# Surface mineral crusts: A priority target in search for life on Mars

Conference or Workshop Item

**SURFACE MINERAL CRUSTS: A PRIORITY TARGET IN SEARCH FOR LIFE ON MARS.** J. Parnell[1], S.A. Bowden[1], C.S. Cockell[2], G.R. Osinski[3], P. Lee[4], [1]Dept. of Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., (J.Parnell@abdn.ac.uk), [2] Open University, Milton Keynes MK6 7AA, U.K., [3]Canadian Space Agency, Saint-Hubert, Quebec J3Y 8Y9, Canada, [4]Mars Institute, Moffett Field, CA 94035-1000, U.S.A.

**Mineral crusts:** Mineral crusts are a widely developed feature at the rock or sediment surface, wherever there is a flux of water. They occur in all climatic zones, from tropical to polar desert, although their chemistry and morphology varies with surface hydrology, temperature and substrate. Thus the range of deposits includes duricrusts (calcrete, silcrete, gypcrete, ferricrete), desert varnish, crusts above permafrost, and salt crusts. This list is much greater if mineral precipitates from flowing fluids are included, such as speleothems, travertine and other hot spring deposits, tufa, and chemosynthetic deposits. We will focus here on precipitates associated with surface moisture.

Mineral crusts are strong candidates in the search for evidence of life, both in terrestrial extreme environments and during planetary exploration. There are several reasons for their suitability:

(1) The growth of any mineral precipitate implies an active flow of water to transport the solutes for mineral growth. Water is a vector for life.

(2) The precipitation of mineral from water also implies that the water has a high load of dissolved ions, which should include nutrients for living matter.

(3) As the mineral precipitates, the growing crystals can entrap, and thereby preserve, organic matter. This can range from different types of biomolecules to whole cells with morphological form, i.e. the evidence entrapped can be both chemical and physical.

(4) Mineral precipitates can also incorporate an inorganic record of life, including microbially mediated crystal growths, and isotopic evidence for microbial metabolism.

(5) In addition to entrapment of ambient life, mineral precipitation may create a new microenvironment (microporosity) for an active biota.

In the particular case of Mars:

(6) The philosophy of searching for evidence of life on Mars has been 'follow the water' [1,2]. Any surface crusts on Mars are likely to represent the most recent mineral precipitation from water.

(7) We already have evidence of crust formation in Martian soil through precipitation of sulphate salts.

(8) Observations of fog/frost in several contexts on Mars [1] suggest that mineral dissolution and reprecipitation on a micro-scale could be still occurring in some surface crusts.

The impact crater environment, widespread on Mars, is an especially favourable case for crust development:

(9) Active circulation of water follows the impact event due to hydrothermal activity.

(10) Ponding of water may occur temporarily in the crater depression.

(11) The impact detritus presents a substantial surface area for mineral dissolution, to create saturated ground waters which can reprecipitate as crusts.

(12) The anomalous heating in a crater allows chemical reactions (including solution, reprecipitation), to proceed at a faster rate than ambient, as well as favouring any organic metabolism.

In terms of sampling, additional advantages are:

(13) Minerals precipitating at the surface tend to be relatively soluble, and soft, making them amenable to processing by both chemical and physical methods.

(14) Wind eflation of crusts, which is likely in dry surface environments, releases abundant crust detritus into the surrounding soil, where it is easy to sample.

**Haughton Crater crusts**: A wide variety of mineral crusts occurs in and around the Haughton Impact Structure, Devon Island, Canadian High Arctic. These include carbonate, gypsiferous and ferruginous crusts. The carbonate crusts (Fig. 1) are varieties of a phenomenon that occurs across the Arctic region [3, 4], but include crusts that occupy fractures relating to the impact event. Pilot studies of the organic geochemistry of the carbonate crusts show that they have a high yield of soluble organic matter.

The organic compounds present in the carbonate crust appear to biological, e.g. squalene, diploptene and the $C_{40}$ carotenoids (Fig. 2); even the n-alkanes (particularly the $C_{17}$ n-alkane and other methyl-branched $C_{17}$ to $C_{21}$ alkanes) have a distribution that is probably biological. $C_{16}$–$C_{18}$ fatty acids dominate the polar fraction and are the most abundant compound that were extracted from the carbonate crust. The relative abundance of $C_{17}$ n-alkane, $C_{30}$ diploptene and the limited distribution of fatty acids are all biomarkers characteristics of cyanobacteria, which are abundant across the sample locality. What is unclear at present is whether the biomarkers were biosynthesised by cyanobacteria living within the crust or whether they carried to the crust by windblown material.

Bacteria are known to precipitate carbonate minerals from solution. Evidence has now been obtained for both aerobic and anaerobic precipitation [5], suggesting that the process may be relevant for surface environments on rocks, but also subsurface environments. The precipitation of carbonates appears to be carried out by a wide diversity of organisms, including sulphate-reducers. As carbonates are precipitated around cell material, the subsequent degradation of the organic material may leave biosignatures [6]. Thus, carbonates can allow the preservation of past life.

**Conclusion**: Mineral crusts are strong candidates in the search for evidence of life during planetary exploration, and should be an important target for examination in impact craters. The pilot study in the Haughton Impact Structure shows that they can readily yield a biological signature.

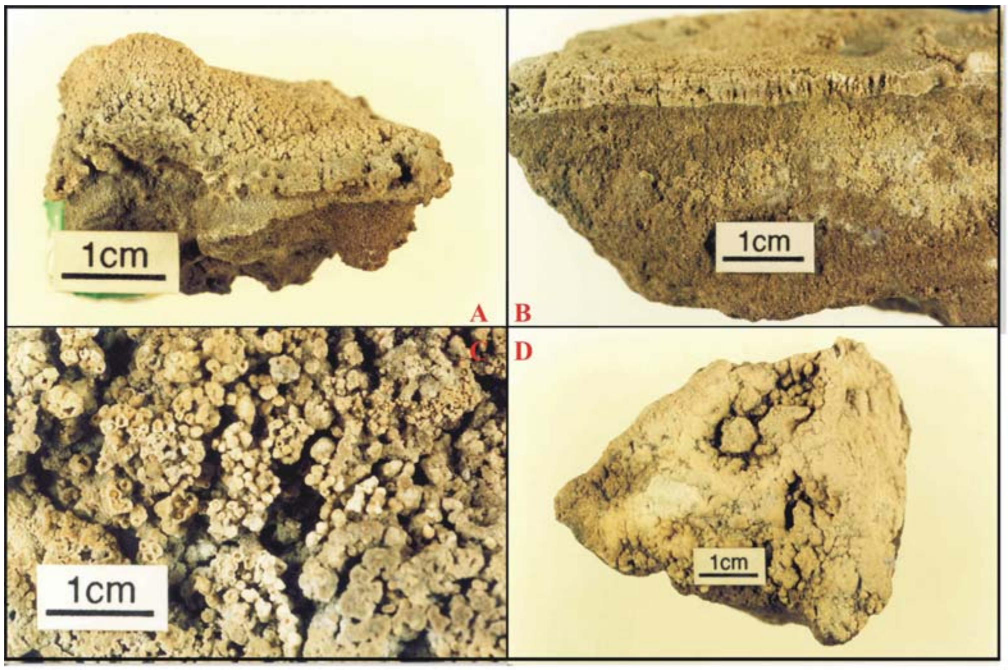


Fig. 1. **A,** Typical hand specimen of carbonate crust growing over the top surface of dolomite bedrock. **B**, The carbonate crust sits upon an uneven erosion surface above the brown dolomite. **C**, Plan view of crustal structure shows that tubular structures are interconnected, but where they have broken off they are hollow inside. **D**, Where tubular structure has not fully formed a white precipitate covers the dolomite. (Photos courtesy of J. Whelan)

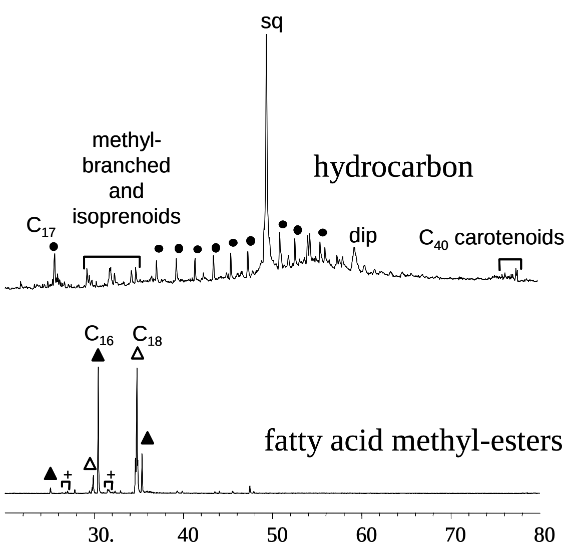


Fig. 2. Reconstructed ion chromatograms of hydrocarbon and polar fractions extracted from Haughton Crater crust. Hydrocarbons dominated by squalene (sq), diploptene (dip) and a series of n-alkanes denoted by circles. $C_{40}$ carotenoids are also present. Polar fraction is dominated by saturated (▲) and mono-unsaturated (Δ) fatty acids.

**Acknowledgement**: Research was under the auspices of the NASA Haughton-Mars Project.

**References**: [1] Kargel J.S. (2004) *Mars: A warmer, wetter planet*. Springer, London, 557pp. [2] Tokano T. (2005) *Water on Mars and Life*. Springer, Berlin, 331pp. [3] Bunting B.T. & Christensen L. (1980) *Geol. Foren. Stock. Forhandl., 100*, 361-367.[4] Clark I. et al. (2004) *Can. J. Earth Sci., 41*, 387-399. [5] Warthman R. et al. (2000) *Geology*, *28*, 1091-94. [6] Bosak T. (2004) *Geology, 32*, 781-84.