

Multiscale textural assessment of the morphogenesis of lenticular microstructures from Archean cherts of the Pilbara Craton

Maxime Coutant^{1,2}, Kevin Lepot^{2,3}, Alexandre Fadel⁴, Ahmed Addad⁴, Kenichiro Sugitani⁵, Emmanuelle J. Javaux¹

¹ *Early Life Traces & Evolution–Astrobiology, UR Astrobiology, University of Liège, Liège, Belgium*

² *Univ. Lille, CNRS, Univ. Littoral Côte d'Opale, UMR 8187 - LOG - Laboratoire d'Océanologie et de Géosciences, F-59000 Lille, France*

³ *Institut Universitaire de France (IUF)*

⁴ *Univ. Lille, CNRS, UMR 8207 - UMET - Unité Matériaux et Transformations, F-59000 Lille, France*

⁵ *Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan*

Criteria used to distinguish genuine Precambrian microfossils from biomorphs have frequently been re-assessed and sometimes led to reconsider the inference of biogenicity for the microstructure of Archean carbonaceous specimens^{1–3}. In particular, mineral growths associated with carbonaceous matter displacement through diagenesis and/or metasomatism may induce biomorphs mimicking simple microfossils shapes^{1,4,5}. The Strelley Pool Formation in the Pilbara craton (Western Australia) hosts the oldest stromatolites for which an origin as microbially-induced sedimentary rocks⁶ remains undisputed^{2,3}. Chert rocks from the 3.4 Ga Strelley Pool Formation (SPF) and the 3.0 Ga Farrel Quartzite (FQ) display occurrences of lenticular carbonaceous microstructures that are interpreted as probable microfossils⁷. These remain enigmatic. Firstly, they display complex, atypical morphologies that make them difficult to relate to living or known fossil taxa⁷. Secondly, heterogeneous carbon isotopic ratios measured within these lenticular microstructures argue against a single hydrocarbon intrusion as the origin of the carbonaceous matter, and may represent original biomass-derived heterogeneities⁸. These sedimentary deposits experienced metamorphism up to greenschist facies (~350°C) and hydrothermal activity that have altered the composition and—most likely—the texture of the carbonaceous matter. Moreover, diagenesis and/or hydrothermalism may have displaced indigenous and/or exogenous (if any) carbonaceous matter (biogenic and/or abiogenic) onto primary carbonaceous structures or mineral biomorphs.

Here we carry detailed petrography of lenticular and associated spheroid microstructures in the SPF and FQ cherts to examine the possible links between carbonaceous matter textures and their host mineral matrix to further assess biogenicity and syngenicity. We used advanced techniques in optical microscopy including confocal laser scanning microscopy (CLSM) coupled to high-resolution scanning transmitted electron microscopy (STEM) of ultrathin sections. Petrography of the crystal matrix has been detailed at the submicrometer scale in Electron backscattered diffraction (EBSD) mapping (in the scanning electron microscope) and with nanodiffraction mapping (in the transmission electron microscope).

Results led to a rigorous documentation of features and characteristics of each type and subtypes of lenticular specimens previously reported⁷. Lenses display sub-continuous carbonaceous walls and/or fillings of reticulated and granular carbonaceous material. All these carbonaceous textures are solely localized at quartz crystal boundaries. Carbonaceous textures, in particular the occasional walls, that define these lenticular structures appear flexible. Their morphogenesis will be discussed as the possible results of taphonomic and/or diagenetic processes. Comparison will be made with similar observations carried on a range of spheroid microstructures, including abiotic forms and dubiofossils, previously studied from the SPF⁴ and from the FQ as part of the present study.

References

1. Rouillard, J., Van Zuilen, M., Pisapia, C. & Garcia-Ruiz, J. M. An Alternative Approach for Assessing Biogenicity. *Astrobiology* **21**, 151–164 (2021).
2. Javaux, E. J. Challenges in evidencing the earliest traces of life. *Nature* **572**, 451–460 (2019).
3. Lepot, K. Signatures of early microbial life from the Archean (4 to 2.5 Ga) eon. *Earth-Science Rev.* **209**, 103296 (2020).
4. Coutant, M. Lepot, K. Fadel, A. Addad, A. Richard, E. Troadec, D. Ventalon, S. Sugitani, K. Javaux, E. J. Distinguishing cellular from abiotic spheroidal microstructures in the ca. 3.4 Ga Strelley Pool Formation. *Geobiology* **22** 1–24 (2022)
5. McMahon, S. & Cosmidis, J. False biosignatures on Mars: anticipating ambiguity. *J. Geol. Soc. London*.
6. Allwood, A. C., Walter, M. R., Kamber, B. S., Marshall, C. P. & Burch, I. W. Stromatolite reef from the Early Archaean era of Australia. *Nature* **441**, 714–718 (2006).
7. Sugitani, K. Early Archean (Pre-3.0 Ga) Cellularly Preserved Microfossils and Microfossil-Like Structures From the Pilbara Craton, Western Australia—A Review. *Earth's Oldest Rocks* (2019).
8. Lepot, K. Williford, K. H. Ushikubo, T. Sugitani, K. Mumura, K. Spicuzza, M.J. Valley, John. W. Texture-specific isotopic compositions in 3.4Gyr old organic matter support selective preservation in cell-like structures. *Geochim. Cosmochim. Acta* **112**, 66–86 (2013).