MARS: ALWAYS COLD, SOMETIMES WET? Pascal Lee[1,2] and Christopher P. McKay[2], [1]Mars Institute and SETI Institute, 2035 Landings Drive, Mountain View, CA 94043, USA, pclee@earthlink.net, [2]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA.

Summary and Introduction: A synthesis of a diverse suite of observations of H_2O-related landforms that are possible Mars analogs from terrestrial polar regions (Devon Island in the Arctic; the Dry Valleys of Antarctica) put into question any requirement for extended episode(s) of warm and wet climate in Mars's past. Geologically *transient* episodes of *localized* H_2O cycling, forced by exogenic impacts, enhanced endogenic heat flow, and/or orbit-driven short-term local environmental change under an otherwise cold, low pressure (=10^2 mbar) global climate, may be *sufficient* to account for the martian surface's exposed record of aqueous activity. A Mars that was only sometimes locally warm and wet while remaining climatically cold throughout its history is consistent with results (difficulties) encountered in modeling efforts attempting to support warm martian climate hypotheses [1], [2]. Possible analogs from terrestrial cold climate regions for the recent gully features on Mars also illustrate how transient localized aqueous activity might, under specific circumstances, also occur on Mars under the present frigid global climatic regime.

Early Mars: Wet and Warm? Two main observations of martian surface landforms are at the core of classical interpretations of Early Mars (Late Noachian) being wet and warm, in contrast to the later dry and cold climate: a) the state of advanced degradation and erosion of impact craters in the martian highland terrain *compared to lunar craters*; b) the ubiquitous presence of small valley networks dissecting the same heavily cratered highlands, with the interpreted implication of relatively moderate discharges and hence extended formation times; meanwhile small valleys are largely absent in younger units with the exception of some recent volcano flank surfaces.

Crater Degradation and Erosion Rates on Late Noachian Mars: Lessons from Haughton Crater. While ancient highland craters on Mars are indeed significantly more degraded and heavily eroded than lunar craters, they remain remarkably well preserved compared to terrestrial impact structures that have experienced only moderate erosion by terrestrial standards. Figures 1 and 2 provide a comparison between Northport Crater in the martian ancient highlands and Haughton Crater on Devon Island, Canadian Arctic. The two structures are of similar diameter (~20 km) and display evidence for substantial aqueous erosion. Although Northport is greater in age than Haughton by at least two orders of magnitude, Northport exhibits less cumulative degradation and erosion than Haughton: Northport presents a well-defined rim, remnant ejecta blanket material, limited dissection of surrounding uplands, and an unfilled well-incised V-shaped crater-cutting valley; Haughton in contrast has lost all original rim and extracrater ejecta materials, and exhibits substantial dissection from glacial peneplanation, extensive meltwater drainage, and limited rain.

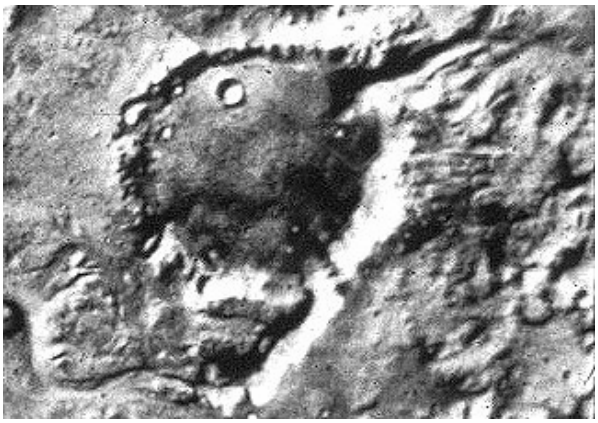

Fig.1: Mars: Northport Crater. Diam: 20 km. Age > $2.5x10^9$ yrs. (Viking Orbiter data. NASA)

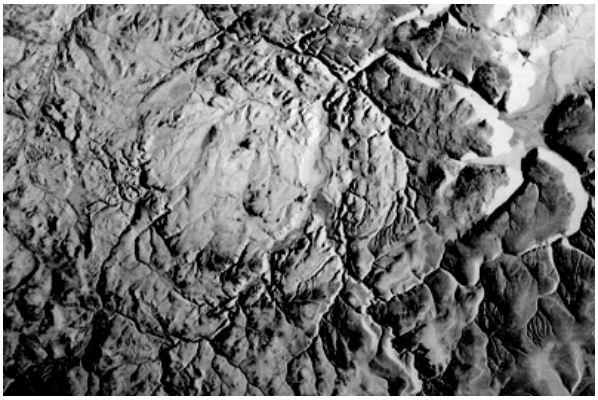

Fig.2: Devon Island: Haughton impact structure. Diam: ~20 km. Age ~$2.5x10^7$ yrs. (Airborne S-band radar. Geological Survey of Canada / NASA HMP)

Current denudation rates associated with glacial meltwater flow at Haughton are estimated to be in the ~10^2-10^3 $\mu m \cdot yr^{-1}$ range, while the average regional denudation rate since the crater's formation in the early Miocene has been ~10 $\mu m \cdot yr^{-1}$. Average regional post-Noachian denudation rates on Mars in the Northport Crater region are estimated to be of order =10^{-3} $\mu m \cdot yr^{-1}$.

During the Noachian, regional denudation rates might have been in the ~10^{-2}-10^{-1} $\mu m yr^{-1}$ range.

Environmental Requirements for Small Valley Formation on Mars: Lessons from the Arctic and Antarctica. Possible analogs for the martian small valley networks have been described from Devon Island previously [3], [4]. The channel networks on Devon are interpreted as having formed from glacial meltwater erosion, an interpretation uniquely consistent with Devon Island's overall landscape of glacial selective linear erosion, which also offers other possible analogs for valley forms seen on Mars, in particular the tributary canyons of Ius Chasma (7°S, 82°W) [5]. The candidate analogs for small valleys from Devon suggest that small valley networks on Mars may not have required a warm and wet climate to form. Instead, they are consistent with a cold climate regime in which impacts and volcanism could have power transient and localized water cycles.

The Dry Valleys of Antarctica provide a clear example of how transient aqueous activity resulting in rivers and lakes can take place in an environment that experiences no rain (but snow precipitation) and annual average temeperatures well below the freezing the point of H_2O (-20°C). In the summer, peak summer temperatures reach +10°C, resulting in snowmelt and transient water flow in seasonal streams such as the Onyx River.

McKay and Davis [6] have shown how Mars's obliquity variations can result in transient peak temperatures above the freezing point of water while mean annual temperatures are -35°C. Provided atmospheric pressure is sufficient (P =100 mbar), liquid water activity can occur.

Gullies on Mars: An extreme case of transient localized aqueous activity? New possible analogs for recent gully features on Mars have been observed on Devon Island. The association of gully activity with transient snow and ice melt on Devon, including instances of confined sub-niveal flow, provides a possible example of how similar transient localized aqueous activity might be possible on Mars if obliquity variations (most likely driver) do result in snow precipitation, transient peak temperatures T>0°C, and P = 100 mbar.

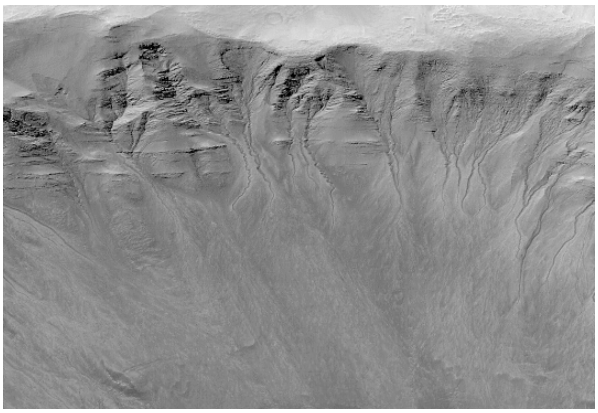

Fig. 3: Mars: Gullies with cliff edge alcoves (NASA JPL / MSSS).

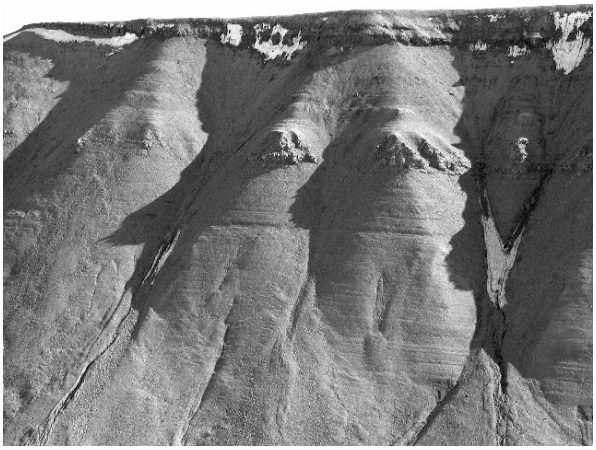

Fig.4: Devon Island: Gullies with cliff edge alcoves (NASA HMP).

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References:

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