Restricted until pub.
in Nature

DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1973/51

MICROORGANISMS OF CARPENTARIA (PRECAMBRIAN) AGE FROM THE AMELIA DOLOMITE McARTHUR GROUP; N.T. AUSTRALIA

By

N.J.W. CROXFORD, J. JANECEK, M.D. MUIR AND
K. PLUMB

Microorganisms of Carpentarian (Precambrian) age from the Amelia Dolomite, McArthur Group, Northern Territory, Australia.

by N.J.W. Croxford, Mount Isa Mines Pty Ltd, Mount Isa, Queensland, Australia,
J. Janecek, Carpentaria Exploration Company Pty Ltd, P.O. Box 321, Bathurst, New South Wales, Australia,
M.D. Muir, Geology Department, Royal School of Mines, Prince Consort Road, London, England, and
K.A. Plumb, Bureau of Mineral Resources, Box 378, Canberra, A.C.T. 2601, Australia.

Abstract.

An assemblage of microfossils from the Carpentarian McArthur Group is described for the first time. They occur in cherty dolomites in the lower part of the group, and are exceptionally well-preserved, and include some colonial organisms. An account is given of the microfossils, the environment of deposition, and the stratigraphy of the deposit with relation to the whole of the McArthur Group, and the microfossil assemblage is compared with the well-known Gunflint and Bitter Springs assemblages. The age of the Amelia Dolomite is not precisely known, but appears to fall within the interval 1500-1800 x 10^6 years. The sediments were deposited in an arid, hypersaline, intertidal environment.

Introduction.

During petrological examination of core from DDH Tawallah Pocket No. 1, a stratigraphic diamond drill hole drilled in 1972 by Carpentaria Exploration Co. Pty Ltd (a subsidiary of Mount Isa Mines Holdings Ltd) as part of its exploration activities in the McArthur River region of the Northern Territory, Australia (Fig. 1), Croxford discovered microfossils. In view of an Australia-wide study of Precambrian microfossils being carried out by Muir and Plumb, the samples

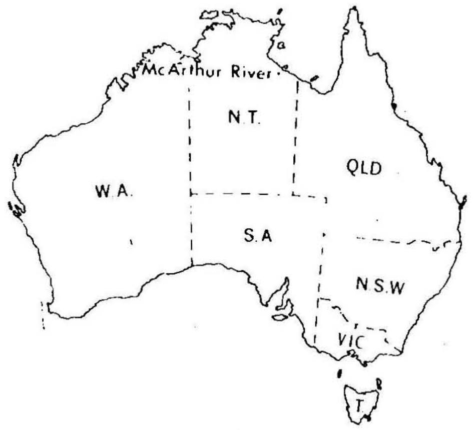

Fig. 1. Locality map

were forwarded to Muir for detailed study, and are briefly described here as the first record of microfossils of their particular age and from this area. The co-ordinates of the hole are 16° 02' 00' S and 135° 35" 30'E.

The Microorganisms.

The microorganisms show features in common with the well-known assemblages from the older Gunflint Chert[1], although in many respects the Amelia Dolomite assemblage is even more reminiscent of the much younger Bitter Springs assemblages described by Schopf[2, 3]. Because previous authors have drawn significant biological conclusions from their material, it is of doubtful value to extend genera and species unless all of the original authors' criteria can be observed in new material. In most cases this has proved impossible in the new microflora, and therefore no definite assignments are made in this preliminary work; more extensive studies are in progress.

Some of the single-celled organisms (Fig. 2) are clearly similar to Huroniospora Barghoorn 1965, and could even be assigned to fossil species on the basis of morphology alone. Considering the considerable age difference between the deposits (certainly greater than 100 x 10^6 years), it is debatable whether it is justifiable to assign specimens from the Amelia Dolomite to genera and species created for forms in the Gunflint Chert in Canada, but, nonetheless, the structures are simple, and on morphological criteria alone it would be difficult to define the Amelia Dolomite forms as new genera and species.

Although most of the cells in the Amelia Dolomite assemblage have much smaller average diameters, several very close comparisons may also be made between Bitter Springs and Amelia Dolomite forms, even though the time difference between the two formations is probable as much as 700 x 10^6 years. As an example, small, usually paired, double-walled cells in the Amelia Dolomite assemblage (Fig. 3) strongly resembler Sphaerophycus parvum Schopf 1968; Schopf regards this spcies as being a blue-green alga and probably Chroococcacean in affinity. Similarly, a large number of colonial Amelia Dolomite forms could be assigned to the genus <u>Myxococcoides</u> Schopf 1968 (Figs. 4 & 5), but here there seems to be a distinct division between loose agglomerations of single cells and genuine colonial structures possessing characteristic outlines (e.g., some colonies are clearly reniform), in which cells possess walls in common with their neighbours.

One of the most interesting of the colonial bodies in the Amelia Dolomite is a multicellular organism (Fig. 6) which was clearly growing within the sediment in which it is now found. It has a basal attachment (now non-cellular; many present day blue-green algae discard their mucilaginous sheath when threatened with burial in sediment), then broadens to a wider multicellular 'bulb' which appears to possess a rim of rather flattened cells around its margin, and finally thins to a tube from which small branches are given off at irregular intervals. The whole structure is more than 250 μm in height, and its diameter ranges from 25 - 50 μm. Individual cells range in size from 4.0 - 15.3 μm, and possess the remains of what may originally have been internal cell contents.

There appears to be clear cellular differentiation in the colonial structure illustrated in Fig. 7. Two types of cell can be clearly seen - one elongated and arranged in a sub-parallel to radiating manner, and the other rounded, and forming terminations to the elongated cells; the whole colony has a somewhat triangular outline. No such organisms have previously been described from the Precambrian.

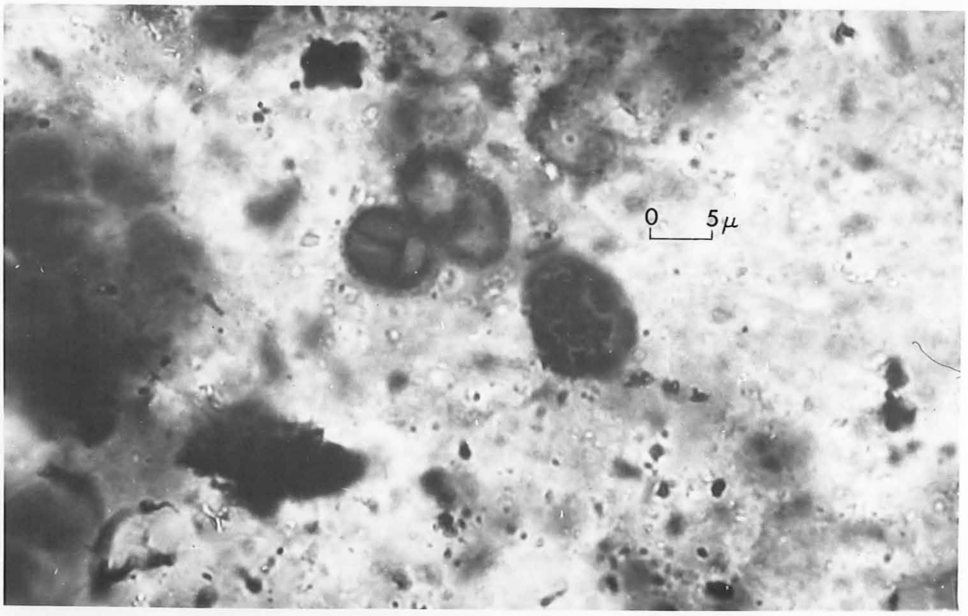

Fig.2. Thick-walled ornamented cells, clearly similar to <u>Huroniospora</u> Barghoorn.

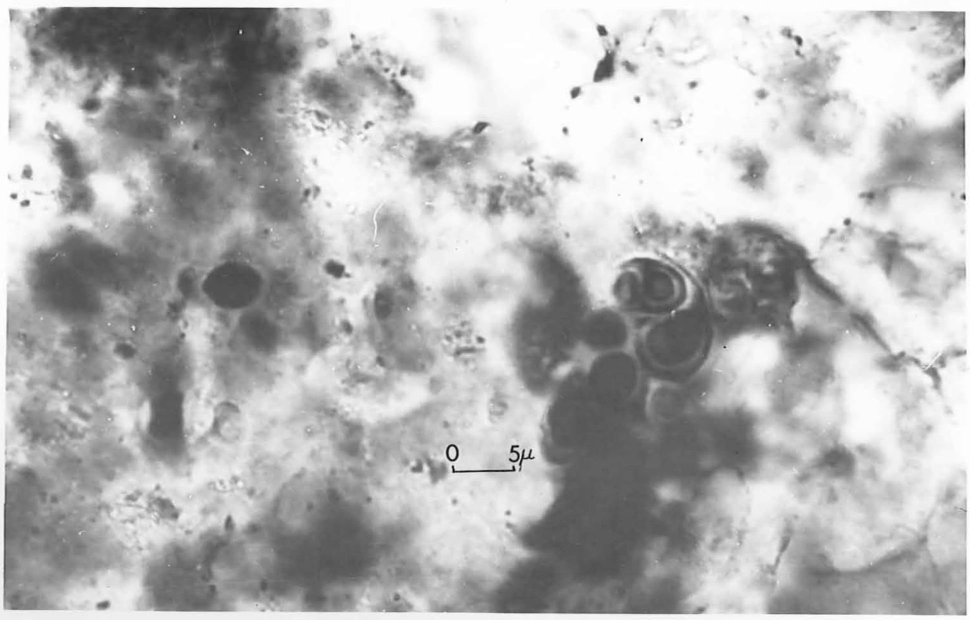

Fig. 3. cf. <u>Sphaerophycus parvum</u> Schopf.

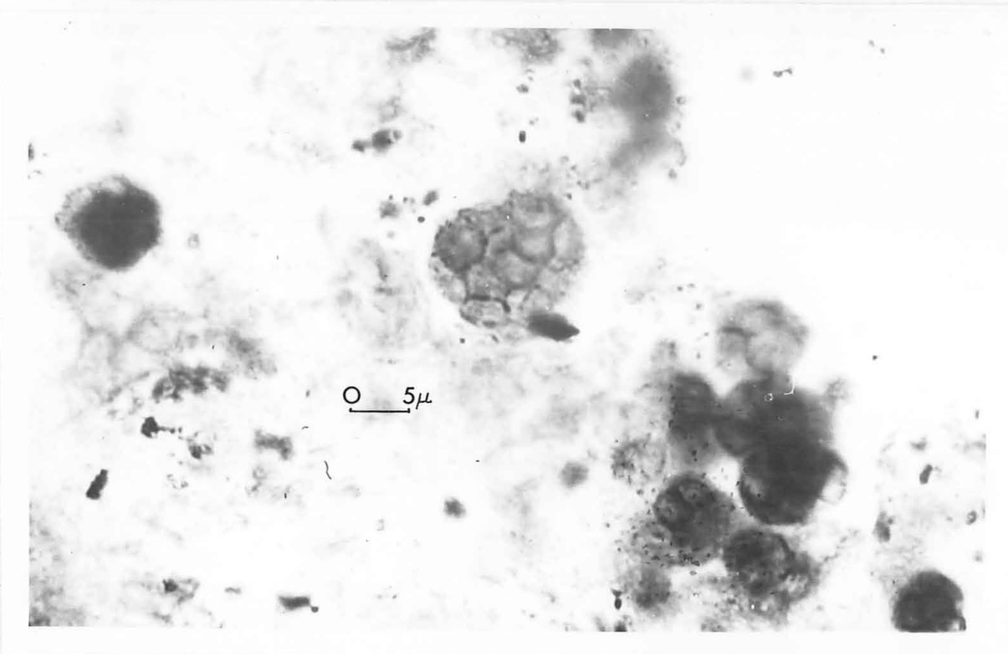

Fig. 4

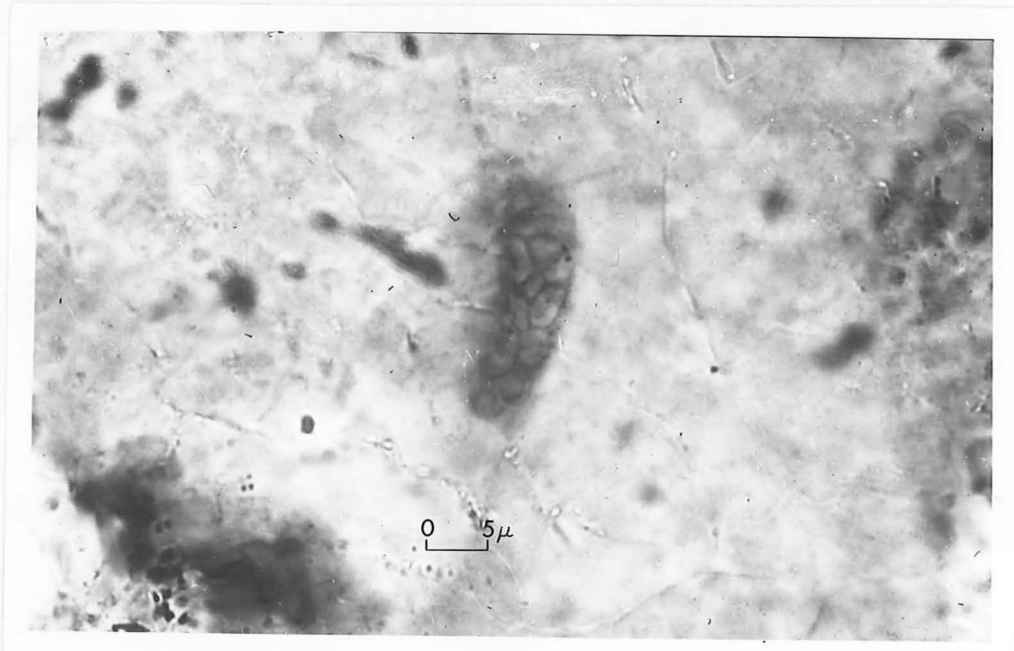

Fig. 5

Fig. 4, 5. Different view of colonial organism cf. Myxococcoides Schopf. One is reuniform and the other is quite straight-sided.

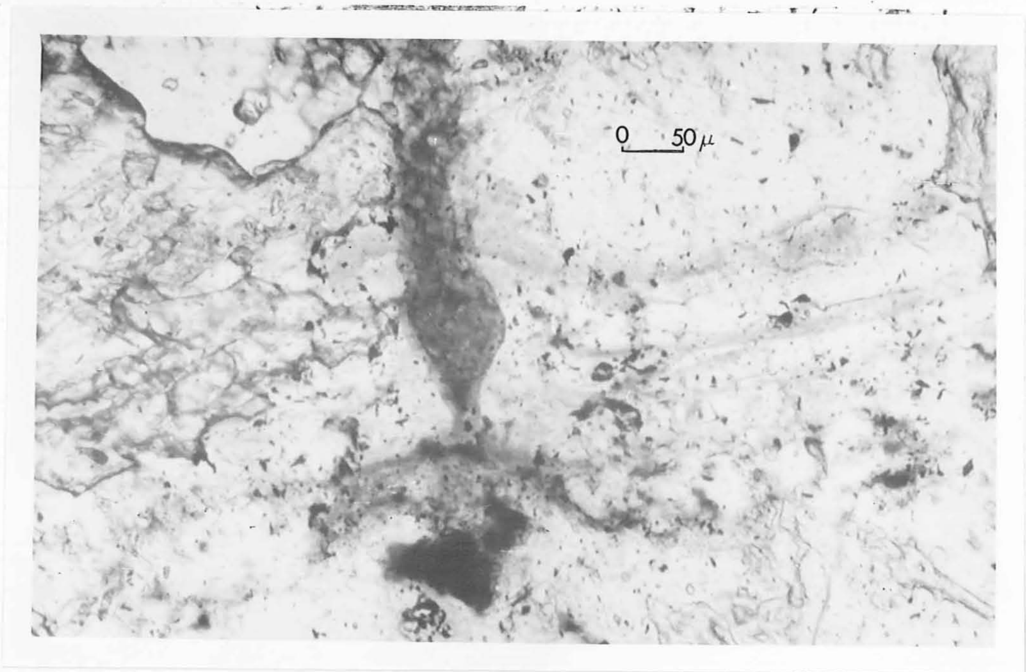

Fig.6.: Multicellular organism showing basal attachment and position of growth.

Fig.7. Multicellular organism showing differentiation of cells, with some sub-parallel elongate cells terminated by smaller spherical cells.

Most of the cells in the Amelia Dolomite are very small, and, even when agglomerated into colonies, they generally show no evidence of cell differentiation. They appear to be on a level of biological organisation similar to that of blue-green algae. However, the two types of colonial structure illustrated in Figs. 6 and 7 possess much larger cells and a high level of organisation, and share many characteristics in common with the higher eukaryotic algae. It is difficult to determine close affinities at this stage because biochemical studies of the cell membranes and contents have yet to be carried out.

Stratigraphy.

The 5.4 km thick McArthur Group is a carbonate sequence forming part of the type Carpentarian succession (Dunn et al.[4]) in the McArthur Basin of the Northern Territory, Australia. The group conformably overlies a four km-thick dominantly arenite succession, the Tawallah Group, and is in turn unconformably overlain by a three km-thick arenite-lutite sequence, the Roper Group. The original stratigraphic relationships in the McArthur Group[5] have been drastically revised in a new account[6]. The McArthur Group stratigraphic column is summarised in Figure 8.

The HYC Pyritic Shale Member of the Barney Creek Formation contains the McArthur Pb-Zn-Ag deposit[7], and DDH Tawallah Pocket No. 1 was drilled in the course of base metal exploration in the area. The drill hole was collared in the lower part of the Amelia Dolomite, and also penetrated the upper part of the conformably underlying Mallapunyah Formation (Fig. 9). The fossiliferous cherts were found in the Amelia Dolomite.

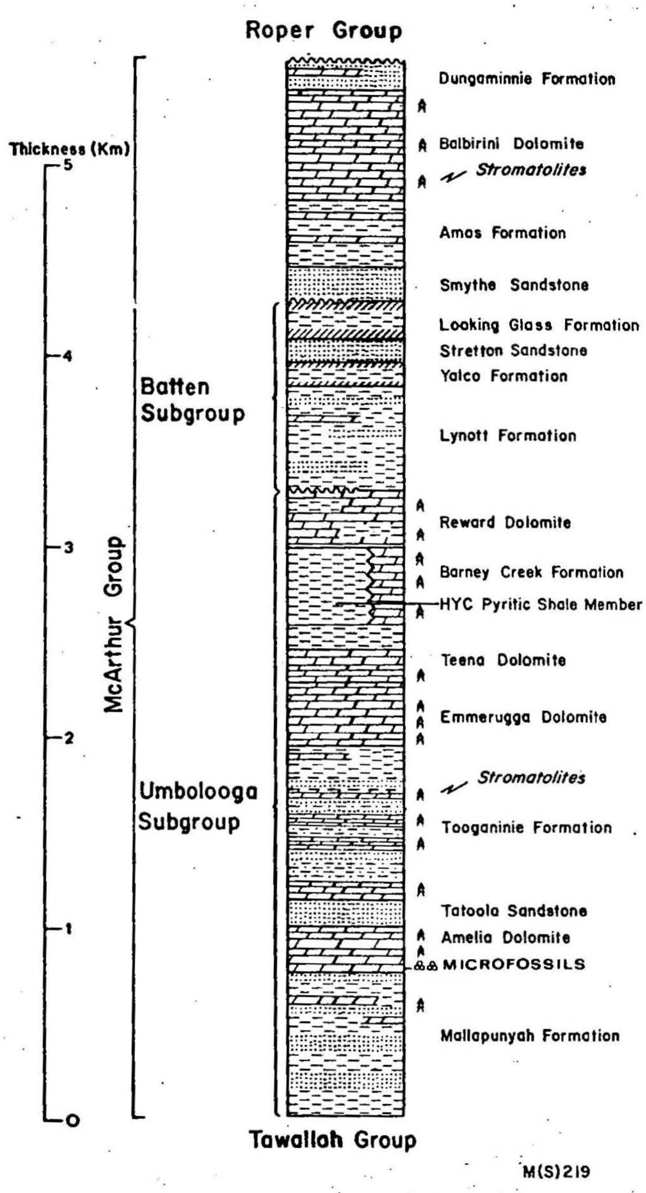

Fig. 8. Schematic column of the stratigraphy of the McArthur Group at McArthur River.

AMENDED GEOLOGICAL LOG FOR DDH TAWALLAH POCKET NO. 1

DEPTH IN METRES FROM	TO	CORE BEDDING ANGLE APPROXIMATELY 80° TO VERTICAL
0.0	1.9	NO CORE - overburden.
1.9	2.3	DEEP RED CLAYEY SOIL with laminated chert fragments.
2.3	12.2	BANDED DOLOMITE - Pale grey fine grained rock with thin dark bands.
		5.1- 5.2 m : recrystallised dolomite (see 12.2-13.2 m)
		9.0- 9.2 m : interbedded clayey and dolomite rock
		9.8- 9.9 m : interbedded clayey and dolomite rock
		11.5-12.2 m : fine grained clayey rock
12.2	13.2	RECRYSTALLISED CARBONACEOUS DOLOMITE - well banded grey rock comprising thick crystalline dolomite bands with wispy carbonaceous matter; calcite blebs lie parallel to bedding.
13.2	14.2	CLAYSTONE - fine buff coloured clayey rock.
14.2	22.0	RECRYSTALLISED CARBONACEOUS DOLOMITE - similar to above section but carbonaceous bands more abundant, some silicification.
		14.5-14.6 m : weathered pseudomorphs
		18.3-18.4 m : curved banding central portion (in concaved part) fractured (?) stromatolites
		18.8-19.0 m : curved banding with fractured (?) stromatolites
22.0	24.2	WEATHERED RECRYSTALLISED CARBONACEOUS DOLOMITE - similar to above; abundant red bands.
24.2	30.4	RECRYSTALLISED CARBONACEOUS DOLOMITE - as in 14.2-22.0 m section, stylolites present. Occasional curved (?) stromatolites. 26.4-29.4 m : occasional specks of chalcopyrite in (?) calcite-rich pods.
30.4	31.3	(?) FAULT - orientated about 1° to core, about 20 mm wide and filled with calcite. At 30.9 m rock porous and weathered (major aquifer?).
31.3	32.6	WEATHERED RECRYSTALLISED CARBONACEOUS DOLOMITE - haematitic staining in fractures.
32.6	47.0	RECRYSTALLISED CARBONACEOUS DOLOMITE - as above. Carbonaceous bands becoming thicker and more abundant. Minor chalcopyrite in calcite vein at 33.7-33.9 m.
		41.7 m - stromatolitic cherts interlayered with dolomite (QX1750).
47.0	48.0	INTERBEDDED CARBONACEOUS SHALE AND FINE GRAINED DOLOMITE
		47.8-48.0 m : spotted green shale with chalcopyrite crystals.
48.0	49.7	BANDED DOLOMITE - similar to 2.3-12.2 m section.
49.7	50.1	GREEN SHALE - fine grained spotted massive green rock.
50.1	51.8	RED SHALE - green chlorite in fractures.
51.8	54.0	INTERBEDDED CARBONACEOUS SHALE AND FINE GRAINED DOLOMITE
		52.4-52.6 m : two thick (20 m) carbonaceous beds with calcite veins
		52.6-52.7 m : stromatolitic debris bed
		52.7-53.2 m : recrystallised dolomite

BASE OF AMELIA DOLOMITE

54.0	54.9	GREEN SHALE
54.9	56.0	RED SHALE
56.0	57.6	DOLOMITIC SHALE - greenish colour - low carbon.
57.6	57.9	GREEN SHALE
57.9	59.5	RED SHALE
59.5	59.8	BRIGHT GREEN SHALE with carbonaceous bands and reddish layers. (?) mud cracks on cleavage plane.
59.8	60.6	BANDED DOLOMITE - medium grained dolomite with carbonaceous bands.
60.6	60.8	GREEN SHALE
60.8	62.6	RED SHALE
62.2	62.6	BRIGHT GREEN SHALE with abundant carbonaceous bands
62.6	67.4	BLACK SHALE - variably contorted carbonaceous shale with dolomitic bands. 66.3-66.5 m : pyrite blebs contort bedding
67.4	68.0	GREEN SHALE AND DOLOMITIC SHALE
68.0	80.0	RED SILTSTONE - coarser than red shale; green shale and arenaceous layers also minor dolomite. 70.0-70.4 m : dolarenite with minor carbonaceous layers 70.4-72.5 m : red arenaceous section 72.5-72.8 m : dolarenite 72.8-74.0 m : red arenaceous section 74.0-74.2 m : green shaley band with dolarenite 74.2-74.7 m : red arenaceous section
80.0	81.9	DOLOMITIC SHALE - dolarenite and carbonaceous matter, some faint red bands. 81.3-81.9 m : irregular patches of red and green shale
81.9	95.5	RED SILTSTONE - deeper red than other sections, both massive, banded and spotted; banding contorted in places. 83.5-86.6 m : arenaceous section. Variable calcite. 90.5-90.8 m : well banded section
95.5	112.2	BANDED RED AND PALE GREY LIMONITIC, SERICITE AND DOLOMITE SHALES

END OF HOLE

Fig. 9. Stratigraphic log of DDH Tawallah Pocket No. 1.

In the core, the Mallapunyah Formation consists mainly of red silty dolomite, with bedding up to 10 mm thick, interlayered with less abundant grey and red sericitic and dolomitic shales and siltstones, as well as coarse dolomite in which fragments of stromatolitic material, slumps, and load casts are preserved. Some beds of red siltstone are massive, and may be up to 3 m thick. Four cyclic sequences of dolomite and red and green shale are present. The base of the Amelia Dolomite is taken at a layer of fine-grained dolomite about 1 m thick containing interbedded bituminous shale, followed by a 35 m succession of recrystallised bituminous dolomite, the lower part of which contains the fossiliferous cherts here discussed. Curved banding in the core could represent stromatolites which are common in Amelia Dolomite outcrops[5, 6]. This sequence is followed by recrystallised bituminous dolomite (referred to in Fig. 9 as 'carbonaceous'). Similar bituminous matter from the McArthur orebody has been examined chemically by Saxby[8].

Age of the Microfossils.

The type Carpentarian sequence is currently the subject of an intensive age determination study; at present the McArthur Group can be placed only within rather broad limits. Granites forming basement to the Tawallah Group are about $1790 \pm 30 \times 10^6$ years old, and the Lower Roper Group has a minimum age of 1390×10^6 years[9]; this is the only positive data available at present.

The South Nicholson Group, 200 km southeast of McArthur River, overlies the McArthur Group, and is thought to be 1510 ± 10^6 years old[10].

It appears, then, that the age of the Amelia Dolomite lies between 1500 and 1800×10^6 years; about 1600×10^6 years would seem a reasonable prediction at this stage.

Environment of Deposition.

Most of the Umbolooga Subgroup reflects very shallow water sedimentation, alternating, commonly cyclically, between supratidal, intertidal, and subtidal. Water depth was greater when the Barney Creek Formation was deposited. The Batten Subgroup represents a carbonate basinal facies with a considerable terrigenous component; water depths decreased again when upper members of the Group were deposited, as shown by the presence of oolites, stromatolites, dolomite etc, in the Balbirini Dolomite, Amos Formation, and other stratigraphically equivalent units.

An arid hypersaline environment is indicated for the Umbolooga Subgroup by abundant halite casts in the Tooganinie Formation and, to a lesser extent, the Mallapunyah Formation and the Amelia, Emmerugga, and Teena Dolomites. Abundant red terrigenous sediments in the Mallapunyah and Tooganinie Formations indicate oxidation, and periodic subaerial exposure is shown by mud-cracks. The red dolomitic siltstones have been interpreted as subaerial deposits[11].

In the Amelia Dolomite itself superficial comparison of stromatolite forms with modern types[12] may suggest an intertidal environment. However, the cores show microalternations of organic matter and carbonate (sometimes replaced by chert) which closely resemble Recent intertidal deposits in the Persian Gulf (sabqha), and others in the geological past, which are a product of a hot dry climate and hypersaline marine conditions with frequent drying out of the sediments.

Conclusions.

The microfossils described here help to fill a gap in our knowledge of Precambrian microorganisms. Stratigraphically, they lie between the well-known Gunflint Chert and Bitter Springs Formation assemblages; morphologically they represent a considerable evolutionary advance on the Gunflint Chert microorganisms. The colonial organisms are the oldest so far discovered, and furthermore, the oldest organisms showing clear evidence of cellular differentiation. The wide variety and large numbers of microorganisms found in the Amelia Dolomite assemblages will repay further intensive study, and represent an exciting advance in our knowledge of Precambrian microbiota.

Acknowledgements.

We gratefully acknowledge the co-operation of the Carpentaria Exploration Co. Pty Ltd for supplying the drill core and information on which this paper is based, and Mount Isa Mines Holdings Ltd for allowing us to use their material. The paper is published with the permission of the Director, Bureau of Mineral Resources, Canberra, Australia, and we are indebted to Conzinc Riotinto of Australia Limited who provided financial support in the form of a grant to the Baas Becking Geobiological Laboratory for one of us (MDM) to visit the area and collect further material. We are also grateful to Mr Haddon F. King for his interest and support.

REFERENCES

1. BARGHOORN, E.S. & TYLER, S.A., 1965. Science, 147, no. 3658, 563-577.
2. SCHOPF, J.W., 1968. Journ. Palaeont., 42, 651-688.
3. SCHOPF, J.W., & BLACIC, J.M., 1971. Journ. Palaeont., 45, 925-960.
4. DUNN, P.R., PLUMB, K.A., & ROBERTS, H.G., J. Geol. Soc. Aust., 13, 593-608 (1966).
5. SMITH, J.W., Bur. Miner. Resour. Aust. Explan. Notes SE/53-3 (1964).
6. PLUMB, K.A., & BROWN, M.C. (in press), Bur. Miner. Resour. Aust. Bull., 139, 101-133 (1973).
7. CROXFORD, N.J.W., & JEPHCOTT, S., Proc. Aust. Inst. Min. Met. 243, 1-26 (1972).
8. SAXBY, J.D., Geochim. Cosmochim. Acta, 34, 1317-1326 (1970).
9. McDOUGALL, I., DUNN, P.R., COMPSTON, W., WEBB, A.W., RICHARDS, J.R., & BOFINGER, V.M., J. Geol. Soc. Aust., 12, 67-90 (1965).
10. COMPSTON, W., & ARRIENS, P.A., Can. J. Earth Sci., 5, 561-583, (1968).
11. BROWN, M.C., (personal communication, 1969).
12. LOGAN, B.W., REZAK, R., & GINSBURG, R.N., J. Geol., 72, 68-83, (1964).