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Key Survival Biomolecules for Extreme Polar Deserts: Antarctica and Mars

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Photosynthetic microbes pioneering present-day Antarctic deserts must withstand extreme concurrent stresses of intense UV and visible light, desiccation and very low temperatures (but rising well above freezing point during intense insolation in summer (Wynn-Williams, 2000). Exposure to light and enhanced UVB radiation during the Ozone hole requires two survival strategies - avoidance or protection. Avoidance, as in the stratified microbial communities of cyanobacterial mats, stromatolites and endolithic communities in translucent sandstone, causes its own problems. When UVB is attenuated to relatively safe levels, the amount of photosynthetically-active radiation (PAR) available is also greatly reduced up to 1000-fold (Nienow et al.,1988). Accessory pigments such as cyanobacterial phycocyanin capable of low-intensity photon-trapping are therefore key biomolecules associated with this strategy. There are two protection strategies against excessive UV and visible light: 1) Screening of incident radiation by compounds such as the cyanobacterial sheath pigment Scytonemin (Wynn-Williams et al., 1999). 2) Quenching of peroxides and free radicals produced by UV radiation by means of compounds such as carotenoids (Holder et al., 2000).

These biomolecules are of limited value unless they are strategically located in the spatial microstructure of the community. This can occur in the mineral stratum itself, the layers of the microbial biofilm, or the configuration of the cells, such as in an external sheath. Analyses of extracts is therefore of limited value for interpreting the functional role of these biomolecules in the ecosystem. However, the technique of laser Raman spectroscopy is a high precision non-intrusive light-scattering technique for locating and characterising biomolecules by the unique fingerprint of their component moieties, such as unsaturated bonds and aromatic rings. With its precision of a 5 micron spot size, this laser technique is eminently suitable for characterising pigments and other habitat-modifying compounds. These include calcium oxalate which mobilises mineral nutrients and optimises the microhabitat of the cells.

We have precise measurements of environmental parameters such as UVB receipt by Bentham spectro-radiometry at British Antarctic Survey field stations within the Ozone hole, in excess of the levels predicted by the BAS Radiative Transfer model for site and season. Our current studies of Antarctic desert communities can therefore provide information for modelling the likely response of microbes surviving and evolving under the even higher UV stress of early Earth. In this era, photosynthetic bacteria and cyanobacteria were pioneers, as revealed by the 3.5 Ga fossil record of Apex chert from Australia (Summons et al., 1999).

Likewise, Mars is hypothesised to have had wet surface conditions under extreme UV stress analogous to those in present Antarctic desert habitats. Studies of biomolecules in microbes surviving in Antarctica therefore give us insights into the sort of moieties that would have been necessary for the survival and evolution of any analogous microbial communities on Mars whose fossil record may still be detectable in the near-subsurface of palaeolake beds (Wynn-Williams and Edwards, 2000). We therefore present Raman spectra of potential biomarkers for the survival of photosynthetic microbial ecosystems in extreme habitats of Antarctica and perhaps Mars.

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