Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 597

The Role of Biomineralization as an Ultraviolet Shield

Kurt Konhauser (k.konhauser@earth.leeds.ac.uk)[1], **Vernon Phoenix** (v.phoenix@earth.leeds.ac.uk) & **David Adams** (micda@south-01.novell.leeds.ac.uk)[2]

[1] School of Earth Sciences, University of Leeds, Leeds, LS2 9JT, UK
[2] Department of Microbiology, University of Leeds, Leeds, LS2 9JT, UK

Many models of atmospheric evolution predict that the Archean atmosphere contained insufficient oxygen to form an effective ozone screen (e.g. Kasting, 1987). Under such conditions, life forms would have required some form of effective ultraviolet screen to survive. Recently, Pierson et al. (1993) have suggested that iron-enriched siliceous sediments could provide a viable UV screen. In their experiments with artificial sediments, they demonstrated that amorphous silica, doped with low levels of Fe^{3+}, significantly absorbed harmful UV, whilst still allowing the passage of photosynthetically active light (PAL, 400 nm - 700 nm). In this study we have advanced upon Pierson et al.'s premise by proposing that micro-organisms may have actively precipitated their own siliceous sediment UV screen, through the process of biomineralization. In this study, samples of the filamentous cyanobacterium Calothrix (strain KC97) were isolated from sinters at the Krisuvik hot spring, Iceland. Cultures were then mineralized by placing inoculated agar plates in a growth medium containing 300 ppm Si (using $Na_2SiO_4.5H_2O$) and 50 ppm Fe (using $FeSO_4.7H_2O$). Controls (non-mineralizing) were similarly prepared, but without Fe or Si. After 20 days the agar plates were removed from the mineralizing solution and then continuously irradiated over a 16 day period in the middle UV-C (254 nm) waveband, at 0.35 Wm^{-2}, the predicted UV irradience for the Archean (Kasting, 1987). To confirm the viability of the remaining cells, the rates of photosynthesis were analyzed, while chlorophyll-a and phycocyanin pigmentation were determined. To further determine the UV shielding capacity of natural siliceous sinter, wafers of 150 mm, 200 mm and 250 mm thickness were thin sectioned. Calothrix cells were then cultured on agar plates, with some sections of the plates covered with wafers. Other areas of the plates were left uncovered and the plates were irradiated for 72 hours. The transmittance of PAL was also measured through the wafers.

The results showed that non-mineralized colonies suffered significant damage from ultraviolet light, with only 15% of the filaments remaining on the plate after just 96 hours irradiation. In contrast, the mineralized colony displayed a notable resistance to UV, with 90% of the filaments remaining after 384 hours irradiation. Prior to irradiation, both mineralized and non-mineralized colonies exhibited similar rates of photosynthesis of 55 x 10^{-9} moles O_2 cm^{-2} sec^{-1} at 10000 lux light intensity . However, after just 96 hours irradiation, the non-mineralized colony exhibited a very low photosynthetic rate of only 2.4 x10^{-9} moles O cm^{-2} sec^{-1}. In contrast, mineralized colonies exhibited rates of photosynthesis on the order of 50% their value prior to irradiation, even after 384 hours. Chlorophyll-a concentration in the mineralized colonies decreased slowly to 50% its original value (5.5 mg cm^{-2}) after 384 hours irradiation. Conversely, the non-mineralized colonies suffered rapid chlorophyll-a loss in just 96 hours, with no detectable chlorophyll-a present after 384 hours. The non-mineralized colonies also suffered from a pronounced 'bleaching' effect, with only 7% of filaments exhibiting phycocyanin autofluorescence after 384 hours. Over 80% of mineralized filaments exhibited phycocyanin fluorescence after the same time period. The wafers of amorphous, iron-rich silica crust also afforded the bacteria with a significant ultraviolet shield; even the thinnest 150 mm wafer provided nearly 100% UV protection. In contrast, those areas left uncovered showed almost 70% of the cells undergoing lysis in the first 24 hours. The wafers also exhibited an approximately 10 fold increase in ultraviolet light absorption compared to PAL absorption. This is significant in that the transmittance of PAL is vital to any phototrophs inhabiting a silicified biofilm.

The ultraviolet shielding capacity of iron-silicate biominerals may have been important to early life forms. Certainly, biomineralization would have been a characteristic of Archean microbial life, due to the high concentrations of dissolved silica and iron in the ancient oceans. This is further substantiated by the preservation of microfossils in Precambrian cherts of primary origin. It follows that those early life forms could have precipitated their own UV shield simply by serving as templates for silicification. Furthermore, the cyanobacteria would have been able to function and grow once silicified, allowing colonization and diversification of shallow water environments intermittently exposed to the atmosphere.

Kasting JF, *Precamb. Res.*, **34**, 205-229, (1987).
Pierson BK, Mitchell HK & Ruff-Roberts AL, *Orig. Life Evol. Biosphere*, **23**, 243-260, (1993).