NEW STROMATOLITES FROM THE UPPER PRECAMBRIAN AÇUNGUI GROUP, EASTERN PARANÁ, BRAZIL, AND THEIR POTENTIAL STRATIGRAPHIC USE

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RESUMO

Foi descoberto recentemente uma nova forma de estromatólito colunar nos dolomitos da Formação Capiru do Grupo Açungui (Pré-Cambriano Superior), em duas localidades distantes 25 km entre si, na região do Anticlinal do Setuva, leste do Estado do Paraná. Estes estromatólitos compreendem numerosas colunas delgadas (1-20 mm de diâmetro e até 100 mm de comprimento), retas a tortas (ou irregularmente maciças), paralelas entre si, com poucas ramificações e com margens denteadas a lisas. Parecem constituir biostromas e, em ambas as localidades, estão associados a estromatólitos colunares maiores. A semelhança entre os estromatólitos das duas seqüências sugere a possibilidade de sua utilização na definição de um horizonte-guia nos dolomitos Capiru. Por outro lado, as diferenças entre estes estromatólitos e os da Formação Itaiacoca, também do Grupo Açungui, favorecem a manutenção destas unidades como entidades estratigráficas distintas.

INTRODUCTION

Stromatolites have been known in the Upper Pre-Cambrian Açungui Group since 1944 when ALMEIDA described *Collenia itapevensis* from dolostones near Itapeva, São Paulo, southeastern Brazil. Later, ALMEIDA (1957) recorded additional occurrences from the same NE-trending band of carbonate-rich metasediments, which he denominated the Itaiacoca Formation, while almost simultaneously BIGARELLA & SALAMUNI (1956) were reporting "*Collenia*"-like stromatolites from the largely dolomitic Capiru Formation, which parallels the Itaiacoca Formation 40 to 60 km to the southeast. The occurrence of stromatolites in these two formations has been cited as evidence favoring their correlation (MARINI *et al.*, 1967). Like MARINI & BÓSIO (1971), FAIRCHILD (1977) questioned this practice, noting that the stromatolite assemblages of the two formations are distinctly different, for example, *Conophyton* occurs in the Itaiacoca Formation but not in the Capiru Formation. The recent discovery of identical, very small, columnar stromatolites from two localities 25 km apart within the Capiru dolostones (Fig. 1) supports this contention, as similar forms are unknown in the Itaiacoca Formation, and provides a potential time-reference criterion for unravelling stratigraphic and structural problems related to the Capiru Formation. Taxonomic classification of these stromatolites and a discussion of their biostratigraphic value will be the subject of another paper.

GEOLOGIC SETTING

Rocks in the area of the discovery, centered around the Setuva Anticline (Fig. 1), belong to at least three different structural units (SCHÖLL *et al.*, 1980): 1) A high-grade metamorphic basement complex ("Pre-Setuva Complex") of migmatites (with lesser anatectic granites, amphibolites, and ultrabasic rocks) and paragneisses, some of which still exhibit sedimentary features, occupies the core of the anticline and the eastern part of the area; 2) The Setuva Formation, in fault contact wich the basement complex, occurs on the flanks of the anticline and comprises no more tham 500 m of mica-schists, quartz-mica schists, and quartzites; 3) The least metamorphosed unit, the Açungui Group, flanks the Setuva Anticline and is made up of the Capiru Formation (BIGARELLA & SALAMUNI, 1956) or, more recently, Facies (SCHÖLL *et al.*, 1980), a predominantly chemical unit (metadolostones with subordinate quartzites, metasiltstones, and phyllites) and the Votuverava Formation (BIGARELLA & SALAMUNI, 1958) or Facies (SCHÖLL *et al.*, 1980), an essentially fine-grained metaclastic unit (phyllites, metasiltstones, metarhythmites, and quartzites) with some carbonate and basic rocks. Together, the Capiru and Votuverava Facies total about 500 m in thickness in this area.

Recent work (SCHÖLL *et al.*, 1980; LOPES, 1981, SCHÖLL, 1981) suggests that deposition of the Açungui Group was strongly influenced by synsedimentary tectonism, such

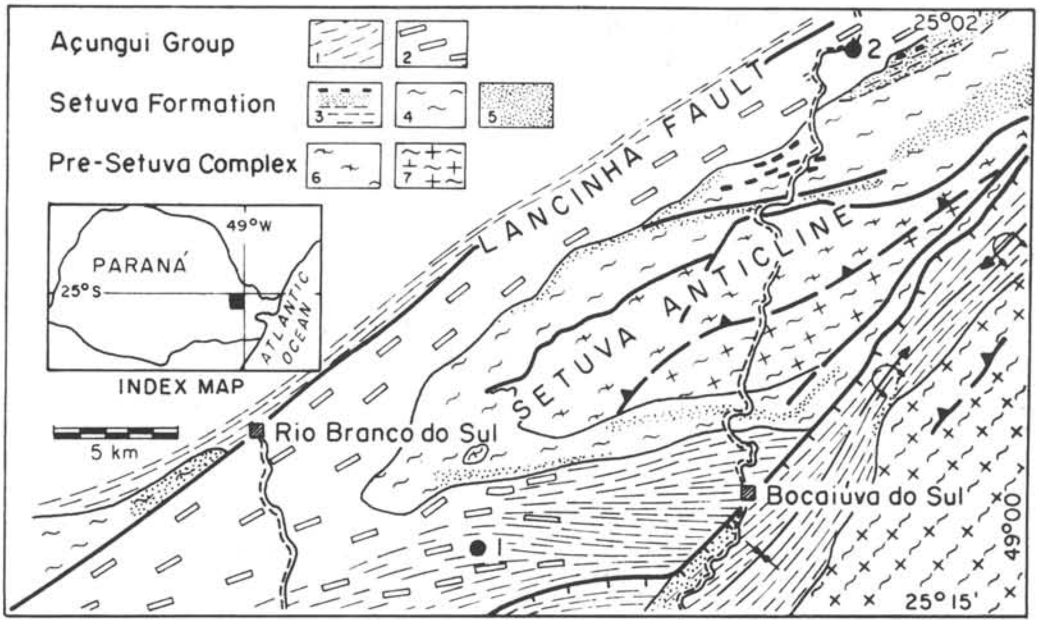


Fig. 1 – Simplified map of Precambrian geology in the Setuva Anticline region (after SCHÖLL *et al.*, 1980). Black circles indicate fossil localities: 1 = Bacaetava; 2 = Calfibra. Faults are shown by heavy lines. Continuous/dashed pair of lines indicates main roads. Legend for lithologic symbols: Açungui Group – *1*, Votuverava Facies, *2*, Capiru Facies. Setuva Formation – *3*, Calc-schists, fine ferruginous quartzites and marbles; *4*, Schists; *5*, Quartzites. Pre-Setuva Complex – *6*, Paragneisses, *7*, Migmatites.

as vertical faulting along the Lancinha Fault and faults in the eastern and southern portions of the area, and by the apparent arching of the Setuva Anticline. Both the Capiru and Votuverava Facies represent calm, shallow-water deposits. The former, with its dolostones, stromatolites, and evidence for intermittent penecontemporaneous karstification (SCHÖLL *et al.*, 1980), was laid down under somewhat evaporitic, periodically exposed, very shallow-water (intertidal?) conditions, while the latter was deposited at least partly penecontemporaneously further east in deeper waters of the same shallow platformal basin.

Metamorphic events of the Late Precambrian Brasiliano Cycle make precise determination of the depositional age of the Açungui Group difficult. The presently available maximum date for initiation of sedimentation is 1395 ± 145 m.y. (Rb-Sr isochronic age of gneisses from the Setuva Formation; BATTOLA *et al.*, 1977). On the other hand, the Açungui must have been deposited prior to 610 m.y. (CORDANI & KAWASHITA, 1971) or 650 m.y. (CORDANI & BITTENCOURT, 1967), the Rb-Sr isochronic and K-Ar ages, respectively, for granites syntectonic with deformation of the Group. Previous stromatolite studies (FAIRCHILD), 1977) tentatively suggest an age older than 850 m.y. for the Itaiacoca Formation, but this value is of unknown applicability for the Capiru Facies since these two units have yet to be shown to be coeval. Thus, presently admissible age limits for the stromatolites described here fall within the Middle to Late Proterozoic or, in other terms, roughly within the Riphean of Soviet geologits (CHUMAKOV & SEMIKHATOV, 1981).

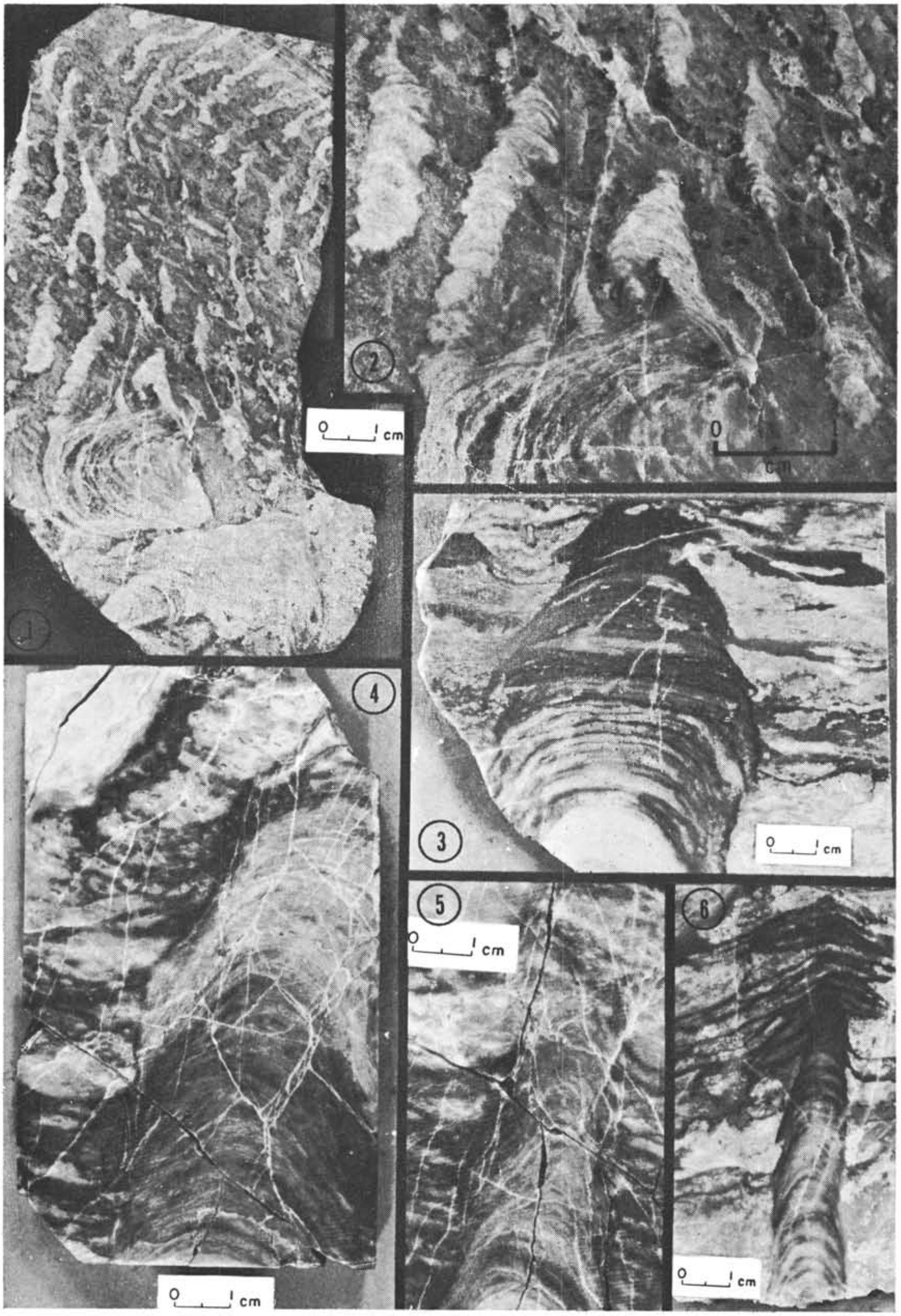
MODE OF OCCURRENCE OF THE STROMATOLITES

The studied material comes from two dolostone quarries in the Capiru Facies of the

Plate 1

Photographs of longitudinal sections of stromatolites from the Capiru Facies, Açungui Group, in the Setuva anticline area. *1, 2,* Sample 3T/1256, Bacaetava locality, showing typical smaller columnar stromatolites. Note the growth of small columns from the larger toppled stromatolite in *2;* compare with Fig. 2c. *3, 6,* Sample 3T/1255, larger stromatolites from the Bacaetava locality (*3*, slab face L-7, *6*, slab face F-4, perpendicular to slab face L-7). Note laminae extending into the intercolumnar area at the top of the sample in *6*. *4, 5,* Sample 3T/1261, larger stromatolites from the Calfibra locality (*4*, slab face 6; *5*, slab face 12); compare with *3* and *6*.

PLATE 1



Açungui Group (Fig. 1). Locality 1, located 8 km north of Colombo, Paraná, is herein referred to as the "Bacaetava" locality because of its proximity to the Gruta de Bacaetava 1-2 km to the east; Locality 2 is the lower quarry of the Calfibra company, immediately east of km 63.5 of the Bacaiúva do Sul – Ribeira road (Highway BR-476). At Locality 1, the stromatolites are better preserverd, though less abundant, than at Locality 2, where they have apparently suffered more intense metamorphism, as evidenced by the presence of fine-grained marbles in the same quarry.

The small stromatolites described below were observed in outcrop only at the Calfibra locality, where, together with rare larger forms, they occur abundantly within a 2-3-m-thick bed, apparently a biostrome, capping a small bioherm, 1.5-2 m thick and at least 4-6 m wide, made up of larger unbranched columnar stromatolites up to 9 cm wide and 28 cm high (Pl. 1, figs. 4-5). The Bacaetava samples were collected from quarry rubble which also yielded blocks containing larger unbranched columnar stromatolites (Pl. 1, figs. 3,6) comparable to the larger Calfibra stromatolites. At Bacaetava, the small stromatolites also seem to cap larger forms, as shown in Pl. 1, figs. 1-2 and in Fig. 2c, but have yet to be observed in beds (biostromes?) thicker than about 20 cm (sample 3T/1258).

Although detailed stratigraphic sections are not yet available for either locality, very similar, distinctive intraformational breccias are present in both sequences. These breccias vary from beds containing medium-gray flat carbonate chips, a few mm thick and less than a cm long, together with some centimetric clasts (including stromatolite fragments at Bacaetava) to more chaotic accumulations of much larger blocks (up to 13 x 27 cm in cross-section, also at Bacaetava).

DESCRIPTION OF THE SMALL STROMATOLITES

Because of their very distinct, easily identifiable morphology and, consequently, their potential value in defining a marker horizon within the Capiru dolostones, the smaller stromatolites (Figs. 2-3; Pl. 1, figs. 1-2) are described in detail below. The larger forms (Pl. 1, figs. 3-6) require further study.

Small branching stromatolites

Mostly parallel or subparallel, straight, bent, crooked, knobby, or irregularly massive, closely spaced, very narrow, abundant columnar stromatolites, commonly thickening and thinning irregularly in diameter, with bumpy, serrate, ragged, or partly smooth margins. Some laminae may extend into the adjacent intercolumnar area, but coalescence and lateral linkage between columns are rare. Approxi-

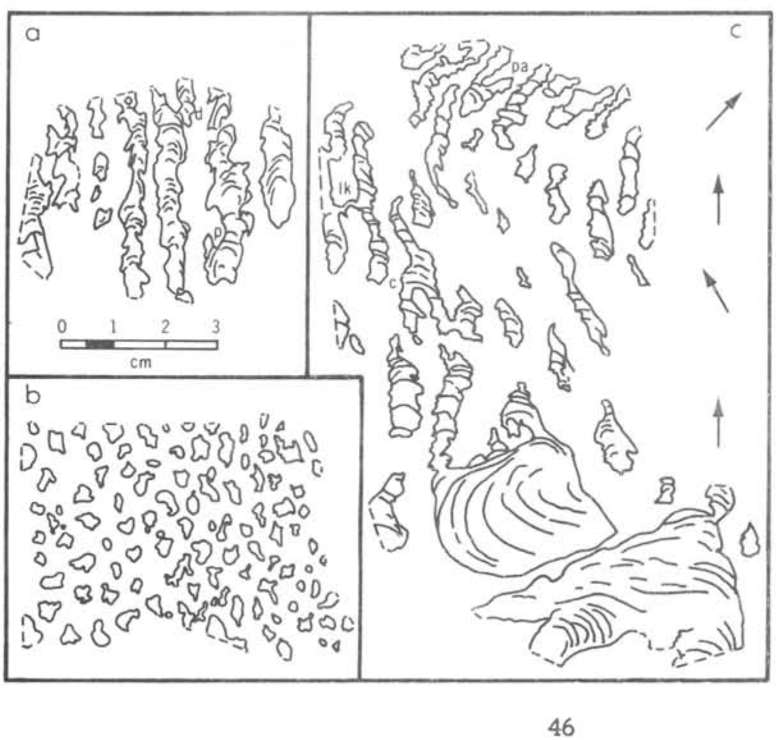


Fig. 2 – Tracings of cut faces of small stromatolites from the Bacaetava locality. Scale in *2a* is valid for all figures. Dashed lines indicate sample margin or approximate limits of the columns. Representative laminae are shown in most columns. *2a, b,* Longitudinal and transverse sections, respectively, of sample 3T/1257. *2c,* Longitudinal section of sample 3T/1256 showing small stromatolites developing directly upon toppled fragment of larger stromatolite. Arrows at right illustrate successive changes in direction of growth vector of the columns (Also see Pl. 1, figs. 1, 2). Legend: *c* = coalescence; *d* = divergent branching; *lk* = lateral linkage; *p* = projection; *pa* = parallel branching.

mately 10% of the columns exhibit branching, which is generally slightly divergent, although varieties in which the column expands slightly or significantly just prior to branching are also present. Short lateral projections are present in some columns. Transverse cross-sections are irregularly shaped and lobate, or equidimensional to elongate with subrounded to subangular contours. Column diameters range between 1 and 12 mm, exceptionally reaching 20 mm. (The largest observed transverse cross-section measured 24 x 49 mm but apparently represents an atypical, compound form.) Lengths (heights) rarely exceed 50 mm, but may reach 100 mm. Laminae are faintly preserved yet distinguishable as very thin (approximately 0.1 – 0.5 mm), slightly to moderately convex, less commonly parabolic, lamellae, not uncommonly slightly asymmetric. Synoptic relief (relief of individual laminae) is generally low, less than 5 mm, rarely reaching 10 mm. Groups of columns may show sudden changes in direction of growth vector yet still retain a roughly parallel orientation among the columns (Pl 1, Fig. 1; Fig. 2c). The stromatolites are typically pale tones of yellowish orange or yellowish gray and much lighter than the surrounding, intercolumnar sediments, which may be as dark as dark-medium gray. Matrix and stromatolites exhibit the same weak effervescence in 10% HCl suggestive of a dolomitic composition for both.

A glance at Table 1 and Figs. 2 and 3 convincingly demonstrates that despite minor differences in size and morphological variety the stromatolites from the two localities are nearly identical in the features most important in stromatolite taxonomy (style and frequency of branching, shape, habit and laminar details).

MORPHOGENESIS

At all stages of their development, the small stromatolites probably appeared as abundant, closely spaced but largely unconnected, tiny mounds less than a cm in diameter and only a few mm to perhaps a cm in height, each covered by a thin, actively growing, microbial mat. Physical elements in their environment, such as water turbulence or currents, may have effected sudden changes in diameter

Fig. 3 – Tracings of cut faces of samples of small stromatolites from the Calfibra locality. Scale in *3a* is valid for all figures. Dashed lines indicate sample margin or approximate limits of the columns. Representative laminae are shown in most columns. *3a, b,* Longitudinal and transverse sections, respectively, of sample 3T/1260. *3c,* Longitudinal sections of larger examples of small stromatolites (sample 3T/1259). *3d,* Longitudinal section of unusually complex example (sample 3T/1262). Legend as in Figure 2 with the following addition: *ib* = incipient branching.

and the occasional off-setting of successive laminae and prevented even very closely spaced columns from developing lateral linkages. Occasional changes in the direction of unidirectional or oscillating currents (tidal currents?) could have caused largely simultaneous changes in the growth vectors of a large number of columns (Pl. 1, fig. 1; Fig. 2c). Such currents may also have played an important role in the preferential transverse elongation of columns (Fig. 3b) (HOFFMAN, 1976a; PLAYFORD & COCKBAIN, 1976) and in the development of laminar asymmetry. Yet had currents or water turbulence been very strong, it is difficult to imagine how such small, unlinked stromatolitic mats could have survived the resultant disruption, abrasion, and/or burial, unless they were lithified very early by carbonate precipitation within or immediately beneath the active microbial mats (GOLUBIC, 1973; MONTY, 1976). The scattered presence of tiny goethite pseudomorphs after pyrite in many of the columns suggests that lithification may not have taken place until after initiation of bacterial reduction of organic sulfate to H_2S and subsequent inorganic formation of FeS_2 (EHRLICH, 1981) within the older portions of the stromatolite-forming mat. Based on these considerations, the depositional environment thus envisaged for these stromatolites is a shallow-water, possibly low-energy intertidal setting with mild current action.

STRATIGRAPHICAL USE

Precambian stromatolites have been used not only in biostratigraphy (BERTRAND-SARFATI & WALTER, 1981) but also in intrabasinal correlation (BERTRAND-SARFATI & TROMPETTE, 1976) and paleogeographic analysis (HOFFMAN, 1967; 1974; 1976b; CAMPBELL & CECILE, 1981). Although it would be premature to attempt intercontinental or even interbasinal biostratigraphic correlations using the still incompletely known Capiru stromatolites, it must be noted that the forms described here are different from all other

TABLE 1 – Comparison of the small stromatolites from the Bacaetava and Calfibra localities

	Bacaetava locality	Calfibra locality
Mode of occurrence	Uncertain, possibly as thin (to 20 cm) biostromes	Biostrome 2-3 m thick, capping, at least in part, a small bioherm of larger stromatolites.
Color	Grayish orange pink (5YR 7/2) to yellowish gray (5Y 8/1)	Intermediate between very pale orange (10YR 8/2) and pale yellowish orange (10YR 8/6)
Size	1-8.5 mm wide; up to 43 m long	1-22 mm wide; up to 100 m long (rarely)
Abundance		
In long section	78 columns in 3 slab faces totalling 98 cm² in area	59 columns in 3 slab faces totalling 172 cm² in area
In transverse section	90 columns in 1 section totalling 25 cm² in area	56 columns in 1 section totalling 71 cm² in area
Branching		
Number of columns	78	59 or 60
Unbranched columns	69	54
Incipiently branched	2	2
Parallel branching	2	1 or 2
Slightly divergently branched	5	0
Markedly divergently branched	0	2
Short lateral projetions	4	7 or 8
Coalescence	3 cases	2 cases
Lateral linkage	1 case	None observed

stromatolites so far reported from Brazil, including those of the nearby Itaiacoca Formation. This last observation supports the maintenance of the Capiru Facies (or Formation) and the Itaiacoca Formation as separate stratigraphic units as advocated previously (FAIRCHILD, 1977).

Locally, however, these stromatolites should have immediate application in defining an important marker horizon within the Capiru Facies. The great similarity in environmentally influenced macrostructural elements (relief, asymetry, spacing, lack of linkage, etc.) and biologically influenced microstructural features (style and frequency of branching, ofr instance) (see GEBELEIN, 1974; SEMIKHATOV *et al.*, 1979) of the small stromatolites at the two localities, together with the apparent similarities in associated stromatolites and other sedimentary structures in the two sequences, connotes complex yet probably very similar physical and biological conditions at both localities. Although other interpretations may be entertained, it seems likely, as a working hypothesis, that the highly distinctive, small stromatolites may be useful as index-fossils for establishing points of temporal equivalence wherever they occur within the area covered by the Capiru Facies. If corroborated, this could have important implications for better understanding the depositional and deformational history of this unit in the area of the Setuva Anticline. Obviously, therefore, additional occurrences of these small stromatolites should be sought and documented in detail in order to test this idea.

CONCLUSIONS

The small stromatolites described here are different from previously reported forms in the Capiru Facies (see FAIRCHILD, 1977); they are easily identified in the field by their very small size, local abundance, parallel to subparallel habit, low freqency of branching, and light color. The fact that essentially identical forms have been found in localities 25 km apart suggests that additional finds may well corroborate their value, postulated here, for physical and quite possibly temporal correlation within the Capiru Facies. Further detailed field and laboratory studies should also clarify the paleoecologic and temporal relations between the Capiru Facies and the Itaiacoca Formation.

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APPENDIX

Figured samples, as well as the unfigured sample (3T/1258) mentioned above, are deposited in the Paleontology Collection of the Department of Paleontology and Stratigraphy, IGUSP.

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