MORPHOLOGICAL AND HETEROATOM PRESERVATIONS SUGGEST CELLULAR ORGANIZATION IN 3.4 GYR-OLD MICROFOSSILS

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Introduction

Organic-walled microfossils are thought to testify for the early widespread of life in Archean metasedimentary rocks. Carbonaceous nature, morphological complexity, cell lumens, carbon isotopic heterogeneity, organization into chains and cluster but also taphonomic degradation features were alternatively used as criteria attesting their biogenicity (Wacey et al., 2011). Despite these criterion, some doubts remain about their biogenicity as (i) formation of mineral/carbonaceous biomorphs can occur (Garcia-Ruiz et al., 2003; Cosmidis and Templeton, 2016), and (iii) some microstructures have been interpreted as vesicular volcanic glasses (Wacey et al., 2018). Thus, complementary investigations including palynology and geochemical analyses are required to document the biogenicity of these putative microfossils. Our goal was therefore to provide new evidences for the biogenecity of carbonaceous microstructures from the 3.4 Gyr-old Strelley Pool Formation by investigating both their morphological and geochemical preservations. Microstructures were first isolated according to a modified version of the classical procedure of hydrochloric/hydrofluoric acid maceration aiming to minimize their potential physical disruption and chemical degradation. Microstructures were imaged and their carbonaceous nature was assessed using Scanning Electron Microscopy- Energy-Dispersive X-ray Spectroscopy (SEM-EDXS). Their syngeneity was then evaluated through Raman spectroscopy. Finally, preservation of nitrogen (N) and phosphorus (P) as building elements for cell wall was tracked at the scale of individual microstructures using Nanoscale secondary ion mass spectrometry (NanoSIMS).

Results

An unexpected and large diversity of morphologies has been observed among the studied microstructure assemblage. Thus, four morphological types (filaments, films, spheroids and lenses) have been identified in the acid maceration residue. SEM-EDXS analyses reveal that all microstructures were almost exclusively composed of OM (C, N, S and O) ruling out any organic coating on mineral biomorphs. In addition, the Raman spectrum of these carbonaceous microstructures is composed of a first-order region (1100–1800 cm^{-1}) exhibiting two broad bands at ca. 1350 and 1600 cm^{-1} whose intensity ratio corresponds to those observed on OM that has experienced prehnite-pumpellyite to lower greenschist metamorphic grades as expected for the SPF (Delarue et al., 2016). Therefore, isolated microstructures should be seen as syngenetic. Investigating the preservation of heteroatoms within individual microfossils through NanoSIMS, we show large variation in the N/C atomic ratio ranging between 5×10^{-3} and 2×10^{-1}, as determined in bulk OM and in some exceptionally well-preserved specimens, respectively (Beaumont and Robert, 1999; Alleon et al., 2018). High N/C atomic ratios are mostly obtained in microstructures with a continuous surface wall. In addition to their high N/C atomic ratio, these microstructures were also characterized by higher amounts of P, which exhibits two distinct spatial patterns. First, P was systematically measured across the entire microstructure surface. Second, P hotspots have been also probed –only in lenses- under the form of micrometric patches. Neither mineral phases nor any microtopographic-induced analytical bias could explain the occurrence of such P patches on the surface wall of carbonaceous lenses. As a result, the P patches appear intimately associated with OM.

Conclusions

Except for filaments, this study provides additional and new evidences for the biogenicity of 3.4 Gyr-old microfossils from the Strelley Pool Formation. We demonstrated that spheroids, films and lenses morphological type include some exceptionally well-preserved specimens characterized by a continuous cell wall surface. These well-preserved microfossils exhibit high yields in both N and P across their whole surface suggesting preservation of cell membrane. In addition, P was also present as micrometric patches. In extant microorganisms, such P patches correspond to polyphosphate granules serving as an energy store in some prokaryotes and eukaryotes during sporulation. Taken together, morphological and geochemical preservations argue for cellular organization as soon as 3.4 Ga.

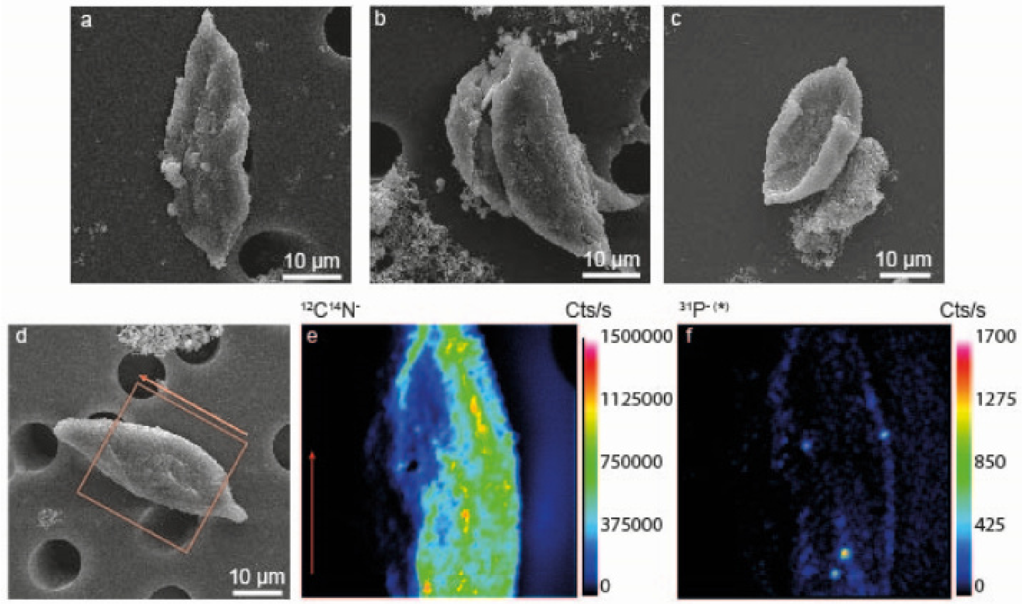

Figure 1 *Figure 9: (a-c) SEM images of lenses. (d) SEM image of a lens and (e, f) corresponding NanoSIMS ion images of* $^{12}C^{14}N^-$ *and* $^{31}P^-$*. The asterisk indicates that the* $^{31}P^-$ *ion image corresponds to a "smoothed image", in which* $^{31}P^-$ *intensities are averaged over regions of 3 × 3 pixels.*

References

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