Geophysical Research Abstracts, Vol. 7, 10220, 2005
SRef-ID: 1607-7962/gra/EGU05-A-10220

Silica Fossilisation: The Importance of Being Ensheathed

Konhauser K. and Lalonde S.

Department of Earth and Atmospheric Sciences

University of Alberta

Edmonton, Alberta, Canada T5N 2A2

kurtk@ualberta.ca

Archean microfossils provide some of the earliest physical evidence for life on Earth. Despite their obvious importance for understanding microbial evolution, there remains a great deal of uncertainty regarding which microorganisms were actually fossilised. What is apparent is that there is a preservational bias towards cells that had thick cell walls and/or sheaths. This is unsurprising since the peptidoglycan and the polymers that comprise the sheath are more resilient to degradation than other cell components, and as long as the constituent autolysins are deactivated, they can persist in the environment long after the cell dies. Therefore, in terms of preservation potential, ancient microfossil assemblages may be biased towards microorganisms, such as some cyanobacteria, simply because they possessed ultrastructures less amenable to degradation. Conversely, other cells with different cellular features degraded and left little evidence of their original organic framework.

A number of experimental studies in the past few decades have tried to determine the physical changes induced on various bacteria during silicification. They have shown that species-specific patterns of silicification exist, and that different microbes are capable of being silicified with different degrees of fidelity. Such findings are predictable

given that the actual mechanisms of silicification rely, in part, on the microorganisms providing reactive surface ligands that adsorb silica from solution, and accordingly, reduce the activation energy barriers to heterogeneous nucleation. In one of the only studies of its kind, Phoenix et al. (2000) tested cell viability during biomineralisation, and observed that experimental silicification of *Calothrix* was not notably detrimental to the microorganism. Even after 12 days of incubation in a 600 mg l^{-1} silica solution, during which many of the filaments developed extensive mineral crusts up to 5 μm thick, the cells still fluoresced, they continued to generate oxygen and the mineralised colonies exhibited comparable rates of photosynthesis to the non-mineralised colonies. Interestingly, silicification of viable cyanobacterial cells only occurred upon the outer surface of sheath material. No viable cells exhibited internal or cell wall mineralisation. This contrasts with dead and lysed cells where mineralisation of the cell wall and cytoplasm had occurred. It is thus likely that the sheath may be necessary in enabling photosynthetically-active cyanobacteria to survive mineralisation, by both acting as an alternative mineral nucleation site that prevents cell wall and/or cytoplasmic mineralisation and by providing a physical filter that restricts colloidal silica to its outer surface.

We have subsequently silicified *Sulfurihydrogenibium Azorense*, a thermophilic and biofilm-forming member of the deeply-branching chemolithoautotrophic *Aquificales*, as well the unsheathed, filamentous cyanobacterium *Anabaena* sp.PCC7120. Using a combination of silica-sorption experiments, electron microscopy, acid-base titrations, and electrophoretic mobility assessments, we aimed to explain the species-specific differences in silicification potential in terms of the profoundly different reactive interfaces these organisms present. We have also considered the inherent variability of the surfaces themselves that may result from the conditions inherent to batch culture growth.

It was found that the metabolically diverse *S. azorense* immobilises colloidal silica to different extents depending on chemolithoautotrophic pathway. Transmission electron micrographs show that silicification is limited to the biofilm surfaces, and that the cell walls remain unmineralised despite the immobilisation of up to 7% of the total silica in supersaturated solutions. While *Anabaena* sp. did not retain appreciable silica during batch culture, silica solution replacement, simulating flow-through conditions, led to the complete encrustation of filaments. TEM analyses also showed that the precipitates were not directly bound to the cell wall surface.

Both species presented obvious reactions to growth under conditions supersaturated with silica - *S. azorense* produce excess biofilm concomitant with increased overall protein production, while *Anabaena* sp. grow in a clumped fashion with distinct changes in surface functional group concentrations and their deprotonation constants.

These results indicate that not only is silicification a highly selective process, but that local geochemical conditions may also influence the facility with which microbes are potentially fossilised. Importantly, neither *S. azorense* or *Anabaena* sp. are likely to be preserved because the silica is not intimately associated with the cell surface.

Phoenix, V.R., Adams, D.G., and Konhauser, K.O., 2000. Cyanobacterial viability during hydrothermal biomineralisation. Chemical Geology, 169:329-338.