Cyanobacterial photoprotective pigments as example of robust signatures of life

Yannick J. Lara[1], Catherine F. Demoulin[1], Arnaud Vansteenkiste[1] and Emmanuelle J. Javaux[1]

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

Cyanobacteria is an ancient bacterial lineage that probably emerged very early during the Earth evolution. The cyanobacterial ancestor has invented oxygenic photosynthesis and may have colonized rocky surface and intertidal zone among other habitat while lethal doses of UV radiations were reaching the Earth surface. To protect cellular components as well as their photosynthetic apparatus from these harmful radiations and from the formation of free radicals poisoning their cells, it is likely that cyanobacteria ancestors developed strategies that included the production of UV-screening pigments.

Pigments are molecules containing chromophoric functional groups that absorb stellar radiations in the visible wavelength whether to transfer or to dissipate energy. Apart from pigments involved in photosynthesis (e.g. carotenoids, chlorophylls, phycobillins), cyanobacteria are known to synthetize two extracellular pigments that also absorb UV-A aka scytonemin [1] and potentially UV-B&C aka gloeocapsin [2]. Scytonemin structures and biosynthesis genes cluster has been elegantly elucidated and illustrated during the last three decades by Professor Garcia-Pichel and his colleagues. However, there is still a substantial gap of knowledge for the gloeocapsin. This halochromic pigment was first observed by Nägeli and Schwenderer in 1877 [3], and named after *Gloeocapsa* spp., and the first Raman signature characterization was only published 138 years after [4].

The fossil record [5] and molecular evolution study of scytonemin biosynthesis gene cluster (*scy*) [6] both suggest a minimum age of scytonemin around 2 Ga. In parallel, the wide distribution of gloeocapsin-producing strains among the cyanobacterial phylum and the precambrian microfossils resembling gloeocapsin-producing modern taxa may also suggest its early emergence [2]. Therefore, both pigments may represent valuable signatures of cyanobacteria in sedimentary samples. Life on other planets, if it exists, might also require the biosynthesis of analogous UV-screening compounds to protect itself from stellar UV emissions, which make cyanobacterial UV-screening pigments also relevant as model study. However, most of the functional groups or compounds present in the molecular structures of cyanobacterial pigments (aromatic ring, polyene structure, tryptophan, polyphenol) are known to form also abiotically. Consequently, it is important to consider such potential terrestrial and extra-terrestrial complex organic compounds in a morphological and chemical context to provide potential robust biosignatures [2].

In the *Early Life Traces & Evolution – Astrobiology laboratory*, we investigate biochemical and morphological cyanobacterial biosignatures, and the distribution of UV-screening pigments in the cyanobacterial phylum to investigate their traces through experimental and natural fossilization processes and to assess the evolutionary implications.

[1] F. Garcia-Pichel, R. W. Castenholz, *Journal of Phycology*, **27,** 395-409 (1991)
[2] Y. J. Lara, (…) and E. J. Javaux, *Astrobiology*, **22,** 6 (2022)
[3] C. Nägeli, and Schwendener, *The Microscope: Theory and application*, **xii,** 679 (1877)
[4] J. Y. Storme, (…) and E. J. Javaux, *Astrobiology*, **15,** 843-857 (2015)
[5] C. F. Demoulin, Y. J. Lara, (…) and E. J. Javaux, *Free Radical Biology and Medicine*, 140**,** 206-223 (2019)
[6] F. Garcia Pichel, (…) and M. F. Wojciechowski, *mBio*, **10,** 1-14 (2019)