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MICROFOSSILS IN THIN SECTION



Black cherts from stromatolitic horizons (Figs. 25, 26) in the McLeary Formation on Tukarak Island (Belcher Islands) preserve clusters of irregular, subspheroidal cells (Figs. 1-5, 8). Hoffman (1976: 8,9) included two figures of "Acritarcha" from the same unit but different locality, which are reproduced here in Figure 3. The term, *acritarch*, implies a eukaryotic origin, but these microfos-sils not not possess a mininimum set of eukaryotic charac-ters and are more likely remains of cells at a prokaryotic

evolutionary grade. Notice the irregularity in both size and shape in these microfossils - they are generally spherical, but not strictly so. Figures 4 and 5 are the same population viewed in different focal planes. Figures 6 and 7 display populations of oriented filamentous heaths preserved within clotted (thrombolitic) fabrics. Figure 7 (Gunflintia minuta) is from the black chert in Fig 25 (McLeary Fm on Tukarak Island). Figure 8 shows a portion of a layer of spheroidal microfossils forming part of an *in situ* lamina from the same outcrop.









sill/Flarity Volcanics (Hamilton et al. 2009) in the Belchers and a 2025 Ma date from apatite cement in the Pachi Fm (Chandler & Parrish 1989) at the base of the Richmond Gulf Group that underlies sediments of the Jastapoka and Belcher groups.

Palynomorphs are normally only though of a eukaryotic because there is a requirement that a robust wall be present to provide the potential for preserva-tion of a fossilized cell. However, with material of this age (ca. 2.0 Ga), we must rely upon preserved morphology as direct proof of eukaryotic affinity. Therefore, we should be open to the idea that a variety of refractory organic substances might preserve and retain some degree of primary biological form. Consequently, EPS derived from prokaryotes might be preserved in a palynological preparation.

THERE ARE NO EUKARYOTES AT 2 GA

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Abstract.-- Shales and cherts from the Belcher Islands, the Nastapoka Group and the Richmond Gulf Group contain well-preserved microfossils in a range of depositional settings. Preservation in silicified stromatolites occurs as organic matter which was trapped in silica prior to compaction (Figs. 1-8). In banded iron formation cherts, haematite has replaced primary organic structure. Siliciclastic mudstones and siltstones preserve primary organic matter, which may be in the form of macroscopic sheets of carbonaceous matter (Figs. 21-24) or discrete palynomorphs (Figs. 9-11, 13-20) released via acid maceration. In spite of this range of preservational taphonomy with respect to organic carbon, no evidence of eukaryotic cells are seen in these ca. 2.0 Ga deposits. Spheroidal and filamentous palynomorphs recovered from these deposits do not possess structurally complex walls or predetermined excystment openings that might be construed as eukaryotic characters. Rather, they appear to consist of granular aggregates of carbonaceous material. Similar granular organic microstructures have been recovered in younger Mesoproterozoic rocks (Fig. 12). The observation that microstructures at a prokaryotic grade of cell evolution can be preserved as discrete palynomorphs, provides a logical explanation for some problematic forms found in Archæan rocks. Additionally, the lack of eukaryotes in fossiliferous palynological assemblages at 2 Ga sets a lower boundary age for the origin window of the eukaryotic cell based on the fossil record. That window is currently 2.0 to 1.8 Ga, given the clearly eukaryotic character of palynomorphs recovered from the Changcheng Group in North China at around 1.8 Ga (Lamb et al., 2009; Peng et al. 2009).

MICROFOSSILS (PALYNOMORPHS) FROM ACID MACERATION



The rocks of the Belcher Island and related Nastapoka and Richmond groups contain extensive exposures of partially silicified stromatolites, shales and sand-stones – all fairly normal platform sediments. I have examined thin sections of black chert in association with carbonate stromatolites, macerations of shales interbedded with these stromatolites and, on Clarke Island (Nastapoka Grp, Fig. 27), macerations of shales interbedded with crossbedded sandstones. Macerated shales reveal structural organic matter, but in no cases have I found any microfos-sils that are convincingly at a eukaryotic level of cellular organization. This leads to the conclusion that rocks of this age are preserving remains of prokaryotes, either as individual organisms, degraded microbial mats or as the remains of exo-polymeric substances (EPS) that do not retain any cellular structure.

Simple vesicular palynomorph with obviously granular wall structure - I now refer to these as granular organic-walled microfossils, or GOMs- are possibly of prokaryotic origin. They may occur alongside eukaryotic forms, such as *Leios*phaeridia crasa, in Mesoproterozoic and Neoproterozoic sediments and one such example is included here in Fig. 12. These forms can be quite large, up to 200 μ m in diameter. If they were single cells, this would be somewhat exceptional in terms of normal bacterial morphology. However, it is important to point out that we never see distinct structure at the level of the cell itself in any of the GOMS.

In cherts, which retain 3-dimensional preservation, vesicular microfossils are generally spherical in shape, but they are always somewhat deformed (Figs. 1, 2, 8). This gives the impression of a non-rigid primary wall. They do not correspond to any particular known bacterial form. So the biological source of these forms is problematic – at the very least, I would not refer to them as *acritarchs*, simply because this term carries with it a strong implication of eukaryotic affinity. In addition, populations of these microspheres do not show direct evidence of growth patterns or cell divisions that so oftern characterize much younger examples that are clearly of cyanobacterial origin. We are left with forms without clear extant analogs.







Palynomorphs were recoverd from shales interbedded with stromatolites (Fig. 26, McLeary Fm) and shales interbedded with cross-bedded sandstones on Clarke Island (Fig. 27, unnamed formation lithostratigraphically equivalent to the Rowatt Fm) in the Nastapoka Group. They typically consist of granular-walled spheroids (Figs. 10, 11, 14-16), but include linear structures as well (Figs. 13, 17-20). Some of the spheroids can be quite large (e.g. Fig. 11 is over 100 µm). The walls are granular in construction and it is not possible to pick out individual wall layers. Granular organic microfossils (GOMs) are also found in latest Mesoproterozoic (Fig. 12, Torridon Group, Scotland) and Neoproterozoic rocks, where Blumenberger et al. (2012) interpret them to be remains of microbial mats. In some cases, rows of bead-like cells are found embedded in linear organic features (Fig. 20). Similar microstructures are found elsewhere in the Belcher Group and are known from other rocks of this age associated with iron formation (Knoll & Simonson, 1981). In all cases, these are interpreted to be prokaryotic in origin.

Organic films and compressions are found in the Richmond Gulf in shales immediately below horizons rich in stromatolites (Fig. 28). Although these are large fragments, readily visible to the naked eye, they do not possess any unequivically eukaryotic characters. Figure 21 shows a thin organic layer with clear margins, but, overall this specimen appears to me more of a stain than a discrete structure. Figure 23 is the most interesting specimen. It is an organic compression with a rounded tip which is detailed in Fig. 24 (white box in Fig. 22). The fossil was originally cohesive, as it appears to have torn (arrow) during the fossilization process. The margin on the right hand side is distinct and entire, but the left hand margin (arrow) appears somewhat fibrous in character. This fossil may have an inderlying filamentous construction which is compatable with its interpretation as mat-like growth of cyanobacteria.

The fossils in figures 21-24 are perhaps the most interesting as the represent organic structures that are visible to the naked eye – comparable in that sense to *Grypania*, although these forms appear far less "organized" than *Grypania*. They occur in shales interbedded with stromatolites in the Richmond Gulf (Fig. 28). They were clearly once cohesive as cracks and tears disrupt the specimens. For now, I would propose that these are the remains of microbial mats or outgrowths of mats which were held together with EPS.

Overall, this result demonstrates that we need to rethink the possibility that pro-karyotes can be preserved in the fossil record as palynomorphs. This approach may be useful in order to correctly interpret organic-walled microfossils that are now being described from Archæan sequences (Javaux *et al.* 2010). Given that no palynomorphs of clearly eukaryotic provenance were obtained from the range of lithofacies sampled in these sequences, it seems likely that eukaryotes had yet to evolve by 2.0 Ga. This would specify, based entirely on the fossil record, a 200 My window, between 2.0 and 1.8 Ga, during which the eukaryotes evolved.

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MESOFOSSILS ON BEDDING PLANE SURFACES



