MICROBIAL PRESERVATION IN SULFATES IN THE HAUGHTON IMPACT STRUCTURE SUGGESTS TARGET IN SEARCH FOR LIFE ON MARS.

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Microbes in Haughton Crater Sulfates: Impact craters are of high interest in planetary exploration because they are viewed as possible sites for evidence of life [1]. Hydrothermal systems in craters are particularly regarded as sites where primitive life could evolve. Evidence from the Miocene Haughton impact structure shows that crater hydrothermal deposits may also be a preferred site for subsequent colonization and hence possible extant life: Hydrothermal sulfates at Haughton are colonized by viable cyanobacteria [2].

The Haughton impact structure, Devon Island, Canadian High Arctic, is a 24 km-diameter crater of mid-Tertiary age. The structure preserves an exceptional record of impact-induced hydrothermal activity, including sulfide, and sulfate mineralization [3]. The target rocks excavated at the site included massive gypsum-bearing carbonate rocks of Ordovician age . Impact-remobilized sulfates occur as metre-scale masses of intergrown crystals of the clear form of gypsum *selenite* in veins and cavity fillings within the crater's impact melt breccia deposits [4]. The selenite is part of the hydrothermal assemblage as it was precipitated by cooling hot waters that were circulating as a result of the impact. Remobilization of the sulfate continues to the present day, such that it occurs in soil crusts (Fig. 1) including sandy beds with a gypsum cement. The sulfate-cemented beds make an interesting comparison with the sulfate-bearing sandy beds encountered by the Opportunity MER [5].

The selenite crystals are up to 0.3 m in width, of high purity, and transparent. They locally exhibit frayed margins where cleavage surfaces have separated. This exfoliation may be a response to freeze-thaw weathering. The selenite contains traces of rock detritus, newly precipitated gypsum, and microbial colonies. The rock detritus consists of sediment particles which penetrated the opened cleavages by up to 2cm from the crystal margins. Some of the detritus is cemented into place by gypsum, which must have been dissolved and reprecipitated from the host selenite.

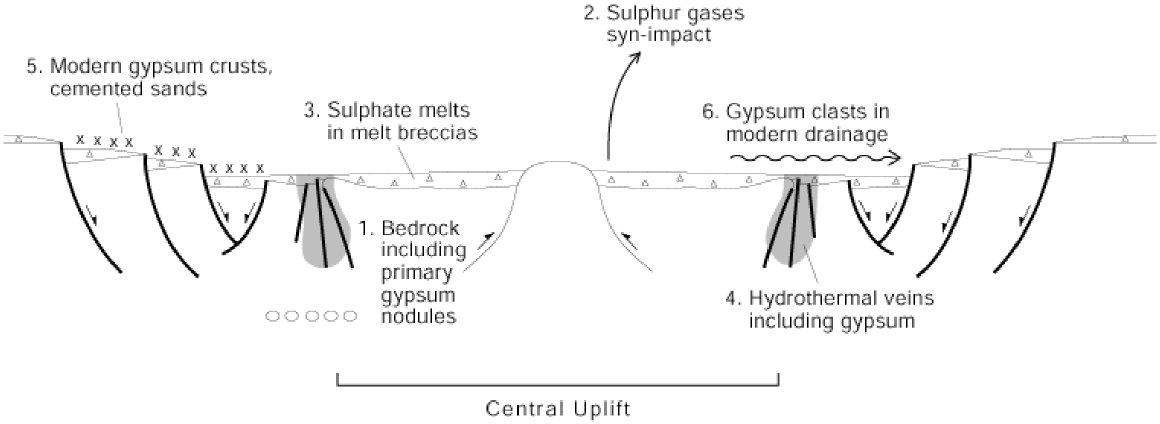

Fig. 1. Range of sulfate components in Haughton impact structure. Numbers indicate time sequence.

Crystals at 7 of 9 localities sampled were found to be colonized by microbial communities. The colonies occur up to 5cm from the crystal margins, i.e. they have penetrated more deeply than the rock detritus. The communities identified are primarily composed of the cyanobacteria *Gloeocapsa alpine* (Nägeli) Brand and *Nostoc commune* Vaucher, and also filamentous components resembling *Scytonema*.

Mode of Occurrence: The *Gloeocapsa* colonies consist of several hundred adjoining cells, which exhibit all stages of cell division (Fig. 2) and have clearly grown in situ. The colonies form sheets a single cell thick along cleavage surfaces, and equidimensional masses of cells in cavities up to 1.5mm, all coloured black. The cleavage surfaces open to the outside, permitting penetration of water, but are no more than a few microns wide. The water is largely limited to the colonies. Apart from the location of the microbes, there is no other reason for dissolution to be focussed in cavities. Therefore, available evidence suggests that the cavities have developed around the colonies. Furthermore, the colonies have grown as the cavities enlarged, such that the largest colonies occur in the largest cavities. As many of these colonies are free of much admixed rock detritus, they must have originated in sites where only one or two cells could penetrate, and subsequently reproduced and enlarged the cavity that they occupy. Although the gypsum cannot supply many nutrients, the melt breccia host is a good source of ions as it is altered and fine-grained.

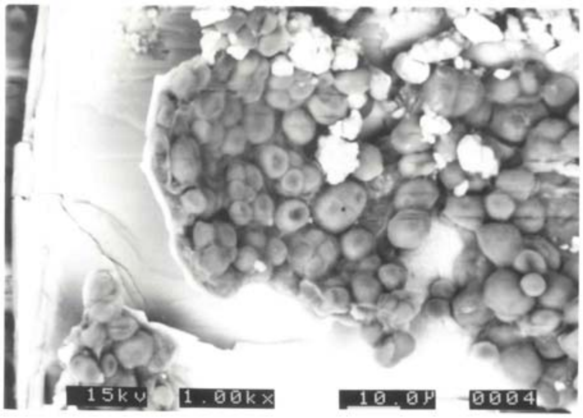

Fig. 2. Cell structures showing various stages of division, on gypsum cleavage surface. Bright matter is inorganic detritus.

Adaptation to Environment: The propensity for sulfates to form clear crystals makes them an advantageous habitat for photosynthesisers. Visible light penetrates the Haughton selenite crystals to a depth of at least 15 cm. The black colouration of the *Gloeocapsa* in the selenite is caused by the synthesis of ultraviolet (UV) screening compounds, particularly the pigments scytonemin and gloeocapsin [6].

The occurrences of microbes in sulfates in the Haughton crater are quite distinct from previous records in evaporite deposits actively precipitating from water. The Haughton microbes have colonized pre-existing selenite in an environment which involved relatively little liquid water. The Haughton gypsum is much more transparent to light than shallow water evaporitic gypsum, which is made translucent by other admixed mineral matter and a smaller crystal size. The gypsum is exceptional as an endolithic habitat in the depth of penetration from the rock surface, the high levels of light exposure for photosynthesis, and the large size of colony that could develop along a cleavage surface.

A calcium-rich (due to gypsum dissolution) brine may have a eutectic point as low as -50ºC, substantially increasing the proportion of the year that the enclosed water is liquid. In environments where low temperature is combined with low precipitation (exemplified in Antarctic, and potentially on other planets such as Mars) it could extend the period of annual activity. A further advantage applicable to low-temperature environments is that diurnal freeze-thaw cycles might be mitigated, reducing freeze-thaw stress to the microbes.

Significance on Mars: Sulfates are the predominant salts detected on the two main targets in the search for life elsewhere in the Solar System, Mars [7] and Europa [8}. As volcanic and/or hydrothermal activity, which introduce volatile sulfur compounds to the planetary surface, appear to be a common feature of rocky planets, sulfur salts should dominate chemical precipitates. Evidence for photosynthetic activity within sulphates is therefore interesting as a habitat that could be widespread on other planets.

Massive deposits of sulfates are suggested at the Opportunity MER landing site [5]. The ready colonization of gypsum in the Haughton impact structure provides strong support that the Martian sulfates are a potential habitat for life. The Haughton gypsum was deposited by the waning, cooling stage of hydrothermal activity [3]. It is therefore a low-temperature precipitate which bears comparison with sulfates on Mars that appear to have been deposited from liquid water at the surface [5]. Colonization within crystals on Mars could be particularly helpful, as this would provide shelter from the very strong winds that sweep the surface. Any primitive life taking advantage of this potential habitat could have an unusually high preservation potential, and sulfate samples could record microbial activity from a period when there was more moisture at the surface. Hence sulfates on Mars must be strong candidates for the analysis for biomarkers, using a range of high-resolution techniques during future exploration.

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References: [1] Rathbun J.A. & Squyres S.W. (2002) *Icarus, 157*, 362-372. [2] Parnell J. et al. (2004) *Int. Jour. Astrobiol., 3*, in press. [3] Osinski G.R. et al. (2001) *Meteor. Planet. Sci., 36*, 731-45. [4] Osinski G.R. & Spray J.G. (2003) *Earth Planet. Sci. Letts, 215*, 357-370. [5] Moore J.M. (2004) *Nature, 428,* 711-712. [6] Cockell C.S.. et al. (1997) *Meteor. Planet. Sci., 37,* 1287-1298. [7] Cooper C.D. & Mustard J.F. (2002) *Icarus*, 158, 42-55. [8] Kargel J.S. et al. (2000) *Icarus*, 148, 226-265.