MICROFOSSILS IN THE "EOPALEOZOIC" JACADIGO GROUP AT URUCUM, MATO GROSSO, SOUTHWEST BRAZIL

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and

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INTRODUCTION

Microfossils have been previously reported (YOSHIDA, et al., 1977) but never well documented from the famed, richly ferruginous, Jacadigo Group of probable "Eopaleozoic" age at Urucum, Mato Grosso, southwest Brazil. We describe here (1) spheroidal to flask-shaped microfossils, of possible protozoan affinity and up to 120 μm in length, in carbonate clasts of the arkosic Urucum Formation and (2) very rare, filamentous, algal or bacterial microfossils, 6-12 μm wide, with iron-oxide-replaced walls, from the overlying jaspilitic Santa Cruz Formation. These discoveries provide insight into problems of the stratigraphic position and provenance of the Jacadigo Group, furnish additional evidence favoring a relatively young age for the banded iron-formation (BIF) of the Santa Cruz Formation, and contribute to our growing paleobiologic understanding of "pre-Silurian" Brazilian sedimentary sequences that lack "conventional" fossils.

GEOLOGIC SETTING AND AGE

The Jacadigo Group is an unmetamorphosed, little deformed sedimentary sequence that occupies an area of more than 1000 km^2 south of Corumbá, Mato Grosso, and consists of two formations: the 280 m-thick Urucum Formation that begins with clastic sediments suggestive of fluviatile/continental conditions and passes upward into lacustrine or near-shore marine arkoses and conglomeratic arkoses with possible ice-rafted dropstones (DORR, 1973), and, disconformably above this, the 420 m-thick Santa Cruz Formation, characterized by jasper and massive, micro-, meso-, and, macro-banded jaspilite (alternating layers of very fine-grained iron oxide and silica – Fig. 1), with several large, important cryptomelane lenses as well as ferruginous and manganiferous arenites ant other clastics (ALMEIDA, 1945, HARALYI and BARBOUR, 1974, 1976). Up to 300m of jaspilite (BIF) were deposited under shallow-water, occasionally emergent conditions (HARALYI and BARBOUR, 1974), presumably within an arid environment (DORR, 1973). Even after initiation of jaspilite deposition, minor clastic sedimentation continued principally near the basin margins. With the gradual depletion of the sources of Mn and Fe, the jaspilite gave way to relatively less ferruginous, more siliceous and more clastic sediments (HARALYI and BARBOUR, 1974). The jaspilite is economically very important, comprising more than 50×10^9 tons of high-grade ore, averaging more than 50% Fe, and more than 300×10^6 tons of Mn-ore (HARALYI and BARBOUR, 1976).

Although imprecisely known, the age of the Jacadigo Group is widely held to be "Eopaleozoic", that is, no older than very latest Proterozoic, on the basis of its stratigraphic position well above the supposedly glaciogenic

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Jangada Group of presumed (but not proven) "Eocambrian" age (ALMEIDA, 1964), and no younger than Silurian because of its unmetamorphosed state and its traditional position above the Corumbá Group whose Bolivian equivalent is overlain unconformably by fossiliferous Silurian strata (LANGE, 1955, ALMEIDA, 1958).

Paleontologic evidence bearing on the age of the Jacadigo Group is scanty and rather inconclusive. Megascopic structures possibly representing impressions of large algae (DORR, 1945, apud DORR, 1973; Barbour and Haralyi, in preparation) from hematitic layers of the Santa Cruz Jaspilite and the flask-shaped microfossils, discussed below, from clasts in the Urucum Formation suggest an age no older than 800-850 Ma (Ma = 10^6 years) based on the known fossil records of complex megascopic algae (see SCHOPF, 1975, p. 233) and possible protozoans (BLOESER et al., 1977). Detailed restudy of stromatolites (ALMEIDA, 1958, 1965), very poorly preserved carbonaceous microfossils (*Bambuites* sp.; SOMMER, 1971), and millimetric tubular structures (*Aulophycus lucianoi*, BERLEN and SOMMER, 1957) in the underlying Corumbá Group may yield a better defined maximum age of the Jacadigo Group. Of the above, *A. lucianoi* offers the greatest potential biostratigraphical value, as it bears enough resemblance in its original description and figures to Early Cambrian worm tubes from Argentina (YOCHELSON and HERRERA, 1974) to warrant restudy of its originally suggested algal affinities and possible Middle to Late Cambrian age (Fairchild, in preparation). At present, however, the fossils in the Jacadigo and Corumbá Groups seem most consistent with an age between "Eocambrian" and Silurian, or perhaps even Cambrian to Silurian, for the Jacadigo Group.

Complicating this picture are DORR'S (1973) glacial interpretation of part of the Urucum Formation, which raises the possibility of an "Eocambrian" age for this formation, and HARALYI'S (1972) claim that the Corumbá Group postdates the Jacadigo Group. However, if globular microstructures from the basal unit of the Corumbá Group in the Serra da Bodoquena (ALMEIDA, 1965) prove identical to those described below from carbonate clasts in the Urucum Formation, Haralyi's case may be weakened in favor of ALMEIDA'S (1945) original stratigraphic scheme.

The filamentous microfossils described below and the questionably biogenic "microfossils" reported by YOSHIDA et al. (1967) from the Santa Cruz BIF have little geochronologic value.

METHOD OF STUDY

We examined 15 petrographic thin sections of conglomeratic arkose (4 with microfossiliferous carbonate clasts) from less than 10 m beneath the top of the Urucum Formation as well as 38 jasper and jaspilite thin sections and 6 unfossiliferous polished plugs of Mn-oxide (kindly provided by J. V. Valarelli, IGUSP) of the Santa Cruz Formation; all samples were collected at Morro do Urucum, 20 km SSE of Corumbá, Mato Grosso, Brazil. Microfossils were measured in thin sections. Figured material is deposited in the Paleontology Collection, Instituto de Geociências, Universidade de São Paulo; sample numbers accompany figure descriptions.

MICROFOSSILS OF THE SANTA CRUZ FORMATION AND THEIR INTERPRETATION

Rather poorly preserved filamentous microfossils (Figs. 2-4) were discovered several years ago by A. P. Barbour within a thin siliceous layer of the jaspilite (Fig. 1) of the Santa Cruz Formation. Subsequent examination of 38 petrographic thin sections of this formation has revealed no other clearly biogenic microstructures, despite YOSHIDA et al.'s (1967) claim of globular microfossils in this BIF.

The Santa Cruz microfossils comprise a cluster of straight to curved filaments, 5.6 to 12 μm in diameter (n = 12), with an average of 8.9 μm, a maximum observed length of 76 μm, and 1-2 μm-thick walls (or sheaths) replaced by submicron-sized, iron-

-oxide (presumably hematite) crystals (Fig. 4). Intracellular remains and cross-walls are not preserved, so that the filaments could be either cellular trichomes or cylindrical sheaths. Their size suggests affinities with either the blue-green algae or certain sheathed filamentous iron-bacteria (PRINGSHEIM, 1949).

The Santa Cruz filaments are also similar in size to silicified tubular algal sheaths in the ca. 2000 Ma-old Gunflint Iron-Formation (Canada) (BARGHOORN and TYLER, 1965, AWRAMIK and BARGHOORN, 1977) but are not sufficiently well preserved to allow closer comparisons. Nevertheless, despite this poor preservation and their apparent scarcity, they do offer hope that carefully collected chert samples may yet provide fossil evidence of the possible role of microorganisms in the deposition of the Santa Cruz BIF.

MICROFOSSILS IN THE URUCUM FORMATION AND THEIR INTERPRETATION

Light-gray, brecciated, partially recrystallized, apparently dolomitic, limestone cobbles and pebbles (Fig. 5) in conglomeratic arkose of the Urucum Formation contain locally abundant (12.5 individuals per cm^2 of thin section) spheroidal to flask-shaped microfossils, most commonly preserved within a micro- to cryptocrystalline matrix (Figs. 7-9). Of 64 measured microfossils, 31 appear spheroidal, 31 ellipsoidal (Figs. 7-10), and 2 flask-shaped (Figs. 11-13). They range from 16 to 120 μm in maximum dimension, most (40) being between 46 and 90 μm long. Five possess a collared or flanged polar opening (Figs. 8, 10-13), and 15 exhibit a thinner wall (Fig. 9) or possible aperture also generally in a polar position; others present poorly defined polar extensions or possible encrustations (Fig. 7).

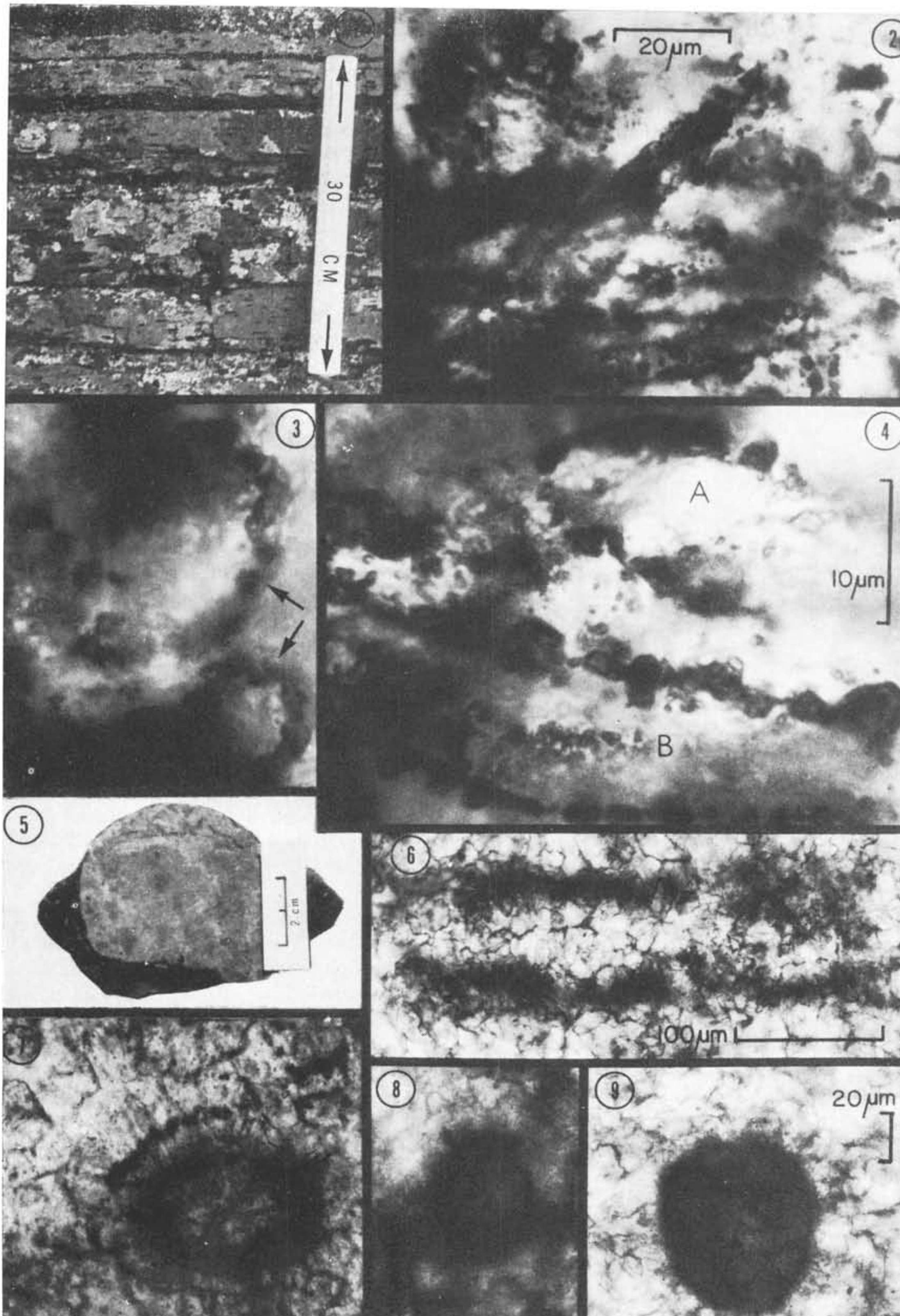
The microfossils are more darkly pigmented by organic matter than the matrix and have diffuse to very distinct margins. Because few individuals appear broken or crushed, the microfossils probably possessed firm, presumably mineralized walls. Original walls, however, are difficult to distinguish but may be present in a few cases as a 2-8 μm-thick layer of very narrow, fibrous crystals perpendicular to the margin. These "walls" are problematic because irregular growths of fibrous or bladed crystals (Fig. 7) radiate outward (up to 80 μm) from the surface of many specimens and penetrate inward in some.

That these microstructures are not altered oolites, despite superficial resemblances in shape and associated radial-fibrous fabric, is adequately demonstrated by the irregularity of the radial-fibrous growths, by the absence of multiple, concentric layering around or within the microstructures, and by the presense of apertures, some collared, in a significant number of specimens.

In size and shape, some of the collared, aperturate microfossils resemble microfossils of two groups of possible protozoans: (1) loricas of tintinnids – planktic, ciliate protozoans having an irregular geologic distribution from Ordovician to Recent (TAPPAN and LOEBLICH, 1968, HOROWITZ and POTTER, 1971); and (2) Precambrian chitinozoans, probably between 650 and 850 Ma old, from the Grand Canyon (USA) (BLOESER et al.,

PLATE 1 – Figs. 1-9

Photomicrographs of microfossils in petrographic thin sections (Figs. 2-4, 6? - 9) and photographs of outcrop (Fig. 1), and microfossiliferous sample (Fig. 5), Jacadigo Group, Urucum, Mato Grosso, Scale in Fig. 4 serves Fig. 3; that in Fig. 9 also serves Figs. 7,8. Microfossiliferous thin sections (Figs. 2-4 = GP/L-3T-46; Figs. 6,9 = GP/L-3T-44; Figs. 7,8 = GP/L-3T-45) and hand sample (Fig. 5 = GP/3T-559) deposited in the Paleontology Collection, IG-USP. Figs. 1-4, Santa Cruz Formation: Fig. 1, Lichen-covered outcrop of iron-ore and less resistent siliceous layers, Morro do Urucum; Fig. 2, Overview of filamentous microfossils having iron-oxide-replaced walls; Fig. 3, Close-up of oblique elliptical and circular cross-sections (arrows); Fig. 4, close-up of oblique (A) and of longitudinal (B) sections clearly showing iron-oxide platelets in walls. Figs. 5-9, Urucum Formation: Fig. 5, sliced microfossiliferous carbonate cobble within darker arkosoic matrix; Fig. 6, Parallel organic streaks possibly representing vestiges of a large tubular (algal?) microfossil; Figs. 7-9. Possibly protozoan microfossils, note irregular, radial-bladed, crystals and "shoved-out" material (dark) in Fig. 7, flanged aperture in Fig. 8 (compare Fig. 10), and thin wall at top (and bottom?) of specimen in Fig. 9.


2
20μm
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9
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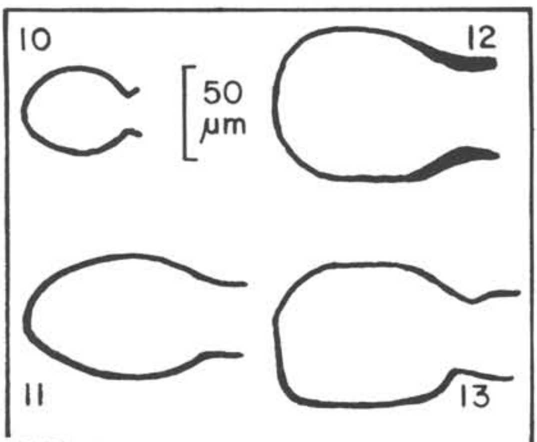
1977). Additionally, the "walls" of the Urucum microfossils are possibly structurally and compositionally similar to those of some tintinnids. Overall, the similarities among these three groups suggest possible protozoan affinities for the Urucum microfossils. Consequently, together with evidence cited in a previous section, this implies an age for the source rocks of the microfossiliferous carbonate clasts of probably no greater than that (850 Ma at most) of the Grand Canyon chitinozoans – the oldest presently known microfossils with possible protozoan affinities.



FIGS. 10-13

Drawings based on transmitted light microscopy of flanged, aperturate microfossils in a petrographic thin section (GP/L-3T-45) of a carbonate clast from the Urucum Formation, Morro do Urucum, Mato Grosso. All figures at same scale. Fig. 10 illustrates specimen shown in Fig. 8. Fig. 12 is an apparently oblique section of a microfossil with thickened "collar".

CONCLUSIONS

The spheroidal to flask-shaped microfossils of possible protozoan affinity in the Urucum Formation and the iron-oxide-replaced filamentous microfossils in the Santa Cruz Formation represent the first well-documented microfossils from the Jacadigo Group of Mato Grosso. The microfossils of the Urucum Formation, especially, comprise a potentially useful biostratigraphic tool. For example, their comparison with possibly very similar microfossils in the Corumbá Group of the Serra da Bodoquena (ALMEIDA, 1965) could have important implications as to the provenance of carbonate clasts in the Urucum Formation and the correct stratigraphic relationship between the Jacadigo and Corumbá Groups. These microfossils also imply an age of probably less than 850 Ma for the banded, shallow-water, Santa Cruz iron-formation. In view of the general restriction of similar jaspilites to sequences older than 1800 Ma, the Santa Cruz BIF is exceptionally "young". Thus, theories (CLOUD, 1973, 1976) claiming that jaspilitic BIF's resulted from the local interaction of abundant dissolved Fe-hydroxide with O_2 produced by procaryotic algae before free O_2 became an equilibrated component in the atmosphere (ca. 2000 - 1800 Ma ago) do not adequately account for the thick, extensive, "young" Jacadigo jaspilites.

We hope that this preliminary study will draw attention to the potential biostratigraphic/geochronologic significance that very fine-grained cherts and carbonates (and also shales and siltstones) may hold for studies of poorly dated, little metamorphosed Brazilian sedimentary sequences of "pre-Silurian", "Eocambrian", or even Precambrian age.

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