

Silicification of trilobites and biofilm from the Cambrian Weeks Formation, Utah: Evidence for microbial mediation of silicification

Yeongju Oh^{1,2,*}, Yong-Hoe Choe³, John S. Peel⁴, Yong Yi Zhen⁵, Patrick Smith^{6,7}, and Tae-Yoon S. Park^{1,2,*}

¹Division of Earth Sciences, Korea Polar Research Institute, Incheon 21990, Republic of Korea

²Polar Science, University of Science and Technology, Daejeon 34113, Republic of Korea

³Division of Life Sciences, Korea Polar Research Institute, Incheon 21990, Republic of Korea

⁴Department of Earth Sciences (Palaeobiology), Uppsala University, SE-752 36 Uppsala, Sweden

⁵Geological Survey of New South Wales, W.B. Clarke Geoscience Centre, Londonderry, NSW 2753, Australia

⁶Palaeontology Department, Australian Museum Research Institute, Sydney, NSW 2010, Australia

⁷Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia

*yjoh@kopri.re.kr; tyepark@kopri.re.kr

Melim et al. (2023) presented potential evidence for the microbial mediation of silicification, citing examples such as “carbon-rich threads, ribbons, and strings.” They interpreted the carbon-rich materials covering the trilobite sclerites and the matrix as a silicified biofilm, suggesting this was the first direct evidence of microbial-mediated silicification. While we agree that biofilms could play a significant role in silicification, we recommend reevaluating some of the evidence for the “silicified biofilm” presented by Melim et al.

First, large subhedral silica crystals (e.g., Melim et al., 2023, their figure 3B; referred to as “megaquartz” in Butts and Briggs, 2011) and the low fidelity of the trilobite sclerites lacking their original structures and mineralogy suggest a late-stage silicification process (mineral cementation occurring after dissolution), rather than true “replacement.”

Melim et al. interpreted the “C-rich mats” as a later biofilm unrelated to silicification, while considering the “C-rich threads, ribbons, and strings” as silica-replaced extracellular polymeric substances (EPS) biofilm. However, the abundant carbon compositions described by Melim et al. do not align with the typical silica precipitation of microorganisms within biofilms (Butts and Briggs, 2011). Second, the carbon-rich materials exhibit distinct fidelity, including flexibility and shrinkage cracks, compared to the underlying sclerites, which are poorly preserved.

Herein, we propose an alternative explanation for the “C-rich threads, ribbons, and strings.” They may correspond to fungal hyphae from modern endoliths that were released during the acid-etching preparation. Endoliths represent a morphologically and physiologically diverse group of microorganisms such as bacteria and fungi that inhabit rocks or animal shells (Marlow et al., 2015), and carbonate rocks are common substrates for rock-

penetrating euendoliths. Furthermore, fungal euendoliths are generally dominant in nonmarine (e.g., soils) and brackish aquatic environments, forming complex filamentous networks of hyphae that typically penetrate deep into rocky outcrops (Fig. 1A; Casanova Municchia et al., 2014; Marlow et al., 2015). Weak acetic or hydrochloric acid solutions have been used to expose endoliths residing in carbonate matrixes (e.g., Casanova Municchia et al., 2014). We confirmed that fungal hyphae from living endolithic microorganisms can be recovered after acid etching to obtain acid-resistant skeletal microfossils in carbonate rocks. The etched fungal hyphae are slimy and flexible (Fig. 1B), often anastomosing, and capable of attaching to solid surfaces, such as microfossil residues, sediment grains, and even carbon tape (Figs. 1C–1G). The morphology, including size, flexibility, and anastomosing patterns of the recovered fungal hyphae, closely resembles the carbon-rich materials depicted in Melim et al. Additionally, we conducted energy dispersive spectroscopy (EDS) analysis on fungal hyphae attached to Cambrian silicified sclerites (Figs. 1H and 1I) to compare with those of Melim et al. The EDS results clearly reveal that the isolated fungal hyphae show an exclusive carbon (C) composition (Fig. 1H). The fungal hyphae attached to the silicified sclerites show silica-oxygen (Si-O) composition as well as abundant C (Spectrum B in Fig. 1I), whereas the silicified trilobite sclerite only exhibits a Si-O composition (Spectrum C in Fig. 1I), as mentioned by Melim et al.

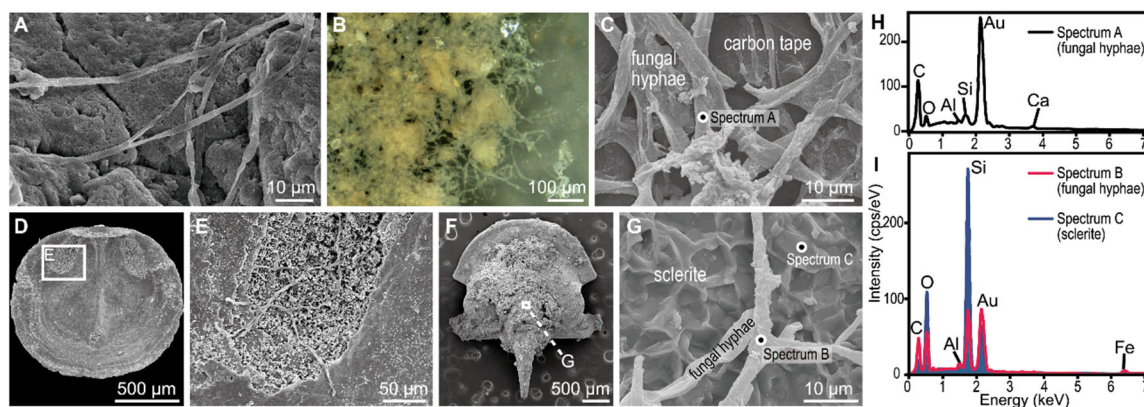


Figure 1. (A) Endolithic fungal hyphae found from limestone in Svalbard, Norway (fixed in 2.5% glutaraldehyde for 8 h and air-dried overnight for the scanning electron microscopy). (B, C) Endolithic fungal hyphae recovered within the acid-etched microfossil residues of the limestone from the Cambrian Coonigan Formation of New South Wales, Australia, showing a slimy texture in wet condition (B) and anastomosing pattern under scanning electron microscopy (C). (D–G) Microfossil sclerites associated with fungal hyphae in the same sample of B and C, including linguliform brachiopod with phosphatic shell (D and E) and trilobite (F and G). The boxes in D and F denote the figured area of E and G, respectively. (H and I) Energy dispersive spectroscopy (EDS) of the isolated fungal hyphae (H), as well as the silicified trilobite sclerites and the fungal hyphae (I). The locations of EDS are indicated in C and G, respectively. Au from coating material.

REFERENCES CITED

- Butts, S.H., and Briggs, D.E.G., 2011, Silicification through time, *in* Allison, P.A., and Bottjer, D.J., eds, *Taphonomy: Process and bias through time*: Springer, p. 411–434.
- Casanova Municchia, A., Percario, Z., and Caneva, G., 2014, Detection of endolithic spatial distribution in marble stone: *Journal of Microscopy*, v. 256, p. 37–45, <https://doi.org/10.1111/jmi.12155>.
- Marlow, J., Peckmann, J., and Orphan, V., 2015, Autoendoliths: A distinct type of rock-hosted microbial life: *Geobiology*, v. 13, p. 303–307, <https://doi.org/10.1111/gbi.12131>.
- Melim, L.A., Mure-Ravaud, S.R., Hegna, T.A., Bellott, B.J., and Lerosey-Aubril, R., 2023, Silicification of trilobites and biofilm from the Cambrian Weeks Formation, Utah: Evidence for microbial mediation of silicification: *Geology*, v. 51, p. 80–84, <https://doi.org/10.1130/G50496.1>.