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GULLIES ON MARS: ORIGIN BY SNOW AND ICE MELTING AND POTENTIAL FOR LIFE BASED ON POSSIBLE ANALOGS FROM DEVON ISLAND, HIGH ARCTIC. Pascal Lee¹, Charles S. Cockell², and Christopher P. McKay³ ¹Mars Institute, SETI Institute, and NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA, pcee@earthlink.net, ²SETI Institute and British Antarctic Survey, Cambridge, U.K., cscoc@bas.ac.uk, ³NASA ARC, MS 145-3, Moffett Field, CA 94035, USA, cmckay@mail.arc.nasa.gov

Summary: Gullies on Devon Island, High Arctic, which form by melting of transient surface ice and snow covers and offer morphologic and contextual analogs for gullies reported on Mars are reported to display enhancements in biological activity in contrast to surrounding polar desert terrain (Fig. 1).

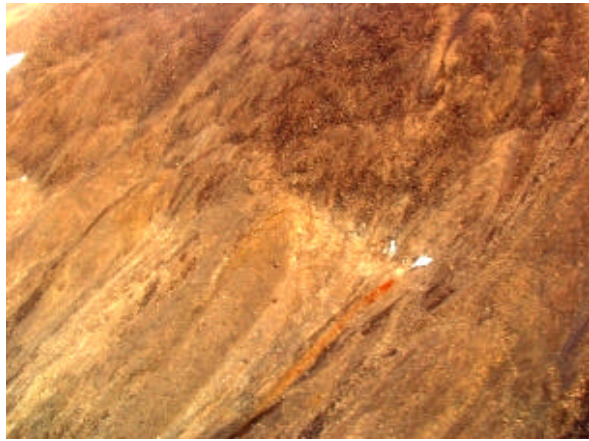


Figure 1. The almost snow-free head alcove area of a gully on Devon Island displays the distinct reddish signature of UV-screening compounds associated with a localized algal mat kept moist and viable by meltwaters streaming from a vanishing snow patch. Surrounding snow-free polar desert slopes do not exhibit this biological activity. (Photo NASA Haughton-Mars Project / P. Lee).

Introduction: The origin, evolution, and possible astrobiological implications of the relatively youthful slope gully features on Mars have been the subject of much wonder ever since they were first reported by Malin and Edgett [1]. Two prevailing initial hypotheses concerning their formation both invoked the discharge of subsurface H₂O: groundwater seepage [1] and melting of ground ice [2, 3]. However, recent MGS MOC and Mars Odyssey Themis imaging data provide evidence that at least some gullies on Mars may owe their origin to the melting of extensive water-rich snow deposits instead [4]. The interpretation that martian gullies might have formed by the melting of transient surface snow and ice deposits in response to obliquity variations on timescales of 10⁵ years or less [e.g., 5, 6, 7] had been hypothesized at an earlier stage on the

basis of morphologic and contextual terrestrial analogs observed on Devon Island, High Arctic [8, 9, 10].

The significance of the martian gully systems for Astrobiology is considerable given that they represent sites on Mars having experienced aqueous activity (the most likely explanation) in relatively recent times, i.e., within the past 10⁸ years or so, and possibly at present still. *Follow the Water* being the overarching strategy recommended by both the COMPLEX and MEPAG Committees for the search for signs of life on Mars, past or present, gullies offer a key opportunity to investigate the possibility of recent or even present life on Mars in the planet's near-surface environment.

Geology of gullies on Devon Island. Over the past few years, we have conducted Mars analog field investigations at the Haughton impact structure (75°22'N, 89°41'W, 23 Ma, 20 km in diameter) and surrounding terrain on Devon Island, Nunavut, Canadian high Arctic, under the auspices of the NASA Haughton-Mars Project (HMP). Among the more intriguing possible analogs identified are morphologic and contextual analogs for several types of martian gullies. While similar gullies may be found in a variety of other alpine and polar settings, the Haughton impact structure site offers a unique opportunity to study snow, ice and ground-ice-related features and processes in the context of impact-generated materials under an extreme polar desert climate

Gullies on Devon are found along the walls and steep slopes of the many valleys and canyons that dissect the island, including the hillslopes of Haughton Crater's melt breccia formation [9, 11]. The gullies occur as isolated formations or in sets of several, sometimes numbering upwards of 20 features per kilometer of wall length.

The Devon Island gullies are morphologically (in form, diversity, and scale) and contextually (in environmental setting) similar in specific detail to many of the gullies observed on Mars [8, 9]. Midsummer in situ surveys reveal that the Devon gullies don't usually present any evidence of ongoing fluid transportation and have a dried-up appearance. However, when observed early enough in the field season, the head alcoves of many gullies may be occupied by deposits of seasonal snow and/or old ice. The head alcoves serve as *nivation hollows* in which blowing snow settles and often hardens into compact drifts. Where denser firn or

ice is present, 8-10 kyr-old deposits from the Last Glacial Maximum (LGM) may be involved [12]. The present aqueous activity of gullies results from the seasonal or secular melting of these surface snow and ice deposits, with contributions from subsurface reservoirs being minor [9]. Field investigations of local geologic relationships on Devon Island suggest that the gullies are systematically younger than the last major erosional episode that formed the glacial trough valleys dissecting Devon, i.e., they are likely $< 10^4$ years old [9]. Measurements of annual and diurnal surface and near-surface (within the top meter) temperature variations on Devon Island indicate that conditions conducive to the melting of snow or ice of low mineralization occur only during short periods each year. Preliminary monitoring of meltwater discharge regimes suggests that the aqueous activity of gullies is extremely transient.

Microbiology of gullies on Devon Island. We report here that several gully sites on Devon Island have been found to present local enhancements in microbiology compared to their polar desert surroundings. Gullies experience only transient aqueous activity, but when active they serve as a local source of liquid water which may support an increased abundance of life. Our preliminary observations reveal localized enrichments in photosynthetic microbiota: mats, primarily composed of the cyanobacterium *Nostoc commune*, are about an order of magnitude more abundant in areal extent on gully aprons than in regions outside gullies; the cyanobacterium *Gloeocapsa*, a black-pigmented microorganism tolerant of freeze-thaw cycles (Howard-Williams *et al.* 1989), is more abundant on rocks over which gully waters run than on rocks outside gullies.

Discussion. While photosynthetic microbial life is not expected to be found on Mars due in particular to the harsh UV radiation environment at the surface, a more in-depth microbiological characterization of the gullies on Devon Island may present significant relevance to Mars. It is well known that environments on Earth favourable for microbiota are those that include a source of liquid water. As well as providing liquid water for surface photosynthetic communities, we suspect that gullies also provide a source of water for subsurface micro-organisms metabolising organics that leach into the soils. These communities would be protected from harsh UV radiation by layers of soil. Because the numbers of these organic-utilizing microbes can be increased by an order of magnitude in polar deserts in areas where soil organics are enriched and liquid water is already available [13, 14], we suspect similar (or even greater) enrichments occur at gully sites, particular in the context of an impact structure where the availability of porous microbial habitats may be increased [15]. On Mars, gullies might similarly provide a transient supply

of liquid water for potential microbiota, and most importantly the seeping of water into the near-surface environment might provide water for buried microbial communities that are protected from the harsh UV radiation environment of Mars, which is up to a thousand times more damaging to DNA than the surface of the Earth [16]. By quantifying the subsurface enrichment of microbial numbers possibly associated with gullies on Devon, one could evaluate on the basis terrestrial observations the merits of an argument that similar sources of water on Mars should be regarded as a high priority astrobiological target for future Mars exploration.

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