INTERACTION OF MARTIAN GROUND ICE WITH MAGMATIC INTRUSIONS. N. M. Jacques$^1$, D. T. Lescinsky$^2$ and P. J. Stooke$^3$, $^1$Dept. of Earth Sciences, University of Western Ontario, London, ON, N6A 5B7, Canada, nmjacque@uwo.ca, $^2$Dept. of Earth Sciences, University of Western Ontario, London, ON, N6A 5B7, Canada, dlescins@uwo.ca., $^3$Dept. of Geography, University of Western Ontario, London, ON, N6A 5C2, Canada, pjstooke@uwo.ca.

Introduction: Over the past decade, the Mars Global Surveyor (MGS) and Mars Odyssey orbiting spacecraft have provided a wealth of data on the structure of the martian surface, as well as characteristics of its subsurface environment. Images returned by these spacecraft suggest that the Martian surface was once substantially modified by the action of liquid water and/or ice [1]. Presently, temperatures and atmospheric conditions do not allow for the stability of liquid water at the planet’s surface (Figure 1). However, recent research strongly supports the existence of substantial reservoirs of subsurface ice [2]. Furthermore, there is evidence for an important spatial and temporal relationship between volcanism and ice on Mars.

Certain geomorphic features observed on Mars have been hypothesized to be the result of the interaction of volcanism with ice at, or near, the martian surface [3,4,5]. In some cases, explosive interactions have been invoked to explain the origin of these features [6]. Many theories call upon Earth-based comparisons of volcano-ice interaction, such as the eruption of magma into standing bodies of water, glaciers and surface ice, due to similarities between these martian landforms and terrestrial products. However, the morphologic evidence for long-term persistence of liquid water or ice at the martian surface is inconclusive for the majority of the planet, and though these features bear resemblance to terrestrial landforms, there are in many cases significant differences in size, scale and structure. Such discrepancies raise obvious uncertainties regarding the origin of these features.

Since ground ice is the largest, most plausible, prospective reservoir for water on Mars, it is the most likely candidate for magmatic interaction. Here we propose a model for the non-explosive interaction of magma with a martian cryosphere (consisting of regolith cemented by ground ice). A thorough investigation of this problem has yet to be undertaken, and as such it will offer a new and valuable perspective to current research on martian landforms.

Model: The premise for this project is a simple conceptual model. A body of magma is emplaced at a given depth within the martian cryosphere in the form of a dike or sill. As the magma cools, it heats the surrounding cryosphere, melting the ground ice and producing a semi-cohesive slurry of water and regolith. This system is envisioned as being analogous to a sub-glacial eruption, with two obvious differences: the overpressure acting on the system is associated with the martian regolith, as opposed to an ice sheet, and the magma is erupting into, and interacting with, a sediment slurry instead of meltwater. With regard to this latter characteristic, the system is also analogous in some ways to a terrestrial eruption into liquefied ocean sediments. This first stage of the model involves the transfer of heat from a magmatic source into the subsurface, which will occur initially via conduction; however, the potential for convective heat transfer is also considered. This stage of the model employs computer simulations (described below) designed to incorporate key properties of the martian environment in an attempt to predict the likely morphology of the resulting features.

Once the heat has been dissipated, and the interactions are complete, the second stage of the model considers the exhumation of the resulting geomorphic features at the martian surface. During the formation of these features melting of the ground ice, which originally cemented the martian regolith, will leave the surrounding regolith relatively unconsolidated. As such, the regolith is more easily eroded, in time exposing the features at the surface. Evidence of such large-scale exhumation is widespread on Mars [7].

Preliminary Results and Application of the Model: The model is being tested numerically using a two-dimensional Crank-Nicholson finite difference method. The program computes the evolution of the thermal regime in a two-dimensional medium with specified steady-state surface temperature and bottom heat flow density, and with no heat flow across the side boundaries, using an Alternating Direction Implicit Method with Operator Splitting. Critical parameters being considered in the overall model are the depth of interaction, nature of the cryosphere (ie. porosity and composition), and the nature of the slurry (density, viscosity, thermal conductivity and heat capacity). The nature of the interaction will also depend on several key factors, such as: thickness of, and depth to, the cryosphere; the presence or absence of a liquid water reservoir; whether or not the slurry convects; whether or not fluidization and/or magma granulation occur; and the rate of differential motion between magma and coolant. To date, the first three factors...
have been taken into consideration in our model, while the latter three will be incorporated at a later date.

The results of the conceptual model and numerical simulation are being tested by a thorough examination of the current and past Mars mission data. Specifically, a survey of images from the MGS Mars Orbiter Camera (MOC), Mars Orbiter Laser Altimeter (MOLA) data, and Mars Odyssey Themis data. This investigation involves analyzing the images for evidence of the predicted geomorphic features, as well as evidence of their exhumation from the subsurface. Several regions of the martian surface have been chosen for this investigation based on the criteria that the regions display/contain: 1) evidence for large-scale exhumation of features such as impact craters, 2) depressions which may have been erosively excavated, 3) little or no evidence for lava flows, 4) the occurrence of isolated geomorphic features, and 5) a location near a source of loose, unconsolidated blanketing material (i.e. volcanic ash). Based on these criteria, the two regions currently being surveyed are Isidis Planitia and Lucus Planum.

Summary: The goal of this study is to offer a better understanding of, and potential explanation for, processes that took place on Mars involving magma-ice interactions, without the need for invoking significantly different environmental conditions than those that exist today. Our aim is to offer an alternative explanation for the formation of geomorphic features that, as yet, have only been considered in the context of near-surface/surface ice interactions or explosive interactions with ground ice. Recent data from the High Resolution Stereo Camera (HRSC) on Mars Express support theories for a young and dynamic hydrosphere within the martian regolith [2]. While evidence of thick bodies of surface water or ice remain tenuous, it is reasonable to propose that magma within the martian subsurface would interact with the subsurface reservoir and/or ground ice.


![Diagram of phase stability of water (dashed lines) and proposed martian geothermal gradients (solid lines; 6, 14, 21 K/km). Shaded box shows zone of interest in the martian subsurface (2-4 km depth).](image-url)