POSSIBLE ANALOGS FOR SMALL VALLEYS ON MARS AT THE HAUGHTON IMPACT CRATER SITE, DEVON ISLAND, CANADIAN HIGH ARCTIC.

P. Lee[1], J. W. Rice, Jr.[2], Theodore E. Bunch[1], R. A. F. Grieve3, C. P. McKay[2], J. W. Schutt, and A. P. Zent[1], [1]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035-1000, USA, pclee@mail.arc.nasa.gov, [2]Lunar and Planetary Laboratory, Univ. of Arizona, Tucson, AZ 85721, USA, 3Geological Survey of Canada, Ottawa, Canada.

Introduction: Small valleys are perhaps the clearest evidence for an aqueous past on Mars. While small valley formation has occurred even in Amazonian times, most small valleys on Mars are associated with the heavily cratered Noachian terrains. Martian small valleys are often cited as evidence for a putative warmer and wetter climate on Early Mars in which rain and subsequent surface runoff would have acted as significant erosional agents, but the morphology of many small valleys has at the same time been recognized as having several unusual characteristics, making their origin still enigmatic and climatic inferences from them uncertain [1]. Meanwhile, martian climate modeling efforts have been facing difficulties over the past decades with the problem of making the early martian climate warm enough to achieve temperatures above 273 K to allow rainfall and the sustained flow of liquid water at the martian surface [2].

We report here on the identification of two distinct types of small valleys on Devon Island, Northwest Territories, Canadian High Arctic, that are morphologically similar in several unique ways to common types of small valleys on Mars: 1) *Ground-ice sapping valleys*, which might be analogs for small valleys such as Nirgal Vallis ; 2*) Glacial meltwater channel networks*, which might be analogs for the many small valley networks seen in particular in the martian highlands. The two proposed potential terrestrial Mars analogs result from different valley-forming processes but are both associated with a cold climate on Earth.

Ground-Ice Sapping Valleys: A number of valleys on Mars have been hypothesized to have formed by headward sapping, a process whereby volatiles initially present in the subsurface depart upon being exposed to the surface (*undermining*), leading to the collapse and retreat of the overhang created in the source area. Sapping valleys grow by progressive migration of the source in the "upstream" (headward) direction. Nirgal Vallis is an example of a valley on Mars thought to have formed by headward sapping (**Fig.1**).

The system presents the following distinctive combination of characteristics: i) a long and narrow main trunk, ii) tributaries that are short and stubby, iii) source areas for the main stem and tributaries that are typically amphitheater-shaped often with several joined alcoves, iv) large tributary junction angles, v) relatively sparse tributary branches with large areas between branches remaining undissected. Sapping features in the Colorado River Plateau have been proposed as possible analogs to martian valleys like Nirgal, only in the case of Mars, ground-ice removal has been hypothesized an alternative to groundwater seepage.

On Devon Island, the massive breccia formation of the Haughton impact crater is dissected by valleys that display all the above characteristic traits (Fig. 2).

Fig.1. Nirgal Vallis on Mars. Scene is 40 km wide. (Viking Orbiter).

Fig. 2. Ground-ice sapping valleys in the Haughton impact breccia, Devon Island, NWT, Canada.

While the valleys in the Haughton breccia are morphologically similar to their potential martian counterparts, they are in general 2 orders of magnitude smaller than the latter. The source-area alcoves at Haughton are typically only a few tens of meters across.

The alcoves in the source regions are not areas of widespread ground-H_2O discharge, even at the peak of

Summer. Instead, they display series of discrete seeps or *active layer detachment slides* along their walls, generally distributed at a constant level below the rim of the alcove [3]. The slides are commonly associated with decimeter-scale debris flows. While the alcoves themselves may act *as nivation hollows* (bowl-shaped depressions experiencing significant seasonal snow accumulation, melting and debris outwashing), headward sapping at the detachment slide sites is clearly taking place and appears to be the process by which the alcove walls recede. We observed active layer detachment slide overhangs collapse in real time at Haughton, along with their associated debris flows.

Ground-ice sapping valleys and active layer detachment slides at Haughton are found only in the allochtnous polymict breccia formation. Their restriction to this impact-generated unit likely reflects the unique combination of physical properties presented by the breccia: it is a poorly consolidated substrate, permeable when experiencing thawing, and rich in ground-ice. Our observations at Haughton support the hypothesis that small valleys such as Nirgal on Mars formed by ground-ice sapping in a physically similar substrate.

Meltwater channel networks: Small valley networks on Mars have been described as having several "seemingly non-fluvial" characteristics [1]. The following combination of traits are distinctive: i) the networks are spaced apart with large undissected areas between networks, ii) the networks display open, branching patterns with large undissected areas between branches, iii) branches often have ill-defined sources but mature in width and depth over short distances relative to the size of the network, iv) branches maintain a constant width and depth over long distances, v) branches split and rejoin to form steep-walled islands, vi) branches have U-shaped cross-sections with steep walls and flat floors, vii) channels on valley floors are absent or poorly expressed.

All these distinctive characteristics are presented by many valley networks on Devon Island. The networks on Devon, however, are smaller in scale by up to 2 orders of magnitude than their potential martian counterparts. The Devon networks are found ubiquitously across the island including at Haughton. We interpret them to be glacial meltwater channel networks: they formed as a result of the decay and retreat of an ice cover, possibly with intervals of glacial reoccupation. The proposed mode of formation of these networks is supported by our observation that similar networks can been seen actively emerging at the margin of the melting ice cap in the eastern part of Devon Island. Both subglacial and ice-marginal streams, and in some instances supraglaical streams and their ice-marginal falls, were seen to contribute to valley formation at several sites along the retreating edge of the cap. The interpretation of valley networks on Devon Island as meltwater channel networks is consistent with the island's overall landscape of glacial *selective linear erosion*, which suggests extensive former glacial occupation [3].

The identification of meltwater channels on Devon Island with morphologies uniquely similar to martian small valley networks with the outstanding exception of their scale may have profound implications for climatic conditions on Early Mars. *If* the many small valley networks associated with Early Mars are indeed ancient meltwater channel systems, possibly formed under the protective insulation of an ice cover, then Noachian Mars might not need to have been as warm as currently targeted in Mars climate models. The scale issue is of course one that remains to be addressed.

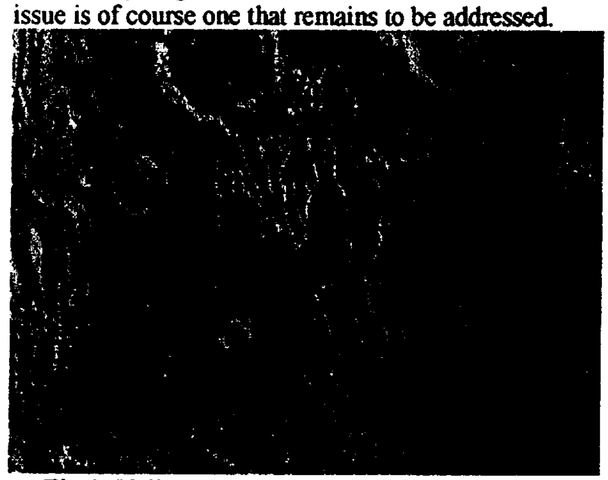

Fig.3. Valleys networks on Mars. Scene is 200 km wide. (Viking Orbiter mosaic).

Fig.4. Glacial meltwater channel networks on Devon Island near Haughton crater. Scene is 10 km wide.

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