Terrestrial Glacial Processes: Analogs for Martian Polar Landform Development.

D. C. Finnegan[1], D. E. Lawson[1] , J. R. Zimbelman[3] and J. W. Rice[2], [1]Cold Regions Research and Engineering Laboratory, 72 Lyme Rd, Hanover NH 03755, dfinnegan@crrel.usace.army.mil , [2]Arizona State University Dept of Geological Sciences, PO Box 876305, Tempe AZ 85287, jrice@asu.edu, CEPS/NASM MRC 315, Smithsonian Institution, Washington D.C. 20560-0315, jrz@nasm.si.edu.

Introduction: Since the Viking and Mariner 9 missions of nearly a quarter of a century ago provided global coverage of the Martian landscape at resolutions of 100-150m/pixel, a plethora of science related information pertaining to Mars and its landscape have become available to the scientific community. This information includes comprehensive global topography (MOLA), both low (Viking) and high-resolution imagery (MOC), and physical-chemical properties of the atmosphere and surface (TES). To complement this astounding ensemble of information, missions underway such as Mars Odyssey have shown compelling new evidence for significant quantities of hydrogen and ground ice within the surface of Mars, especially in the Polar Regions. In addition, future endeavors such as Mars Express (2003) and the Mars Exploration Rovers (2003) will contribute to our knowledge and understanding of the history and surficial processes that have shaped the Martian landscape. Hence, it is vital for planetary researchers to understand the terrestrial geologic and geomorphic processes that may have determined the development of the surface in the modern and ancient cold regions of Mars. Interpretation of planetary surfaces must first begin with Earth analogs. A knowledge of the physical systems and surficial processes that develop erosional and depositional landforms is essential. In the case of modern and ancient glacial and periglacial regions of Mars, research conducted in Iceland, the ice-free regions of Antarctica and the High Arctic may provide the knowledge necessary to interpret landforms from remotely sensed imagery and other datasets of the Martian surface. It is interesting to conjecture that some processes and landforms on Mars may be distinctly and uniquely Martian. Nevertheless, the value of field research in deciphering Martian geologic processes and landform development is unquestionable and will be crucial to future research missions onto the Martian surface.

Terrestrial Analogs: Iceland is unique as an analog in that it provides a proper, first hand perspective to planetary researchers of geologic processes that are known or thought to have shaped the contemporary Martian surface. These include such systems as large-scale basalt volcanism, the largest active glacial outwash plains in the world which are frequently inundated by catastrophic flood events (jökulhlaups), and active piedmont and valley glaciers and icecaps. Icelandic glaciers and ice sheets are dynamic, with high flow rates, positive mass balances but high ice mass flow through, and high rates of meltwater production. Overlying highly erodable beds, typical landforms are large outwash plains (sandur), end, ground and hummocky moraines, kettles, drumlins and flutes, as well as cirques, troughs and u-shaped valleys. Glacier surges and jökulhlaups from ice-dammed lakes occur frequently. About 60% of all glaciers and icecaps in Iceland are underlain by an active neovolcanic zone, and here, jökulhlaup activity occurs regularly due to subglacial volcanic activity [1],[2]. The dynamic nature of such glaciofluvial events clearly adds a dimension to the glacial and periglacial systems, with the resulting erosional and depositional process determining landform distribution and terrain signatures.

Temperate Processes: Glaciofluvial and glacial processes may have contributed significantly to the overall development and contemporary character of the Martian surface. The first images returned by the Viking orbiters and Mariner 9, nearly a quarter of a century ago, revealed geomorphic features like those found in high latitude, terrestrial glacial environments. Recently, the Mars Orbiter Camera (MOC) and precise topographic data from the Mars Orbiter Laser Altimeter (MOLA) have provided increasingly convincing evidence that glacial processes have been important in the polar and near polar regions of Mars [3]. Previous studies have also suggested glacial processes were active in other regions of Mars based on similar geomorphic evidence [4]. The distribution of glacial landforms, including ridges (eskers), lineations and moraine-like structures, suggests that vast austral and boreal ice sheets may have occupied large portions of the Martian surface in the past.

Furthermore, polar regions on Mars, as on Earth, are sensitive to climate change. Like on Earth, deposits in the polar regions may hold a record of changes in the Martian climate that could have originated from orbital obliquity changes, prominent volcanic activity and other geologic phenomena. Recent MOC Narrow Angle images of ice stratigraphy or layering in the North Polar ice cap (Fig. 1) are suggestive of layering similar to that developed in metamorphosing snow to glacier ice as occurs in the accumulation areas of glaciers and ice sheets on Earth. This stratigraphy might then be interpreted in terms of paleoclimate and related information, as best illustrated by the GISP2 and GRIP ice core investigations in central Greenland [5]. Chemical (such as stable isotopes) and physical (such as debris type and content) properties of these ice layers may provide paleo-data on the Martian climate and volcanism, if the processes of formation are similar to those on Earth. In addition, the apparent zone of stratified basal ice (Fig. 2) may bear evidence on the subglacial processes of Martian glaciers, similar to those of Matanuska Glacier and others on Earth [6], [7].

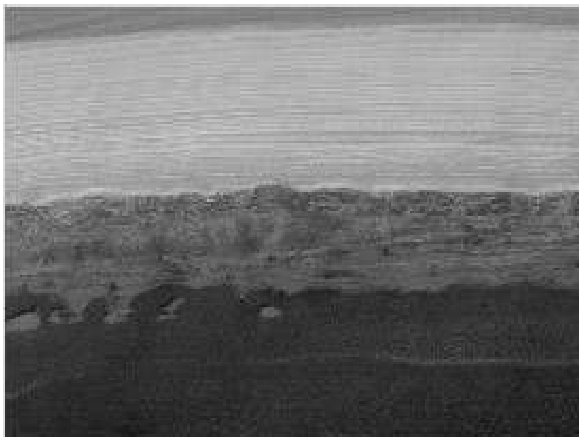

Figure 1. *MOC image of the North Polar layered terrain showing the layers comprising the north polar cap exposed in an arcuate scarp that occurs at one end of Chasma Boreale.) Image illuminated from the lower right (MGS MOC Release No. MOC2-300; Image Credit: NASA/JPL/Malin Space Science Systems)*

Figure 2. *Ice banding and stratigraphy exhibited in the basal ice section of an active glacier, South Iceland*

Summary: An integrated, field-based understanding of terrestrial glacier and ice sheet processes has broad implications for assessing the landforms and terrain origins of modern and ancient glaciers and ice sheets on Mars. As on Earth, the physical attributes and chemical composition of polar ice caps may bear evidence of ice dynamics and climate and their changes over time. The processes by which erosional and depositional glacial and glaciofluvial landforms develop may further our overall understanding of Martian landscape evolution.

Therefore, we suggest that there is a genuine need for an integrated field-based workshop that will focus on bringing the Mars research community together with terrestrial glacial scientists to provide a better understanding of glacier dynamics and the physical processes that determine how glacial and glaciofluvial deposits and landforms develop, including those of large floods associated with glaciers and ice sheets. The long-term development and characteristics of the Martian landscape may be better understood by direct interaction and exchange of information by the terrestrial and planetary research communities.

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