NON-EQUILIBRIUM FREEZING OF WATER-ICE IN SANDY BASALTIC REGOLITHS AND IMPLICATIONS FOR FLUIDIZED DEBRIS FLOWS ON MARS.

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Introduction. Many geomorphic features on Mars have been attributed to Earth-analogous, cold-climate processes involving movement of water- or ice-lubricated debris. Clearly, knowledge of the behavior of water in regolith materials under Martian conditions is essential to understanding the postulated geomorphic processes. Pertinent laboratory data have been reported by D. M. Anderson and collaborators [e.g., 1-2]) but have been based mostly on experiments with ultrafine-grained samples of clay minerals or their admixtures. New experiments have been performed with sand-sized samples of natural "basaltic" regoliths in order to further elucidate how water/regolith interactions depend upon grain size and mineralogy. The new data reveal important contrasts with data for clay-mineral substrates and suggest that the microphysics of water/mineral interactions might affect Martian geomorphic processes in ways that have not been fully appreciated.

Ice-Formation Experiments. Sand- and silt-sized fractions of two soils from the summit region of Mauna Kea, Hawaii [3] were used as Mars-analogous regolith materials. Makanaka glacial outwash consisted of relatively little-weathered lithic and mineral fragments of basalts whereas Puu Poliahu weathered tephra consisted largely of palagonitized pyroclastic debris [3,4]. Using previously described equipment and methods [5], differential scanning calorimetry (DSC) was used to measure temperatures of water/ice phase transitions as wet slurries of individual soil fractions were cooled or heated at controlled rates under a carbon dioxide atmosphere. Freezing and melting of ice was studied as a function of water/soil mass ratio, soil particle size, and thermal-cycle rate. Comparison tests were done under the same conditions with U. S. Geological Survey standard rock powders PCC-1 (peridotite) and BHVO-1 (basalt), and with powdered Lithology A (olivine-pyroxene-maskelynite) of the shergottite meteorite, EETA79001.

Freezing and melting temperatures of water-ice in the soils were only weakly dependent on particle size over the silt- and sand-sized intervals. Freezing points were essentially independent of water/soil mass ratio but varied inversely with cooling rate. Melting points varied directly with heating rate (Fig. 1). For both the soils and the comparison rocks, though, freezing occurred at temperatures $>$ 6 K below the equilibrium freezing point of pure bulk water (Fig. 2). Depressed freezing points were not controlled by salts in the samples (salt contents were negligible) but were a consequence of the difficulty with which water-ice nucleates on igneous minerals and noncrystalline weathering products. Olivine, pyroxene, plagioclase, and glass (mafic or felsic) are all poor nucleators of water-ice [5]. Although crystalline clay minerals are good nucleators of water-ice [1,5], the mineraloids palagonite and allophane are demonstrably poor nucleators [5]. Therefore, even at slow cooling rates, water mixed with either fresh or palagonitized basalts or closely related materials can survive metastably at temperatures significantly below 273 K.

Implications for Martian Geomorphology. Lifetimes of outburst floods with low sediment/water ratios would probably be controlled by discharge rates and degree of cover by ice bridges [6,7], rather than by the microphysical phenomena reported here. However, in any process that might form a water-based slurry (high sediment/water ratio) on Mars, undercooling of water should be an important factor in determining the longevity and efficacy of the slurry as an agent of geomorphic change. Degree of undercooling should be a strong function of the mineralogy of the sediment. Debris flows composed of fresh igneous materials or poorly crystalline weathering products (e.g., palagonite) should support greater degrees of undercooling and, therefore, greater dynamic lifetimes, than should debris flows composed of crystalline weathering products such as smectites. Photogeologic studies of debris flows on Mars might profit from greater attention to possible correlations between styles and distances of debris-flow movements and the lithologic characters of local regolith materials.

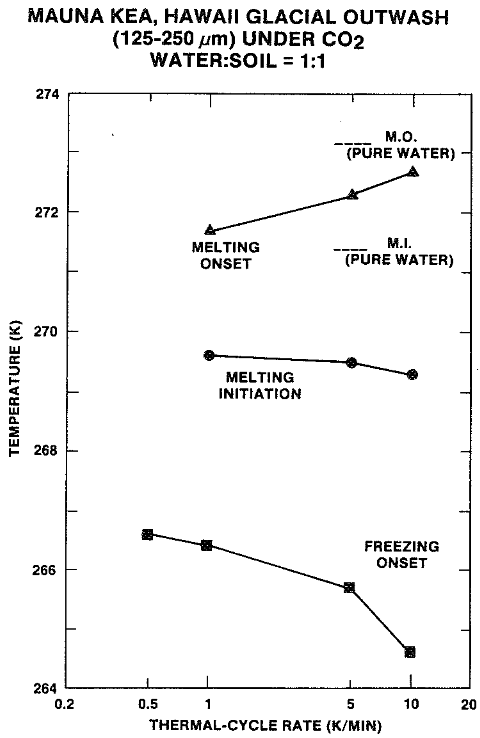

Figure 1. Phase-transition temperatures of water, as a function of heating and cooling rate, in slurries prepared from Mauna Kea glacial outwash soil.

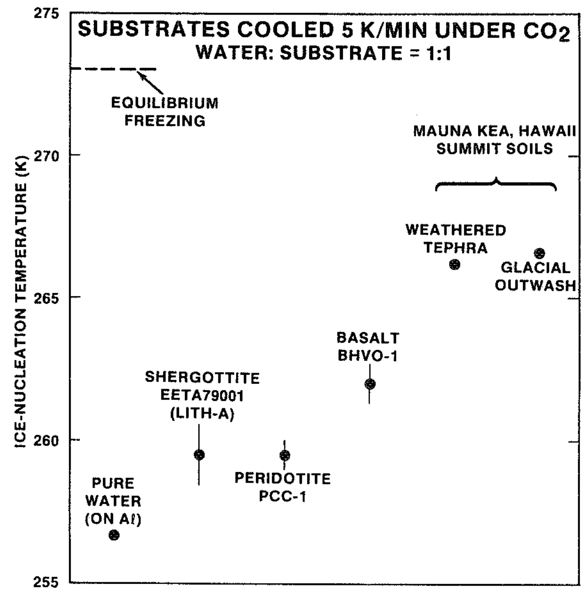

Figure 2. Freezing temperatures for wet slurries of silt-sized "basaltic" materials. Error bars represent standard deviations of replicate measurements.

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