Snow and ice melt flow features on Devon Island, Nunavut, Arctic Canada as possible analogs for recent slope flow features on Mars

Conference or Workshop Item

SNOW AND ICE MELT FLOW FEATURES ON DEVON ISLAND, NUNAVUT, ARCTIC CANADA AS POSSIBLE ANALOGS FOR RECENT SLOPE FLOW FEATURES ON MARS. Pascal Lee[1], Charles S. Cockell[2], Margarita M. Marinova[3], Christopher P. McKay[5] and James W. Rice, Jr.[4] [1]SETI Institute and NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA., pclee@best.com. [2]British Antarctic Survey, Cambridge, U.K. csco@pcmail.nerc-bas.ac.uk. [3]Massachusetts Institute of Technology, Cambridge, MA, mmm@mit.edu. [4]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA., cmckay@mail.arc.nasa.gov. [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, jrice@lpl.arizona.edu.

Summary: On the basis of morphologic and contextual analogs from Devon Island, Nunavut, Arctic Canada, the relatively youthful martian slope flow features recently reported by Malin and Edgett [1] are reinterpreted as being due not necessarily to groundwater seepage but possibly to snowmelt and/or surficial ice melt. Conditions allowing snow and ice accumulation may have been met episodically on Mars on timescales of 10^5 years or less, including at high latitudes possibly in response to obliquity variations of the planet.

Background: Malin and Edgett [1] recently revealed Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) high-resolution images of fresh-looking slope flow features on Mars which they interpret as evidence for recent groundwater seepage in the martian surface environment. They propose a formation mechanism involving the gradual percolation of groundwater along layers of bedrock, daming beneath localized near-surface ice barriers, and runoff of emerging groundwater following “outbursts” as ice barriers are breached. We report here on observations of morphologic and contextual terrestrial analogs to the formations described by Malin and Edgett, from Devon Island, Nunavut, Arctic Canada.

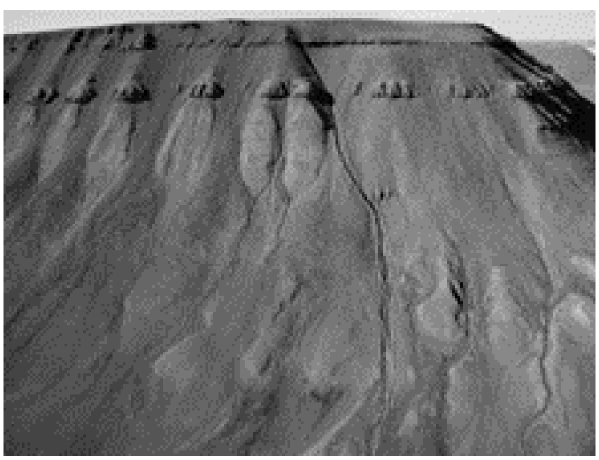

Figure 1: Slope flow features along a trough valley wall on Devon Island. The gullies originate in V-shaped head alcoves between rocky spurs. Several generations of gullying can be recognized. Scene is 0.8 km wide. (Photo 000730-69 NASA Haughton-Mars Project).

Feature description: The flow features reported here are found along the walls and steep slopes of the many valleys and canyons that dissect Devon Island [2] (Fig. 1), and also distinctively on the hillslopes of Haughton Crater’s impact breccia formation. Similar slope flow features may be found on Earth along valley walls and cliff faces in other polar and alpine settings. The flow features on Devon occur as isolated formations or in sets of several, sometimes numbering upwards of 20 features per kilometer of wall length. No clear preference for poleward or equatorward slope orientation is evident. Like the martian formations, the Devon Island slope flow features present three components, from top to bottom: a source area, a main channel with occasional secondaries, and a depositional apron. Source areas typically coincide with reentrants or shallow depressions on slope surfaces and often present triangular or theater-shaped forms with an apex pointing downhill. These head alcoves line up typically in subhorizontal sets as they nich in gaps along rows of rocky bluffs marking exposed stratigraphic layers on valley walls. More complex forms also occur, including ones that fit in the four martian morphologic categories distinguished by Malin and Edgett [1]. The head alcoves on Devon range in size from a few decimeters to several tens of meters across, the larger ones coinciding in scale with those reported on Mars. Most slope flow features on Devon present a single channel emanating from the apex of the head alcove, but more complex patterns of channels also occur, including braided and anastomosing networks. Channel courses are typically rectilinear, suggesting relatively rapid flow downhill, but examples of sinuous courses also occur. Bifurcation is common although not systematic. The channels themselves typically have v-shaped cross sections and are often incised into the slope surface, an aspect that may be reinforced by the presence of raised banks, including multiple sets of these imbricated along a given channel course. Individual channel lengths range from a few decimeters to several tens of meters, while channel widths are between a few centimeters and several meters with no substantial width variation along channel length. Channels terminate distally over depositional aprons, often in divergent digitate patterns with lobate flow fronts (Fig. 2).

Feature origin: Aerial and ground surveys in midsummer on Devon Island reveal that the flow features described above do not usually present any evidence for ongoing fluid transportation and have a dried-up appearance similar to that of their potential martian counterparts. However, when observed earlier in the field season and also through midsummer for those features located in areas remaining better sheltered from insolation, the head alcoves are covered or partially occupied by deposits of seasonal snow or compact secular ice. The head alcoves serve as nivation hollows in which blowing snow settles and may harden into compact snowdrifts. Where denser firn or ice rather than snow is present, deposits from the Last Glacial Maximum may be involved [2] (Fig. 3).

In-situ examination shows that it is the liquid water derived from the melting of the snow and/or the surficial ice deposits filling the head alcoves and often the channels themselves that is primarily responsible for the development of the slope flow features. Groundwater seepage, which along Devon's valley walls results mostly from thawing ground-ice from the active layer and percolated meltwater from ablating snow and ice deposits on nearby high grounds, plays only a secondary role. Although some evaporitic deposits, mostly $CaCO_3$ and $MgCO_3$ precipitates from the local limestone and dolomite-dominated bedrock were found lining some gully walls, the amounts are trivial, reinforcing a dominantly snowmelt origin for the gullies rather than a groundwater seepage one.

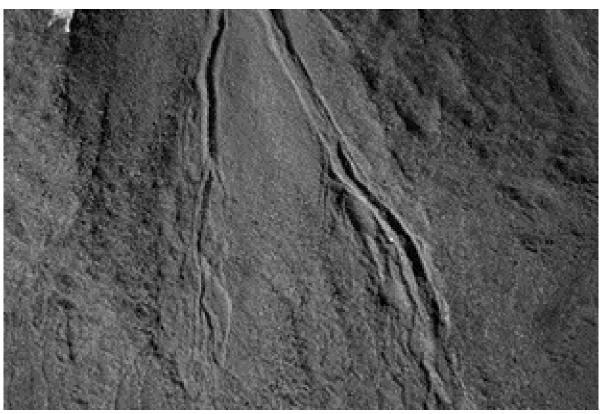

Figure 2. Gullies on Devon Island terminating over complex depositional aprons. Scene is 30 m wide. (Photo 000730-72 NASA Haughton-Mars Project).

Conclusion: Our study suggests that alternative hypotheses for the formation of the slope flow features on Mars to that proposed by Malin and Edgett [1] need to be considered, i.e., the features do not imply groundwater seepage. Other, less extraordinary explanations cannot be ruled out. A snowmelt and/or surficial ice melt origin for the martian formations provides a plausible explanation in the context of the environmental evolution of Mars in recent times. No site-specific subsurface thermal regime or aquifer configuration is required. To first order, a sufficient condition for slope flow feature formation on Mars is that the triple point of water be transiently exceeded ($P_{atm} > 6.1$ mbar, $T_{atm} > 273$ K) at the boundary between H_2O ice deposits and the underlying martian regolith. This condition may have been met on Mars on timescales of 10^5 years or less [3, 4], including at high latitudes possibly in response to obliquity variations of the planet [5, 6, 7].

Figure 3: Close-up of slope flow features with seasonal snow patch in head alcove still present. Scene is 30 m wide. (Photo 000730-76 NASA Haughton-Mars Project).

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