Degradation of biological components of a microbial crust in a Mars Analogue Environment. S.A. Bowden[1], J. Parnell[1], P. Lingdren[1], R. Wilson[2], J.M. Cooper[2], P. Lee[3] [1]Dept Geology and Petroleum Geology, Univeristy of Aberdeen, Aberdeen AB24 3UE, UK. [2]Dept Electronics and Bioelectronics, Univeristy of Glasgow, Glasgow, G12 8LT, UK. [3]SETI Institute, NASA Ames Research Centre, Moffet Field, CA 94035-100 USA.

Introduction: There are many chemical compounds that constitute fossils or provide evidence of life. How persistent these compounds are is an important consideration when deciding how to explore planetary bodies to search for evidence of life. Using the Haughton Impact Structure as an analogue we have previously reported on the survival of a Palaeozoic aged chemical fossils within impact deposits and melt breccias [1,2], and the survival of Eocene-aged fossil lipids derived from an impact-induced hydrothermal system [3].

Although Devon Island is a cold Arctic desert located within the Canadian Arctic, micro-oases of enhanced productivity exist [4]. Weathered detritus was sampled from an outwash plain adjacent to a micro-oasis (Fig. 1). The aim of the sampling was to obtain materials that would permit the characterization of the degradation of a biological signature in a dry arctic environment.

Setting: Mineral crusts from the Haughton Impact Structure have previously yielded biomarkers for cyanobacteria, and studies of the microbial ecology have identified various cyanobacteria [4]. Although it is possible that a range of organisms may be responsible for precipitating the carbonate that comprises the crusts, in many mat-forming environments it is cyanobacteria that secrete the majority of the extracellular polymeric secretions (EPS) crucial to carbonate crust formation [5]. Currently we believe these crusts to be primarily of cyanobacterial origin.

Methods: Samples of sediment and surface material were obtained from the top 8 cm using a small trowel. After crushing samples were extracted by sonication in DCM/MeOH. Extracts were derivatised prior to analysis by GC-MS and quantification of fatty acids was performed relative to an internal standard of nonadecanoic acid. The relative percentage of aragonite was determined by powder X-ray diffraction.

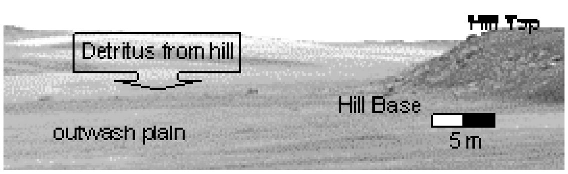

Fig. 1 Sample locality on Devon Island

Results: The hill top within the sampling locality is covered with many microbial crusts (Fig. 1). The microbial crusts have formed around pebble sized clasts of bedrock. Clasts collected from the bottom of the hill posses crusts that contain less protrusions and surface relief than clasts collected at the top of the hill (Fig. 2). Although weathered and physically degraded, clasts collected from the base of the hill still contain coatings that can be identified. An SEM image of a section of spalled crust is shown in Fig. 3. The exterior of the crusts comprises organic-rich laminae of aragonite and calcite.

Fig. 2. Crusts from the top of the hill (right) and base of hill (left).

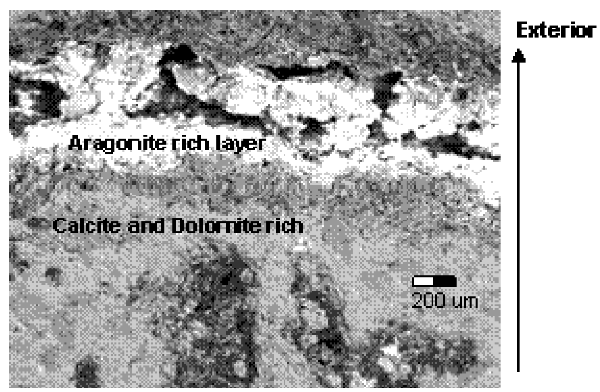

Fig.3 SEM backscattered electron image of a section of crust.

Minerals and molecules: Calcite and dolomite are bedrock components within the sample locality. Aragonite is not a common component of the bed rock as it is not geologically stable over long periods of time. Aragonite has previously been reported within the lithified layers of cyanobacterial mats and embedded within the extracellular polymeric secretions of cyanobacteria [6]. The extracellular polymeric secretions comprise acidic polysacherides and proteins. Samples from the top of the hill contain the highest proportion of aragonite; clasts from the bottom of hill contain proportionally less. Ribitol and uronic acid, while abundant in the extracts of samples from the top of hill are not as abundant in samples from the base of the hill.

These observations can be interperated as evidence that the exterior of the crusts, enriched in aragonite and organic matter, are being physically weathered and broken down and that this is the primary control on the rate of degradation of their biosignatures.

Lipids and other compounds: The concentration of fatty acids also decreases down hill (Fig. 4), although notably not to the same degree as crust forming components such as aragonite. Fatty acids are the building blocks of phospholipids that comprise the cell membranes of prokaryotes and eukaryotes. Within the microbial mat they are surrounded by protective organic sheaths and minerals. This may aid their preservation (relative to extracellular components) if crust degradation is controlled by physical phenonena and crusts are being degraded from the exterior inwards. An alternative explanation maybe that new biomass is being added (e.g. organisms utilizing the EPS as a substrate will synthesize fatty acids). This will be explored by analyzing the distribution of fatty acids and looking for markers unique to certain heterotrophs.

A number of other compounds were detected although they are not discussed further; hopanoids (diploptene and diplopterol) characteristic of bacteria and some plants, ergosterol characteristic of fungi and scytonemin a biological pigment synthesized by certain cyanobacteria in response to exposure to high levels of UV B radiation.

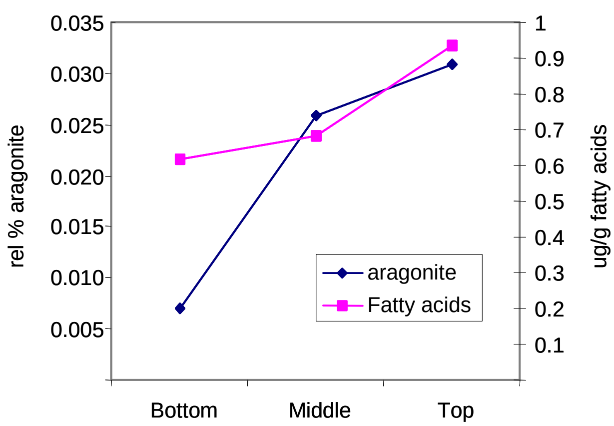

Fig. 4 Graph of the relative % of aragonite and concentration of extractable fatty acids

Conclusions: All of the crust components are still present at the base of the hill, although those concentrated at the exterior are most degraded. The apparent greater persistence of cellular other extracellular material differs from models based on observations of the preservation of carbonate-rich lithified cyanobacterial mats; where extracellular sheaths are not degraded even thought the cyanobacteria cell has been altered. Existing models of microbial mat death and preservation are largely based on observations made in aquatic environments. Such studies contrast intact life structures observed in modern settings to those present in the fossil record. In these instances heterotrophic members of the mat community utilize cellular over extracellular material.

For microbial crusts weathering in a non-aquatic arctic environment the crust structure is being mechanically broken down. This is likely to cause them to decay via a different pathway than their aquatic-mat counterparts. The types and rates of the processes involved will be different. Future work will focus on sampling the outwash plain beneath the hill to investigate at what distances from the hill minerals and molecules can still be detected.

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References: [1] Parnell et al. 2005, Geology 33, 373–376. [2] Lingdren et al. 2006, LPSC XXXVII, 1028. [3] Bowden & Parnell (In Press) Icarus, doi:10.1016/j.icarus.2006.10.013. [4] Cockell et al. 2001, Arctic, Antarctic, Alpine Res. 33, 306–318. [5] Reid et al., 2000, Nature 406, 989-992. [6] Kawaguchi and Decho, J. Crystal Growth 2002, 230–235.