RELATIONSHIP BETWEEN MORPHOLOGICAL AND GEOCHEMICAL PRESERVATION IN ARCHEAN MICROFOSSILS (3.0 GYR; FARREL QUARTZITE)

F. Delarue[1,2], F. Robert[2], S. Derenne[1]

[1]CNRS/UPMC/EPHE, France
[2]CNRS/MNHN/UPMC, France

Introduction

Archean microorganisms are generally thought to be fossilized through permineralization resulting from the "early infiltration and permeation of tissues by mineral-charged water" (Schopf 1975). Consequently, the organic constituents are progressively replaced by silica or carbonates. However, the presence of organic-walled microfossils in some Archean rocks (Sugitani et al., 2015) points to the existence of other mechanisms of fossilization, such as encapsulation of microorganisms through nucleation of adjacent mineral crystals. Encapsulation is known to favour both morphological and geochemical preservation of microfossils (Konhauser and Ferris, 1996). However, such an issue remains undocumented in Archean rocks despite its great potential for preservation of microorganisms. We investigated the morphological and geochemical preservation of encapsulated microfossils from the Farrel Quartzite (3.0 Gyr-old). To this end, we studied the nitrogen and hydrogen composition of microfossils isolated following a mild acid treatment. Syngenecity of microfossils were controlled by Raman microspectrometry. Elemental (N and H) preservation was then studied at the scale of microfossils using Nanoscale secondary ion mass spectrometry (NanoSIMS). The degree of surface and internal morphological preservation of microfossils was assessed by (i) scanning electron microscopy (SEM) and (ii) performing Laser Focused Ion Beam ultra-thin sections followed by SEM observations.

Results

Microfossils were observed in the organic matter (OM) isolated by a mild procedure (no grinding and use of HF/HCl 9/1, v/v solution). SEM observations of their surface and internal morphological preservation suggest the existence of a large gradient of physical disruption among microfossils. In parallel, we observe an increasing contribution of carbonaceous globules tightly associated with degraded microfossils. These globules are therefore interpreted as degradation by-products of the microfossils.
Although all microfossils share the same thermal alteration history as evidenced by Raman microspectrometry, the *in situ* $^{12}C^{14}N^{-}/^{12}C_2^{-}$ ionic ratios obtained by NanoSIMS led to distinguish three geochemical groups of microfossils (Fig. 1). Using the *in situ* N/C atomic ratio as a proxy of the geochemical preservation of microfossils, we show that most *in situ* N/C atomic ratios are in agreement with the bulk N/C atomic ratio ($5\ 10^{-3}$). However, a substantial part of the microfossils (15-20%) presents more than 10 times higher *in situ* N/C atomic ratio values evidencing in turn, an exceptional preservation of their N content. The preservation of N was not associated with any changes in the H content. Indeed, the three distinct geochemical groups of microfossils present the same content in hydrogenated moieties as evidenced by $^{12}CH^{-}/^{12}C_2^{-}$ ionic ratios in NanoSIMS (Fig. 1). Finally, preservation of the N content was linked to the degree of surface and internal preservation as revealed by

the abundance of carbonaceous globules since the highest *in situ* N/C atomic ratio were systematically found in globule-lacking microfossils.

Conclusions

Combining SEM and NanoSIMS on isolated microfossils from the Farrel Quartzite, we report that their encapsulation favoured both morphological and geochemical N preservation which seems tightly linked. However, no effect could be recorded on their H content. Since (i) N moiety degradation occurs during early diagenesis and (ii) N preservation is not a function of microfossil type, we suggest that more than a geochemical preservation proxy, the *in situ* N/C atomic ratio value of encapsulated microfossils may record the geochemical state of the microorganism before fossilization.

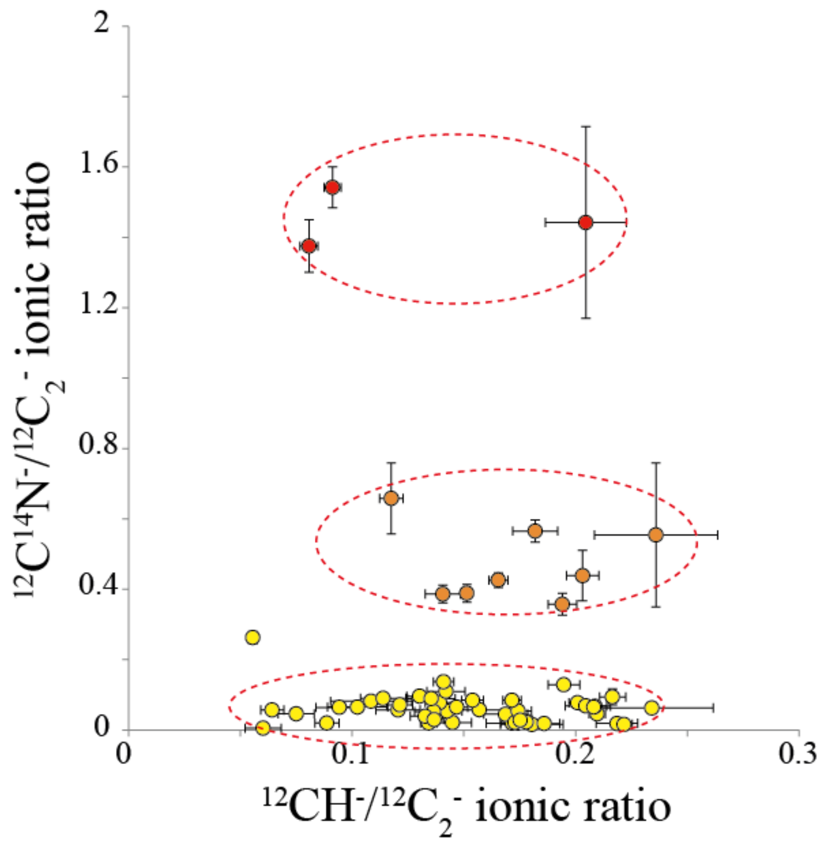

Figure 1 *Distinction of the three organic N preservation groups (yellow, orange and red circles) determined by NanoSIMS in the 3.0 Gyr-old Farrel Quartzite.*

References

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