Influence of early ocean chemistry on cell biochemistry and prokaryotic metallomic biosignatures

KEYRON HICKMAN-LEWIS[1,2], BARBARA CAVALAZZI[2,3], STÉPHANIE SORIEUL[4], PASCALE GAUTRET[5], FRÉDÉRIC FOUCHER[1], THOMAS GEORGELIN[1,6], CHARLES S. COCKELL[7], FRANCES WESTALL[1]

[1]CNRS CBM, Orléans, France, keyron.hickman-lewis@cnrs-orleans.fr; [2]Univ. Bologna, Italy; [3]Univ. Johannesburg, S. Africa; [4]Univ. Bordeaux, France; [5]Univ. Orléans, France; [6]UPMC, Paris, France; [7]Univ. Edinburgh, UK.

Trace elements and life: Modern biological dependency on trace elements in the oceans may be a consequence of their richness in the habitats of early life. This suggests that the early oceans were rich in elements that we now term 'trace'[1]. Geochemical analyses of putatively biogenic organic matter in 3.33 Ga cherts of the Barberton greenstone belt – using particle-induced X-ray emission (PIXE) and ion beam analysis – quantitatively assess the concentrations and distributions of bio-essential and bio-functional trace elements, and may provide a tool to evaluate this hypothesis.

Trace element biosignatures: We demonstrate that a number of biologically essential trace metals are recurrently enriched within specific morphologies of ^{12}C-rich carbonaceous material (CM) from hydrothermal cherts. CM in the form of irregular clots and coatings on volcanic particles – known life modes of colonial chemotrophs – exhibits patterns in elemental signatures resembling the *metallome*, i.e. the elemental complement enabling cell functionality, of anaerobic, thermophilic methanogens and diazotrophs[2]. Patterns of enrichment in Fe, Ni, Cu, Co and As within CM argue against abiotic concentration.

This clotted carbonaceous chert therefore likely has a biological precursor, possibly lithotrophic and organotrophic micro-organisms. Our approach provides a novel and non-invasive method of estimating biogenicity and perhaps microbial metabolism in the absence of cellular preservation and could be applied throughout the Archaean rock record[2].

Broadly, we support that modern cellular enrichments in trace elements are not coincidental, but rather vestiges of the thermophilic, nutrient-rich environment in which primitive life evolved[1]. Consistency between these trace element distributions, the estimated identity of early life, proposed Archaean biomes, co-ordination chemistry, and ancient ocean chemistry correlatively sustain that quantified trace element distributions represent a potential unrecognised biosignature.

[1] Frausto da Silva, J.J.R. Williams, R.J.P., 2001. *OUP*.

[2] Hickman-Lewis, K., *et al.*, submitted to *Nat. Geosci*.