LAVA AND ICE INTERACTION ON MARS: APPLICATION OF TERRESTRIAL OBSERVATIONS AND LABORATORY SIMULATIONS; *D.T. Lescinsky,* and *J.H. Fink,* Department of Geology, Arizona State University, Box 871404, Tempe, AZ 85287-1404

Observations of terrestrial examples of lava and ice interaction have been combined with laboratory simulations to provide a framework for investigating lava and ice interaction on Mars. Identification of large- and small-scale characteristic features will indicate whether large quantities of meltwater were trapped or whether lava flow confinement occurred. These features should also enable the distinction between interaction with glacial ice or permafrost. Relationships between lava flow morphology and eruption parameters determined by laboratory simulation can be applied to Martian deposits to estimate lava composition and effusion rate, and consequently constrain mantle processes.

Introduction. Identification of the products of lava and ice interaction on Mars can provide important clues about the planetary geologic history. Did glaciers and ice sheets once cover portions of Mars or has ice only been present in the form of permafrost? What were the mantle compositions, rates of magma genesis, magma chamber size and magma rise rates through the crust responsible for volcanic activity? The quality and resolution of existing imagery and the absence of compositional data has made it difficult to address these questions. While landforms similar in appearance to Terrestrial examples of lava and ice interaction have been identified in images of Mars [1,2], their origin remains ambiguous. The interaction of permafrost and lava, as evidenced by apparent pseudocraters (attributed to phreatic explosions associated with lava flowing over permafrost) and deposits from large outburst floods (attributed to melting of permafrost; [3-5]), is more widely accepted. The difficulty in assessing whether lava has interacted with ice also effects the determination of lava composition and eruption dynamics. These constraints on mantle processes are estimated using flow geometry and morphology, both of which are greatly dependent on the presence or absence of flow confinement and the rate of lava cooling, and therefore, the presence or absence of ice.

Terrestrial Observations. The interaction between lava and ice on Mars can be better understood by studying terrestrial analogs. Accounts of historic subglacial and supraglacial eruptions in Kamchatka, Alaska, Chile, and Iceland indicate that, in most cases, lava is confined by glaciers because of its inability to rapidly melt ice. Lava brought into contact with ice quickly develops a chilled margin and/or breccia zone which serves as an insulator preventing both rapid melting of the ice and quenching of the lava flow interior. The large quantities of meltwater (outburst floods - jökulhlaups) and glacial modification (trenches eroded through the ice) associated with eruptions are largely the result of long term pre-eruptive geothermal activity [6] and the thermal and kinetic effects of flowing meltwater. If water and/or steam is trapped in contact with lava, phreatic explosions and autobrecciation can occur.

Field examination of deposits attributed to lava and ice interaction located in the Cascades of North America combined with descriptions of deposits in Iceland and Antarctica reveals a number of characteristic large and small-scale features consistent with the eruption observations [7-11]. A list of these features and the relative importance of confinement and interaction with varying quantities of meltwater is shown in Table 1. Identification in the field of interaction features provides information about paleotopography and state of glaciation during eruption; water is more easily trapped on gentle slopes and by thick ice sheets. In addition, cooling surfaces and flow deposit geometry can be used to determine the location and minimum thickness of the ice, as well as whether an eruption was sub- or supraglacial.

Laboratory Simulations. The relationship between lava flow morphology and eruption parameters (ie. lava composition, effusion rate, paleotopography) has been investigated by laboratory simulations using polyethylene glycol wax extruded into a sucrose solution [12-15]. These experiments have only been applied to unconfined flow in subaerial and submarine conditions, so we will conduct new experiments using confined flow conditions. By correlating

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the resultant morphologies with the experimental conditions we will develop a means to determine eruption parameters of confined lava flows, specifically those confined by ice.

Application to Mars. The anticipated imaging capabilities of the Mars Global Surveyor Camera should make it possible to distinguish features characteristic of lava and ice interaction. Investigation will target areas with previously identified evidence of volcanic activity and meltwater flows. Interaction of lava with glaciers, as opposed to permafrost, should be distinct if features indicative of confinement are found with no visible confining topography. Application of the terrestrial observations and laboratory simulations should still be valid even if no evidence of surface ice is found. If lava is channeled by collapse troughs related to melting permafrost, observations and simulations of confined flow can be applied to constrain eruption dynamics and magma composition. If lava is erupted into bodies of meltwater (above or below ground), observations and simulations of unconfined submarine flow can be applied regardless of the origin of the water. Comparison of terrestrial observations with features observed on Mars should improve both our ability to identify where of lava and ice has interacted and our understanding of related landforms (ie. outflow channels and collapse troughs). Estimation of the compositions and effusion rates of Martian lava flows that have interacted with ice, should be possible using laboratory studies of lava flows and lava flow morphologies.

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FEATURE	POSSIBLE GENESIS
Large-scale features indicative of confinement with little trapped meltwater	
Anomalously thick, steep margins, perched flows	Lava flowed against ice and down channels in ice
Laccolith and esker shapes	Extrusion of lava into large existing subglacial voids
Draping flows	Lava filling small voids melted in ice immediately adjacent to lava
Sudden termination, disjointed deposit	Lava extended onto ice that was subsequently removed
Large-scale features indicative of large quantities of trapped meltwater	
Circular or ridge-like rolling hills	Lava pillows and hyaloclastites formed by rapid quenching of lava in water, major landforms called möberg ridges
Flat-topped hill or butte	Pillows and hyaloclastites overlain by subaerially emplaced lava flows, major landforms called tuyas or table mountains
"Pseudocraters"	Phreatic explosions associated with the presence of water and steam trapped below lava
Small-scale features indicative of the presence of some meltwater	
Well- developed, irregularly oriented polygonal joints	Rapid quenching assoc. with convective cooling by water penetration along joints
Sheet-like polygonal joints	Fracturing caused by rapid quenching in non-isotropic conditions
Palagonite	Rapid quenching in large quantities of meltwater

Table 1. Lava features associated with lava and ice interaction.