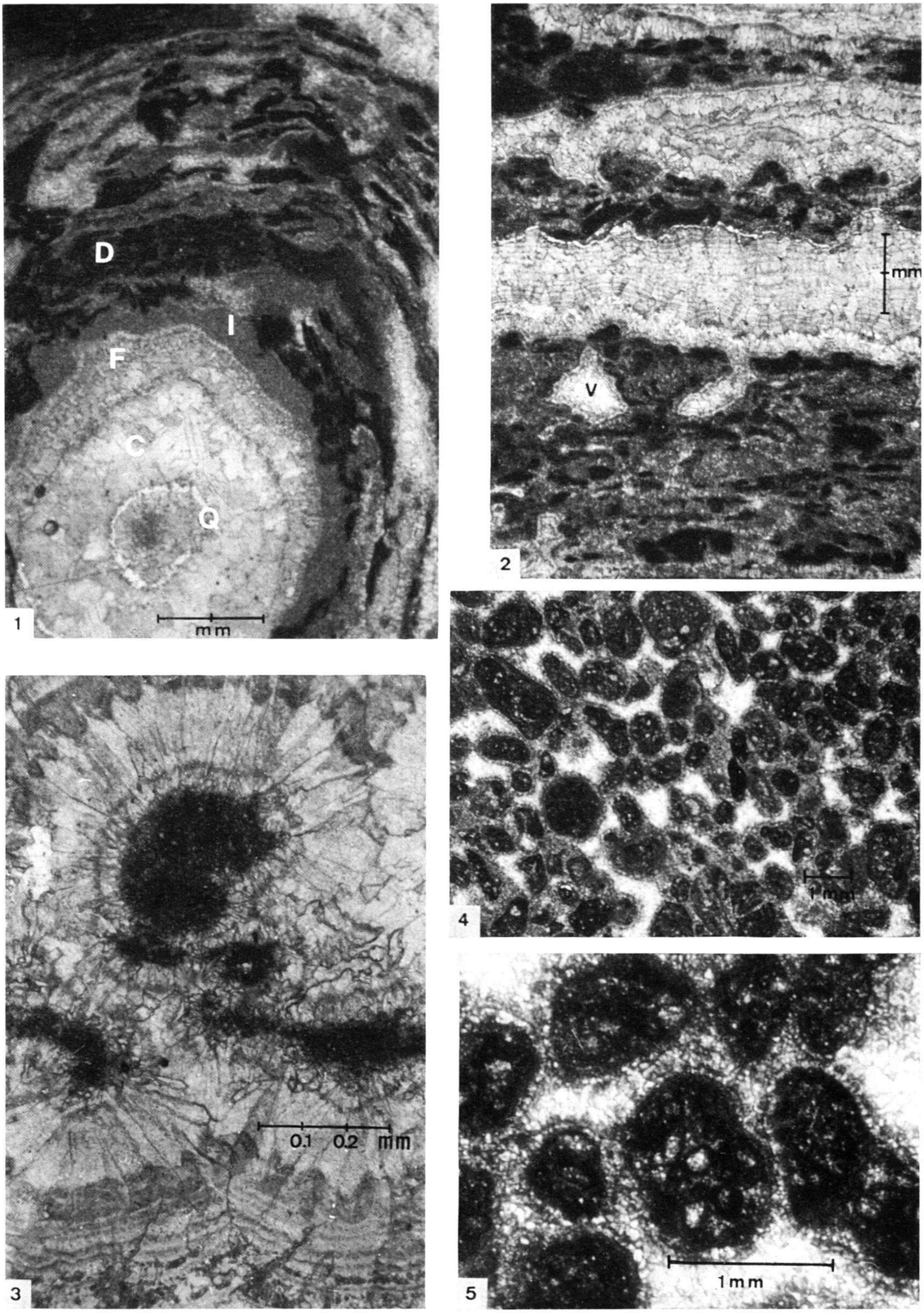
Fig. 1 Thin section of central part of slab shown on Plate II, Fig. 2.
Explanations: Q (silicified circle around axial zone), M (coarse crystalline dolomitic cement), F (fibrous cement), I (internal sediment), D (dark cryptocrystalline lamellae, irregularly broken and partly pelleted).

Fig. 2 External part of slab shown on Plate II, Fig. 2. Pelleted dark lamellae are well visible in the lower part. Small vugs (V), filled with fibrous and drusy cement. Dolomitization at least of the dark lamellae is of early diagenetic origin (before deposition of the internal sediment).

Fig. 3 Detail of fibrous cement growing from dark algal granules into vugs. Concentric growing is obvious. The dark granules represent fragments of dark stromatolitic lamellae (thin section of slab shown on Plate II, Fig. 2).

Fig. 4 Intrasparitic dolomite with micritic, internally structured dark intraclasts, consisting of aggregated possibly algal fragments. The intraclasts are encircled by a fine fibrous cement. Interparticle pores are filled with sparry mosaic. Environmental interpretation: shallow marine, high to moderate energy.

Fig. 5 Detail of Fig. 4, showing the internal structure of the intraclasts.


D
I
F
C
Q
mm
1
mm
V
2
1 mm
4
0.1 0.2 mm
3
1mm
5