**GULLIES ON MARS: FRESH GULLIES IN DIRTY SNOW, DEVON ISLAND, HIGH ARCTIC, AS END-MEMBER ANALOGS.** Pascal Lee[1], Brian J. Glass[2], Gordon R. Osinski[3], John Parnell[4], John W. Schutt[1], and Christopher P. McKay[2]. [1]Mars Institute, SETI Institute, and NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA, pascal.lee@marsinstitute.info, [2]NASA ARC, MS 145-3, Moffett Field, CA 94035, USA, [3]Canadian Space Agency, St. Hubert, Canada, [4]University of Aberdeen, Aberdeen, U.K..

**Introduction:** We report observations of freshly-formed gullies in dirty snow on Devon Island, High Arctic, that may serve as end-member analogs for gullies on Mars. The dirty snow gullies on Devon are of surficial origin and transient on annual timescales.

**Figure 1.** Freshly-formed gullies incised along a dirty snow bench on Devon Island, High Arctic. Scene is 20 m wide. (Photo 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 $H_2O$: groundwater seepage [1] and melting of ground ice [2, 3]. However, on the basis of morphologic and contextual terrestrial analogs observed on Devon Island, High Arctic, it was proposed that martian gullies might have formed by surficial processes instead, specifically the melting of transient surface snow and/or ice deposits, possibly in response to obliquity variations of Mars on timescales of $10^5$ years or less [4, 5, 6, 7]. This interpretation was further strengthened as a possible mode of gully formation when MGS MOC and Mars Odyssey Themis data revealed the existence of gullies in apparent association with possible present $H_2O$-rich deposits [8].

The significance of gully systems on Mars for the planet's climate evolution, geology, and astrobiological potential is considerable given that gullies represent sites of aqueous activity (the most likely explanation) in recent times (within the last $10^8$ years or so, including possibly through the present).

**Gullies on Devon Island: A Review.** Over the past few years, we have been investigating the Haughton impact structure (75°22'N, 89°41'W, 38 Ma, 23 km in diameter) and surrounding terrain on Devon Island, High Arctic, viewed as a planetary analog site of particular relevance to Mars. Our studies are conducted under the auspices of the Haughton-Mars Project (HMP) (www.marsonearth.org). Among the more intriguing possible analogs identified to date are morphologic and contextual analogs for several types of gullies observed on Mars [4, 5, 6, 7]. 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, under an extreme polar desert climate, snow, ice and ground-ice-related features and processes in the context of both common terrestrial lithologies (carbonate platform) and impact-generated materials.

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]. The gullies occur as isolated features or in sets of several, sometimes numbering upwards of 20 gullies per kilometer of wall length. They are morphologically (in form, diversity, and scale) and contextually (in topographic setting) similar in specific detail to many of the gullies observed on Mars [4, 5, 6, 7]. Midsummer (July-August) 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 earlier in the field season (May-June), the head alcoves of many gullies may be occupied by deposits of seasonal snow and/or older ice. The head alcoves serve as *nivation hollows* in which blowing snow settles and hardens into compact drifts. Where denser firn or ice is present, 8-10 kyr-old deposits from the Last Glacial Maximum (LGM) may be present [10]. 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 [6]. 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 [6]. 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. Multiyear monitoring of meltwater discharge regimes suggests that the aqueous activity of gullies is highly transient: gullies display morphology modifying activity on meter scales or greater only over the course of few days each year. Finally, gully sites on Devon Island have been found to present local enhancements in microbiology compared to their polar desert surroundings [7,11].

**New Observations: Dirty Snow Gullies.** We report new observations of an extreme case of gully formation on Devon Island resulting from the melting and incision of transient seasonal snow deposits (Fig. 1). In this case, the local bedrock and underlying rocky scree slopes are left uncut by any gullies. Only surficial annual snow deposits appear incised.

The snow gullies observed on Devon generally display well-defined head alcoves with a distinct inverted triangle shape and have well-developed main channels (Fig. 2). Individual head alcoves are typically 1 m wide at their linear threshold while main channels narrow downstream from the alcoves at a rate of approximately 10% per meter of gully length. The longest snow gullies are therefore only 10 m or so in total length. Coalescence of adjacent individual head alcoves may create broader apparent source areas for some gullies. Similarly, the occasional coalescence of individual main channels may result in anomalously wide gully channels. Head alcove and main channel floors are distinctively flat, only slightly depressed in relation to surrounding snow surfaces (max depth is 0.2 m), and systematically lined with dirty snow and ice. Snowmelt flow was observed in some channels at a trickle. In all instances observed to date, snow gullies do not present any significant basal apron development, unlike their previously-reported counterparts on Devon Island developed in bedrock and/or on rocky scree slopes [4, 5, 6]. This implies that relatively little or no sediment is mobilized and accumulated in the formation of snow gullies, in contrast to the formation of gullies developed in other lithologies. Snow gullies, therefore, must result almost exclusively from the removal of surficial snow, with little opportunity for any meltwater involved to dissolve or wash out sediments from underlying lithologies. Finally, snow gullies do not present any evidence for local enhancements in biological activity (compared to surrounding terrain) as observed elsewhere for gullies with well-developed debris aprons [7].

**Figure 2**. Dirty snow gullies presenting well-defined head alcoves and well-developed main channels. There is almost no basal apron development, as $H_2O$ from snow is removed by melting and sublimation, leaving little sediment to accumulate. Scene is 5 m across. (Photo Haughton-Mars Project / P. Lee).

**Discussion**. The dirty snow gullies reported here provide a clear example of gully formation from the dissection of transient snow deposits from a surficial source of $H_2O$. These gullies may be regarded as an end-member type for gullies formed by snow and ice melt on Devon Island and possibly Mars in that there is, in this case, no or only minimal incision of any subniveal lithologies. Our current working hypothesis is that the dirty snow gullies on Devon represent an initial, immature stage of snowmelt gully development. Additional observations of such gully forms elsewhere on Devon Island and/or in other alpine or polar settings would be highly desirable.

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