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A microfossil assemblage from the Wollogorang Formation, Tawallah Group, Middle Proterozoic, N.T., Australia

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SUMMARY

Poorly preserved microfossils from a black dolomitic shale from the Wollogorang Formation are described and tentatively identified. The assemblage is similar to others of mid-Proterozoic age elsewhere in the World.

INTRODUCTION

The microfossils described in this paper come from the Wollogorang Formation of the Tawallah Group (Table 1). The Wollogorang Formation is a mixed carbonate-clastic unit with red-beds, carbonates (locally stromatolitic), breccias, arenites and evaporites, at present being studied in detail by Jackson (in prep.). His preliminary conclusions are that the formation is mainly lacustrine and fluvial in origin, and that it bears many striking resemblances to the Barney Creek Formation, the host to the McArthur River mineralization. Jackson has been able to correlate the environments of deposition of the Wollogorang Formation over an extensive area from the Queensland Border to the Limmen Bight River in the N.T. Minor variations in stratigraphic detail and thickness of sediments are present, but the constituent parts of the formation can be traced throughout the McArthur Basin.

MATERIAL AND METHODS

The microfossils described here occur in petrographic thin sections of extremely carbonaceous dolomitic black shale. The shale contains between 5 and 10% kerogen on a visual estimate, and is light in weight, poorly fissile and touch (resistant to breakage). Fine-grained dolomite, chert, kerogen, and up to 5% apatite has been identified on XRD analyses. The apatite is well crystallised, and occurs as hexagonal crystals in the organic matter (Figure 1). The microfossils are very poorly preserved in small cherty lenses parallel to bedding and are extremely abundant in these lenses. For example, in a single field of view, using an oil immersion X100 lens, up to 2,000 spherical specimens can be observed at different focal levels. Filaments also occur in the compacted, finely bedded organic-rich laminites (sensu Hutton et al., 1980), but these are badly preserved, and would require maceration before detailed studies could be carried out.

The five specimens (BL13 A, B, C, D & E) were collected from drill core of Wollogorang Formation stored at Redbank Mine, by I.B. Lambert (Baas Becking Geobiological Laboratory) in August 1977. Details of the core number, or sample depth, were inadequately rrecorded, and it has not been possible to locate the sample with any accuracy either as to depth or to stratigraphy. However, the samples are most likely to have come from the 'Ovoid Beds' (Jackson, in prep.).

DESCRIPTION OF THE ASSEMBLAGE

The microfossil assemblage is varied and will be described as named species so far as is possible. Due to poor preservation identifications are tentative and because of the inaccuracy of location, new species will be described as species "A", "B", etc.. A striking feature of the assemblage is a number of larger organic structures which are described here as unmineralised stromatolites. They may, however, be very large filamentous microfossils, and they are, accordingly, described under that section.

The new morphological classification developed by Diver & Peat (1979) for microfossils, mainly but not exclusively Proterozoic, has been used throughout this study.

Group CRYPTARCHA Diver and Peat 1979

Subgroup Nematomorphitae Diver and Peat 1979

EOASTRION Barghoorn 1965

Eoastrion simplex Barghoorn 1965

(Figures 2 and 3)

Discussion: The specimen figured here at two focal levels shows the characteristic spidery appearance of this species, which consists of small filaments radiating out from a central body. Many examples of *Eoastrion simplex* from other parts of the geological column are mineral-encrusted with oxides of iron and manganese (Muir, 1978), but the Wollogorang specimens appear to consist only of organic matter.

Distribution: *E. simplex* has an extensive geological record (Muir, 1978; J.H. Oehler, 1977) and it occurs in the McArthur Group, in the Cooley Dolomite and H.Y.C. Pyritic Shale Members of the Barney Creek Formation. The Cooley Dolomite Member specimens are manganese-coated and the H.Y.C. Pyritic Shale specimens are iron-encrusted. In the H.Y.C. example the present iron mineral is pyrite, but this presumably diagenetically replaces limonite or goethite, since the living equivalent organism is an obligate aerobe (*Metallogenium personatum* Perfil'yev) which lives in shallow waters of low pH. The lack of encrustation of the Wollogorang Formation specimens indicates either lack of iron or manganese in their habitat (which is unlikely, since small cubes of pyrite occur throughout the sample), or, more likely, too high a pH during deposition. This latter is more likely because the abundant fine-grained carbonate associated with the organic matter could only have precipitated above about pH 8.

BIOCATENOIDES J.H. Oehler 1977

Biocatenoides pertenuis J.H. Oehler 1977
(Figures 4 and 5)

Discussion: These small, thread-like microfossils were described by J.H. Oehler (1977) as probably bacterial in origin, because of their abundance, small size, and simple morphology.
Distribution: These have been described previously from the H.Y.C. Pyritic Shale Member by J.H. Oehler (1977) where they occur associated with pyrite, and sometimes encrusted by it. Poorly preserved specimens of the same species also occur in the Cooley Dolomite Member (Muir, unpublished data) and the Emmerugga Dolomite (Muir, 1982, in press). In the latter example, poorly preserved specimens of B. pertenuis are so abundant that they make up a tangled mass which controls the fabric of the rock. They have obviously been growing in great abundance, although it is not clear whether they have grown as benthos, all attached to the same substrate, or all living on, but free (not attached) to the same substrate, or if they were living in the water column, at or near the surface. Similar queries can be raised about the habitat of B. pertenuis from formations other than the Emmerugga Dolomite. Microbial microfossils like B. pertenuis cannot be used to indicate water depths because of the uncertainties described above.

COLEOBACTER J.H. Oehler 1977

Coleobacter primus J.H. Oehler 1977
(Figures 6 & 7)

Discussion: The specimens from the Wollogorang Formation are very similar to those compared with sheathed bacterial forms described by J.H. Oehler (1977) from the H.Y.C. Member of the Barney Creek Formation.
Distribution: J.H. Oehler (1977) comments that many of the pyrite-encrusted filaments in the Barney Creek Formation may actually be C. primus, and that because of its characteristic pyrite encrustration Biocatenoides incrustata J.H. Oehler 1977 may encompass several species of small filaments. Some of the small manganese-encrusted filaments from the Cooley Dolomite Member may also belong to this species.

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CYANONEMA J.H. Oehler 1977

Cyanonema inflatum J.H. Oehler 1977
(Figure 8)

Discussion: J.H. Oehler (1977) allocates this species to the Family Oscillatoriaceae of the Order Nostocales and regards it as a cyanobacterium. The specimens from the Wollogorang Formation, although fragmentary, show all the characteristics and size range of J.H. Oehler's species.

Distribution: This species has been described from the Barney Creek Formation and the Wollogorang Formation. J.H. Oehler (1977) believed it to be planktonic in habit, by analogy with the living members of the family, and believed it was washed into the depositional basin from more marginal areas. The fragmentary nature of the Wollogorang Formation specimens gives some slender support to the "washed-in" theory, but could also indicate merely local transport and damage in a turbulent zone.

GUNFLINTIA Barghoorn 1965

Gunflintia minuta Barghoorn 1965
(Figures 9 & 10)

Discussion: Small filaments assigned to Gunflintia Barghoorn 1965 occur in most Proterozoic microfossil assemblages. Barghoorn and Tyler (1965) considered that they were the remains of sheathed cyanobacteria and this view has been upheld by later workers, notably Schopf (1977).

Distribution: They have been described from several McArthur Group Formations: Amelia Dolomite (Muir, 1974, 1976); Barney Creek Formation (J.H. Oehler, 1977; Muir, 1978); Mara Dolomite Member (Muir, 1982, in prep.); and from the Bungle Bungle Dolomite in the East Kimberleys (Diver, 1974). Apart from the occurrence in the Cooley Dolomite Member (Muir, 1978), specimens of Gunflintia minuta appear not to be mineralised with iron or manganese.

OSCILLATORIOPSIS Schopf 1968

Oscillatoriopsis sp. A.
(Figures 12 & 13)

Description: Trichomes multicellular, uniseriate, unbranched, not constricted at septae. Trichomes solitary, slightly curved, sinuous, always fragmentary. Cross walls distinct, cells cylindrical, 1.2 - 2.0 µm long, 2.6 - 3.9 µm wide. Apical cells not observed (30 cells measured). Cellular contents granuuar.
Discussion: Although these microfossils are not abundant, and always fragmentary, they are sufficiently different, on the basis of size and cell shape from their nearest equivalent O. schopfii J.H. Oehler 1977 to warrant erection of a separate species. Oscillatoriopsis Schopf is very similar to the living cyanobacterial genus Oscillatoria and the fossil genus probably represents members of the same family.
Distribution: Oscillatoriopsis occurs in a number of Proterozoic microfossil assemblages rom various parts of the world. It is never very abundant, and usually fragmentary. The modern examples can be either unattached benthos or plankton and can tell us little about the habitat of the fossil specimens.

Oscillatoriopsis sp. B
(Figure 14)

Description: This species can be described in the same terms as O. sp. A, except that the proportions of the cell dimensions are markedly different. The cells are biconvex and equidimensional, 2.3 - 2.6 µm long and 2.2 - 2.4µm wide (20 specimens). Trichomes are always fragmentary.
Discussion: This species is identical with an un-named species from the Bungle Bungle Dolomite (Diver, 1974) of the East Kimberleys, W.A., which is reasonably regarded as cyanobacterial.
Distribution: This species has been recorded only from the Bungle Bungle Dolomite (Diver, 1974) and the present assemblage.

Oscillatoriopsis robusta Horodyski and Donaldson, 1980
(Figures 15 & 16)

Discussion: These species correspond in size and morphology with Horodyski and Donaldson's specimens from the Middle Proterozoic Dismal Lakes Group of Arctic Canada. Despite its large size, the species is regarded by its authors as being cyanobacterial in affinity. Similarly large filaments were described by Peat (1979) from the Roper Group of the Northern Territory.

Distribution: Stratigraphically, these microfossils have been described from the Wollogorang Formation and Roper Group (both Carpentarian (1800 - 1400 m.y.) and the Dismal Lakes Group (Adelaidean, 1200 m.y. old). The occurrence in the Dismal Lakes Group is in a sequence very similar to that of the Wollogorang Formation in organic-rich laminites overlying evaporitic red-beds. The fossiliferous laminites are overlain by a prominent stromatolitic horizon, as, in the Redbank area, are the microfossiliferous laminites. The Dismal Lakes Group black chert occurs as layers, lenses, nodules and concretions, (Horodyski & Donaldson, 1980), a description suggestive of a lithology similar to that of the Ovoid Beds of the Wollogorang Formation.

? twisted large filaments
(Figure 17)

Discussion: One prominent morphology in the Wollogorang Formation assemblage is the large (5- 6 μm diameter) twisted, knotted filament shown in Figure 17. Other examples occur, and the filaments, which have a spherical cross-section, appear to be non-segmented, although irregular paler cross-cutting areas may represent some poorly preserved form of septae. The biological affinity of these structures cannot be ascertained although by analogy with most other microstructures from the Proterozoic, they may be cyanobacteria.

Distribution: These morphologies have not been described from any assemblage other than that of the Wollogorang Formation.

?Organic Stromatolites
(Figures (18-23)

Discussion: The structures illustrated appear to be composed of discs of granulated organic matter, stacked up on each other, that are domed upwards. Vague spiralling structures can be seen in the discs (Figure 23) but, although they may represent some kind of filament, it is impossible to make any estimate of its biological affinities. The structures resemble stromatolites. They range in dameter from 30 - 65 μm and in height up to 1 mm. They are present in only some of the chert lenses.
Distribution: These forms occur in the Wollogorang Formation. A somewhat similar "mini-stromatolite" was described by Schopf (1975) from the Adelaidean River Wakefield Groups, but its morphology is more distinctive, and it appears to have the discs (which have a central conical ssction) separated by organic lamellae.

Poorly preserved filaments.
(Figure 24)

Discussion: On the margins of the dense black compacted organic matter, there are large numbers of filaments poorly preserved in the adjacent carbonate or chert. They are much darker in colour than filaments preserved in the chert lenses, and this increase in apparent carbonization is interpreted as a result of compactional pressure. The studied thin sections were cut at right angles to the bedding, with the results that most morphologies would have been crushed and flattened, making identification difficult. Thus although filaments are the only recognisable morphologies emerging from the compacted kerogenous mass, they may not be the dominant types in the assemblages from which the mass of organic matter was formed.

Subgroup Sphaeromorphitae (emend. Diver & Peat 1979)
Huroniospora psilata Barghoorn 1965
(Figure 25)

Discussion: These small spherioids have been reported from almost every Proterozoic microfossil assemblage, and may represent cells, cysts, spores or sheaths of many different organisms. Similar forms occur in the Archaena, although they have not so far been given names, and in the Phanerozoic, under a variety of names.

Distribution: These microfossils have been described from almost all of the McArthur Group assemblages, and have no stratigraphic or environmental significance.

Huroniospora microreticulata Barghoorn 1965

(Figure 26)

Discussion and Distribution: The same comments apply as to *H. psilata*.

Subgroup Synaplomorphitae Diver & Peat 1979

CLONOPHYCUS J.H. Oehler 1977

Clonophycus laceyi Muir 1982

(Figure 27)

Discussion: Eleven specimens of *C. laceyi* were found in the Wollogorang Formation thin sections. They are identical in size range and morphology with the specimens described form the Mara Dolomite Member (Muir, 1982, in prep), and the type material described by D.Z. Oehler (1978) from the Balbirini Dolomite.

Distribution: This species is known only rom the three formations mentioned above.

NANOCOCCUS J.H. Oehler 1977

Nanococcus sp. A.

(Figures 28-30)

Description: Cells spheroidal to ellipsoidal, loosely arranged in clusters of about 20 to hundreds of individuals. Cells appear to be set in a pale brown organic matrix. Cell walls psilate to granular, appearing to be thicker and darker in smaller (degraded?) specimens. Cells appear not to have individual sheaths. Cell diameter from 0.3 - 2.1 µm, mostly about 1.5 µm (average 1.46 µm - 200 specimens).

Discussion: These small spheroids are by are the most abundant element in the Wollogorang Formation assemblage. They occupy most fields of view in the chert lenses in all the slides. The genus, Nanococcus, is believed by J.H. Oehler to be assignable to the Family Chroococcaceae (Cyanophyceae). N. sp. A is distinguished from N. vulgaris by its much smaller size range.
Distribution: N. sp. A has so far only been recorded from the chert lenses in the Wollogorang Formation, but very small spheriods may readily have been overlooked in other assemblages.

Nanococcus vulgaris J.H. Oehler 1977
(Figure 31)

Discussion: This slightly larger form of Nanococcus is described by J.H. Oehler as being the most common organism in microfossil assemblages from the H.Y.C. Pyritic Shale Member. He compares it with modern Chroococcacean genus Aphanocapsa Nageli. It is abundant in the Wollogorang Formation assemblage.
Distribution: This species is abundant in the Wollogorang Formation, H.Y.C. Pyritic Shale Member and Urquhart Shale (Mt Isa) assemblages (Muir, 1981; Hamilton & Muir (1974) described but did not name this species; J.H. Oehler, 1977). Muir (1981) made the suggestion that the extreme abundance of these micorfossils may have been the result of their growth as uncontrolled blooms in a lacustrine environment. Jackson's (in prep) interpretation of the Wollogorang Formation, and Williams & Logna's (1981) interpretation of the H.Y.C. Pyritic Shale Member as being partially shallow lacustrine deposits confirm the previous interpretation.

MYXOCOCCOIDES Schopf 1968 Emend.
Schopf & Barghoorn 1969

Myxococcoides kingii Muir 1976
(Figure 32)

Discussion: Microfossils assigned to M. kingii are not very common in the Wollogorang Formation assemblage, and not well preserved. The species is believed to be Chroococcacean in affinities.
Distribution: M. kingii has been described from the Amelia Dolomite (Muir, 1976), the H.Y.C. Pyritic Shale Member (J.H. Oehler, 1977) and Balbirini

Dolomite (D.Z. Oehler, 1978). It is very abundant in the Amelia Dolomite and H.Y.C. Pyritic Shale Member assemblages, but less so in the Balbirini Dolomite or Wollogorang Formation Assemblages. Similar forms are moderately abundant in the Bungle Bungle Dolomite assemblages (Muir, unpub. data).

BISACCULOIDES J.H. Oehler 1977

Bisacculoides tabeoviscus J.H. Oehler 1977

(Figures 33-36)

Discussion: This is an abundant form in the Wollogorang Formation. J.H. Oehler (1977) described it to the Chroococaceae largly on the basis of its multiple sheaths, in which feature it resembles Glenobotrydion Schopf 1968. It is distinguished from Glenobotrydion on the basis of its smaller size.

Distribution: Bisacculoides tabeoviscus is abundant in the Wollogorang Formation, in the H.Y.C. Pyritic Shale Member (J.H. Oehler 1977; Hamilton & Muir (1974) who described but did not name the species) and the Urquhart Shale (Muir, 1981). It appears to require the same environmental parameters as Nanococcus.

DISCUSSION

Environmental significance

The microfossils from the Wollogorang Formation show considerable morphological diversity, and great abundance of individuals of particular species. In this, they show considerable contrast with microfossil assemblages from the stromatolitic carbonate-hosted Amelia Dolomite and Balbirini Dolomite microfossil assemblages. The Wollogorang Formation assemblage is also considerably more diverse than the non-stromatolitic-laminite assemblage from the Mara Dolomite Member. The assemblages from the Amelia and Balbirini Dolomites, and from the Mara Dolomite Member, also tend to have one species numerically dominant over all the others, which may be represented by one or two specimens only.

The assemblage most comparable with the Wollogorang Formation microfossils is that described by J.H. Oehler (1977) from the H.Y.C. Pyritic Shale Member. Both in species present, and in individual numbers within species groupings, the assemblages have a great deal in common (Table 2). A particular feature in common is the abundant filamentous microfossils, quite reasonably regarded by J.H. Oehler (1977) as probably bacterial in origin. Most of the spheriodal microfossil types are abundant in both assemblages, and some of these have been interpreted as cyanobacterial blooms on lakes, or enclosed water bodies (Muir, 1981). Recent environmental studies on the H.Y.C. Pyritic Shale Member (Williams and Logan 1981) have indicated a shallow water to emergent, lacustrine environment for the depositional environmnt of the H.Y.C. Pyritic Shale.

Stratigraphic significance.

Although the assemblage described in this record is abundant and varied, the environmental controls appear to be much stronger than stratigraphic controls. In local terms, it would be impossible to distinguish between this assemblage from the Wollogorang Formation and that from the H.Y.C. Pyritic Shale Member. However, on a more general basis, the Wollogorang Formation assemblage is typical of others of its age world-wide. Too little information is available to make detailed comparisons at this atage.

Acknowledgement. I wish to thank K.J. Armstrong for his generous assistance at various stages of this project.

GROUP	Subgroup	Formation	Member	New Environmental Interpretations
ROPER				
"NATHAN"		Dungaminnie		Shallow, lacustrine, fluvial
		Balbirini Dolomite		*Shallow, lacustrine, fluvial
	Batten	Amos		Vadose, calcrete
		Looking Glass		Shallow, lacustrine
		Stretton Sst.		Fluvial
		Yalco		Very Shallow lacustrine
		Lynnott	Donnegan	Lacustrine, sabkha, fluvial
MCARTHUR		Reward		Lacustrine
		Barney Ck	Cooley Dol.	*Fault scarp deposits, vadose
			HYC Pyr. Sh.	*Lacustrine, vadose
	Umbolooga	Teena Dol.	Coxco Dol.	Lacustrine, vadose
		Emmerugga	Mitchell Yd Dol.	*Vadose
			Mara Dol.	*?Lacustrine
		Tooganinie	Myrtle Sh.	Continental, fluvial, lacustrine
			Leila Sst.	Fluvial
		Tatoola Sst.		Fluvial
		Amelia Dol.		*Lacustrine or marine, sabhka
		Mallapunyah		Continental, playa, sabkha
				Lithology
TAWALLAH		Masterton		Blocky, purple and white, medium-grained quartz sandstone conglomerate: minor intermediate-basic volcanics and lapilli tuff
			(Gold Creek (Volcanic	Basalt; trachyte
		Wollogorang		*Flaggy grey and pink finely crystalline dolomite, dolarenite, dolomitic siltstone, dolomitic sandstone, sandstone, chert
		Settlement Creek Volcanics		Basalt, siltstone, tuff
		Rosie Creek Sandstone		Flaggy very coarse to fine-grained quartz sandstone, ferruginous sandstone, feldspathic sandstone, glauconitic sandstone, boulder conglomerate

GROUP	Subgroup	Formation	Member	New Environmental Interpretations
		Sly Creek sandstone		Blocky white to pink medium-grained quartz sandstone; some pebbly bands; minor ferruginous siltstone
TAWALLAH				
		Siegal Volcanics		Amygdaloidal basalt, minor trachyte
		Yiyintyi Sandstone (West moreland conglomerate)		Blacky white medium to coarse-grained quartz sandstone; minor pebble to boulder conglomerate

TATBLE 1. STRATIGRAPHY. (showing formations containing microfossil assemblages.*)

Cryptarch Subgroup	Wollogorang Formation	Amelia Dolomite (1)	Mara Dolomite Mbr. (2)	H.Y.C. chert (3)	H.Y.C. shale (4)	Cooley Dol. Mbr. (5)	Balbirini Dolomite (6)	Bungle Bungle Dolomite (7)	Preservation state
Nematomorphitae									
Gunflinitia minuta	X	X	X	X		X		X	Poor
Ecmycetopsis filiformis	X	X	X	X			X	X	Poor, may form mats.
E. robusta	X	X	X	X			X		Poor
Biocatenoides Pertenuis	X	X	X	X		X	?	X	Poor
Synaplomorphitae									
Bisacculoides gradis		?	X	X	X		?	X	Fair-good
Clonophysuc elegans			X	X					Good
C. laceyi	X		X						Good
C. sp			X						Good
Nannococcus vulgaris	X			X		X			Good
Sphaeromorphitae									
Huroniospora microreticulata	X	X	X	X	X		?	X	Fair-good
H. psilata	X	X	X		X		?	X	Fair-good
Incertae sedis									
Eoastrion simplex	X			X	X				Good
Lithology	Carb. Shale Chert	cert, strom. dol.	chert lamin. & strm. dol.	chert lamin. dol.	dol. shale	chert conlg. dol.	chert lamin. & strm. dol.	chert strom.	

Table 2. Distribution of microfossils in units of the McArthur Group, Wollongorang Formation and Bungle Bungle Dolomite. Sources are (1) Muir, 1974, 1976, (2) Muir 1982 (3) J.H. Oehler 1977, (4) Hamilton and Muir, 1974, Muir, 1981, (5) Muir, 1978, (6) D.Z. Oehler 1978, (7) Diver, 1974, and unpublished information.

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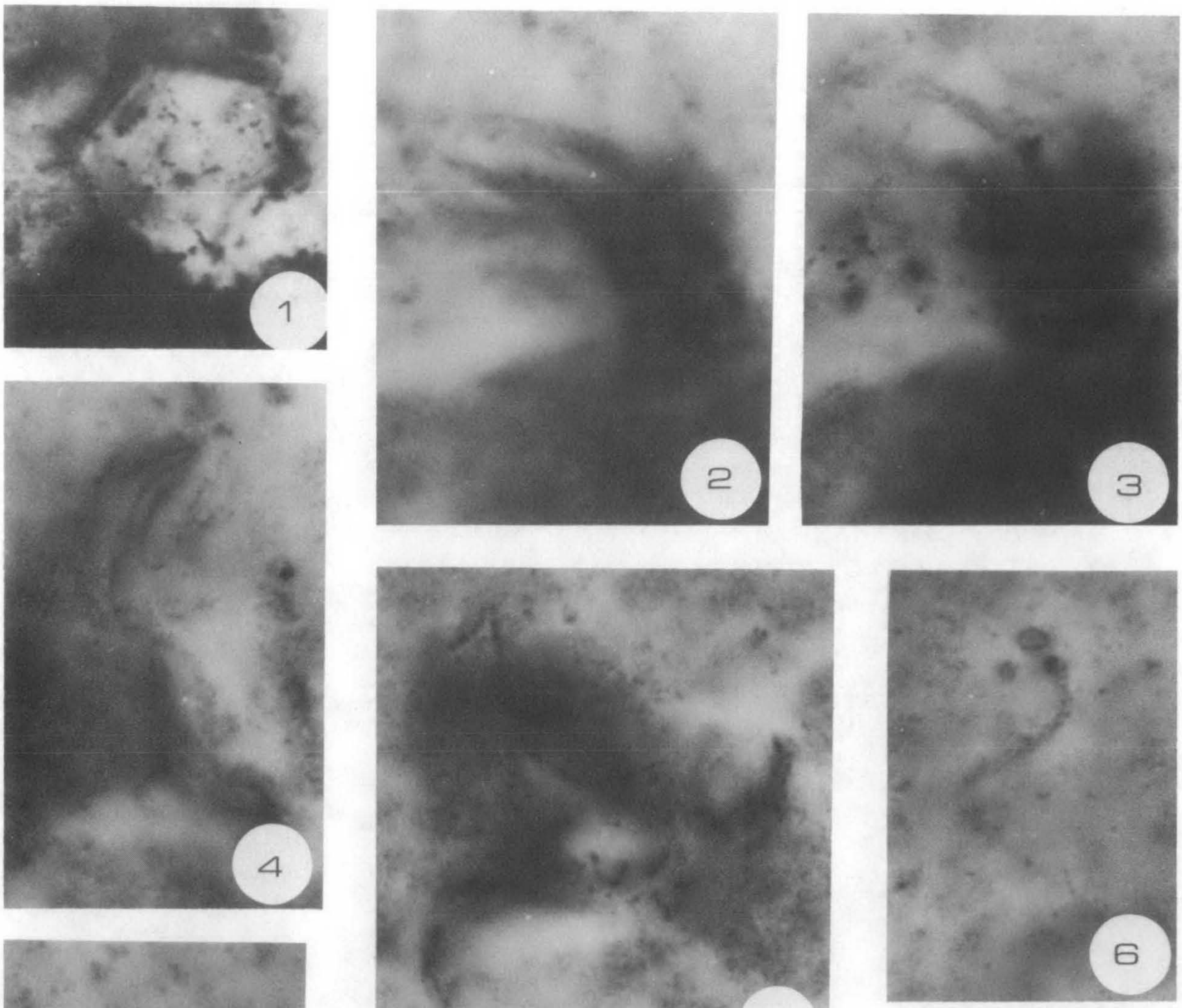
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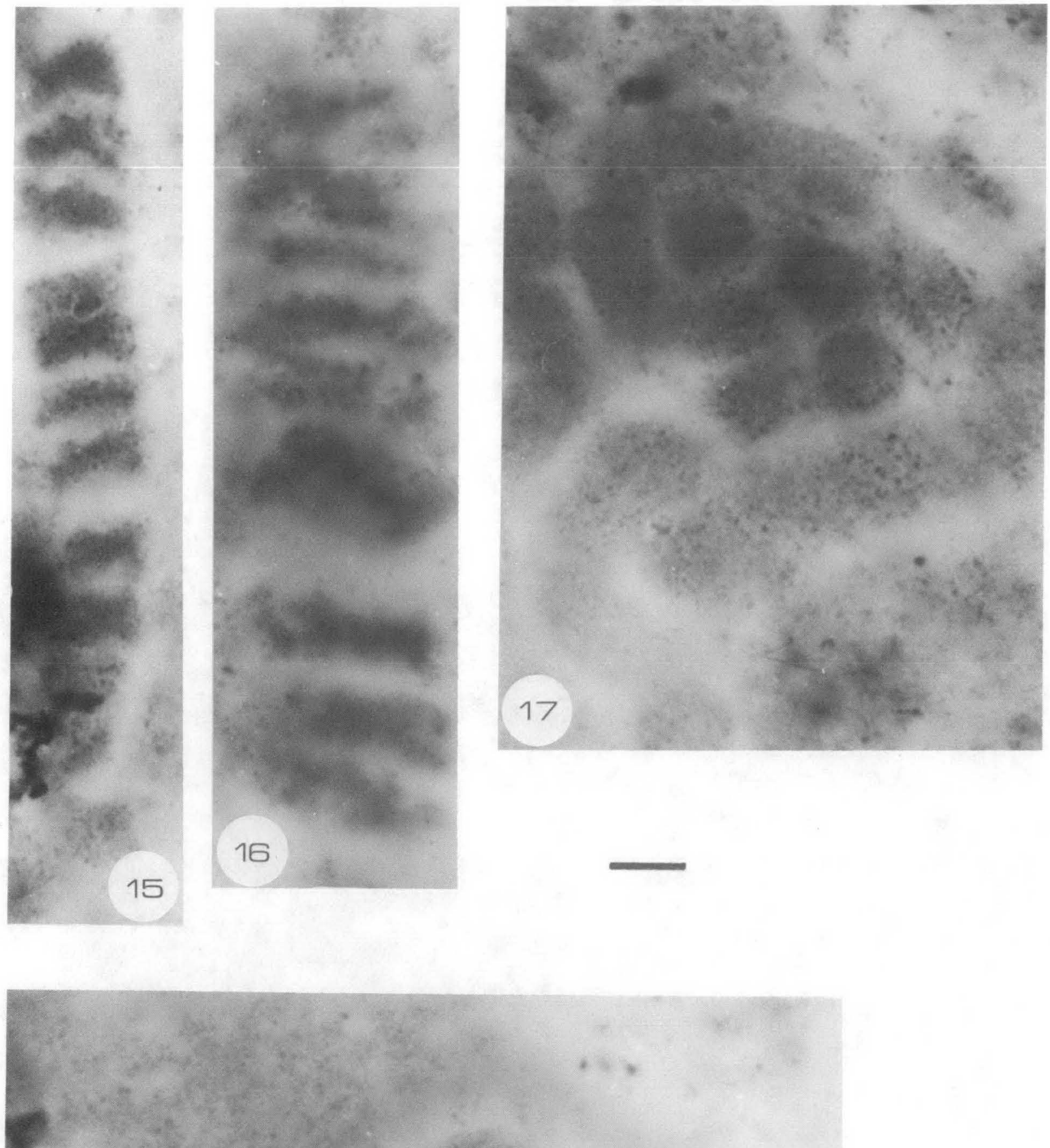
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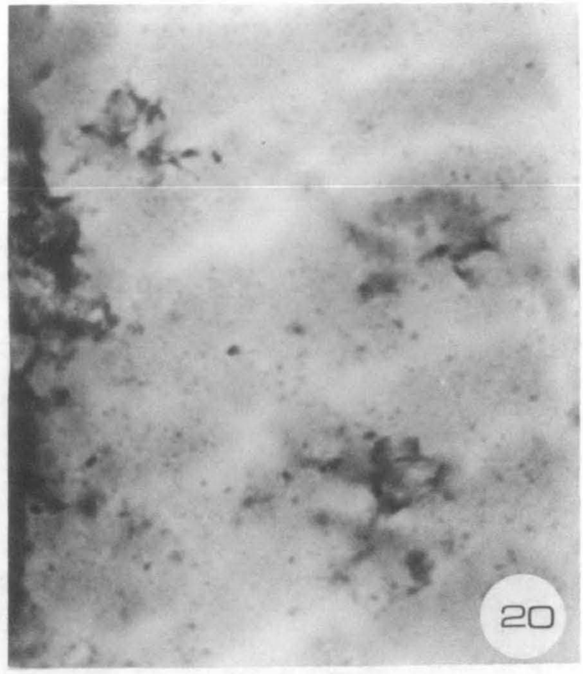
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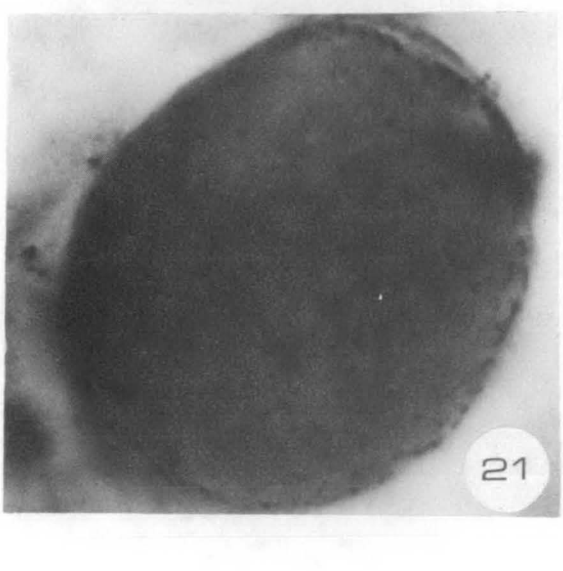
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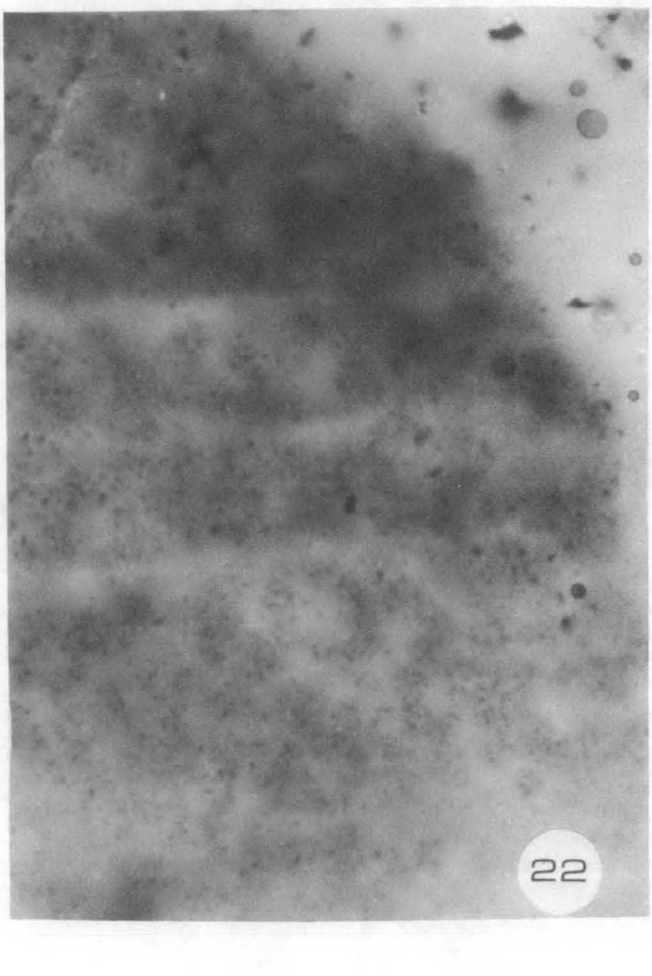
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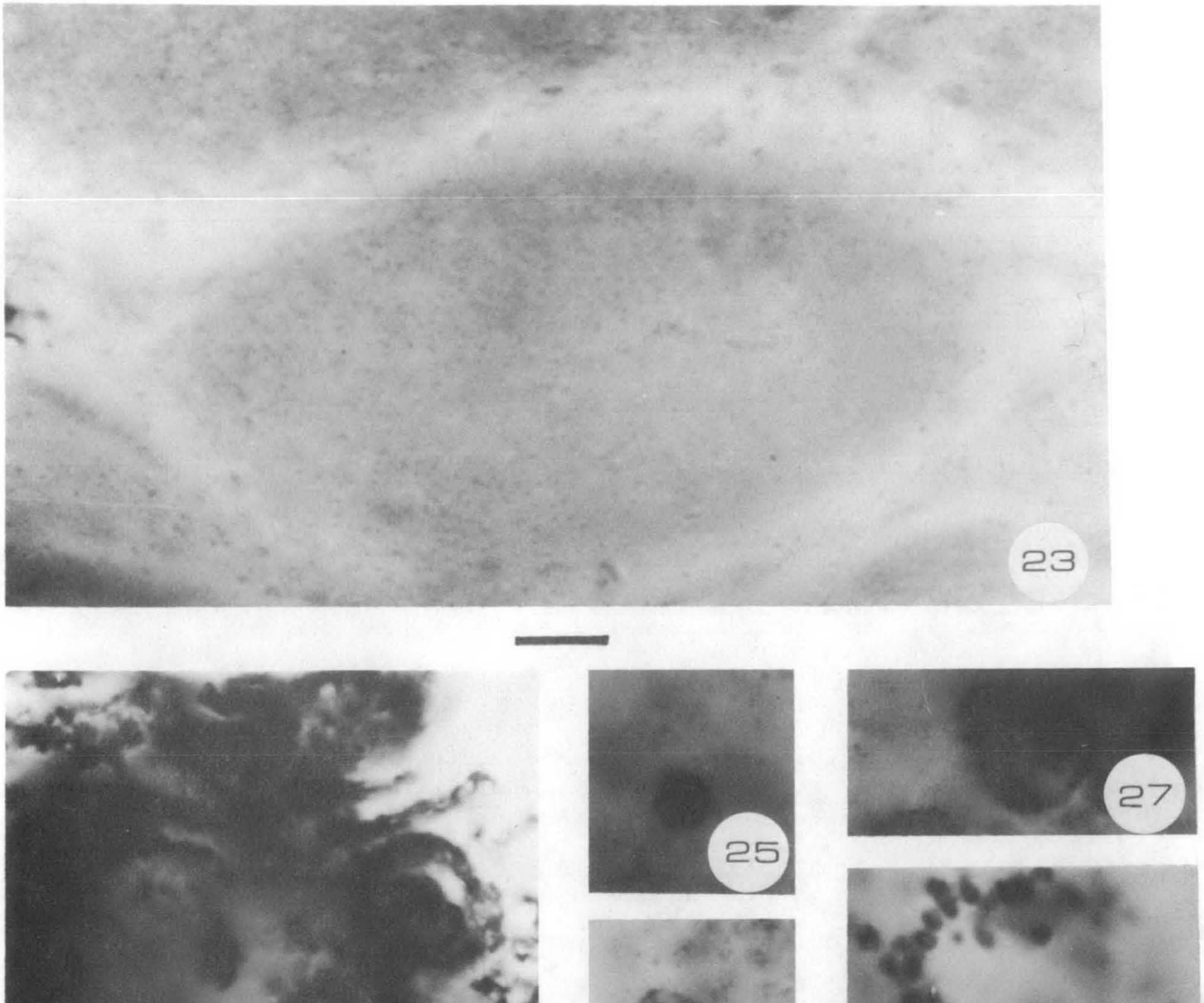
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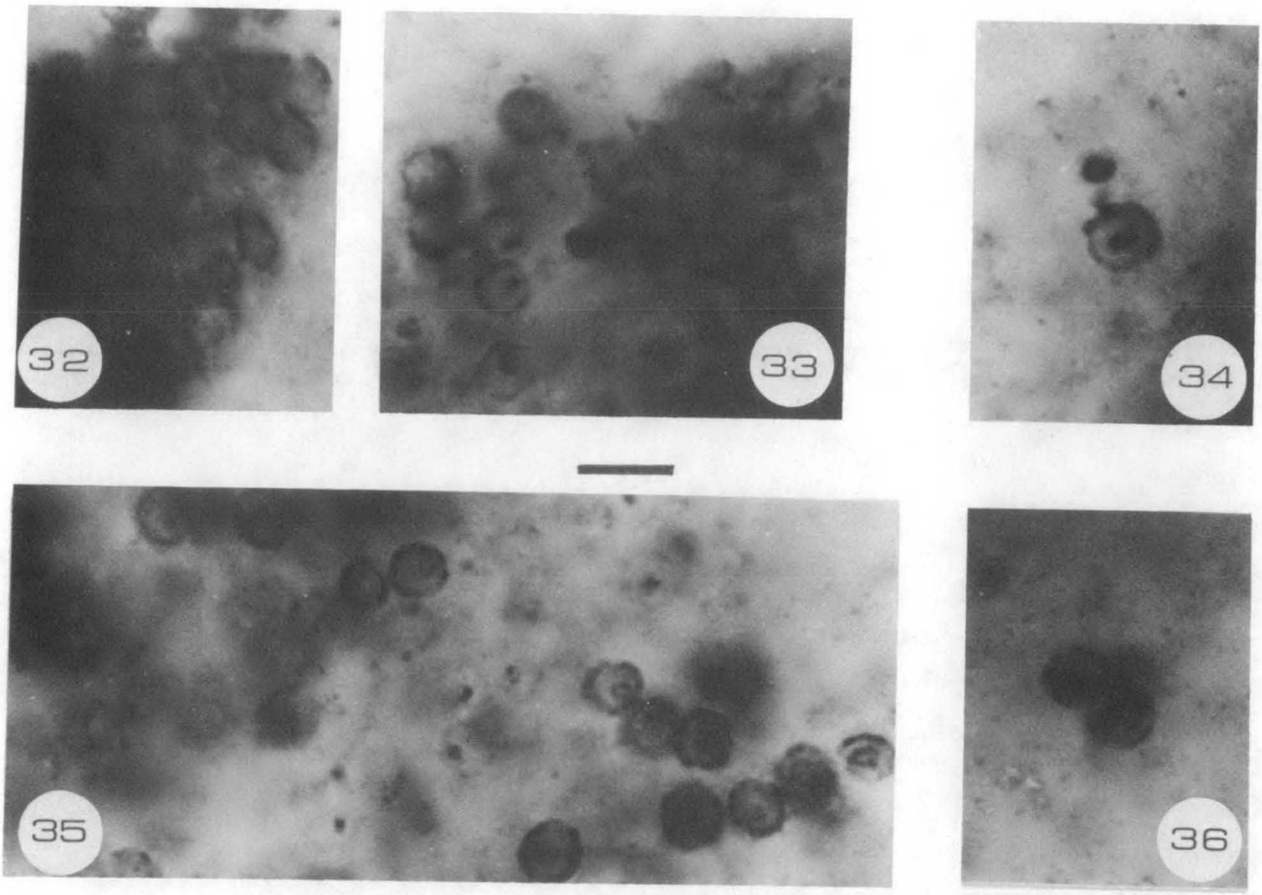
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