A REEVALUATION OF MASS MOVEMENTS WITHIN THE VALLES MARINERIS REGION OF MARS USING MOLA AND MOC DATA.

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Introduction: Valles Marineris (VM) has remained a prime research site for twenty-five years. Various processes ranging from fluvial to volcanic are believed to have contributed to its complex geomorphology. Studies of the features within VM, thus, have implications for the evolution of Mars.

We present here a reevaluation of mass movements within the VM region, and a unique comparison between VM landslides and submarine landslides based on MOLA and MOC data. A total of twenty-one mass movements (nine landslides and 12 slumps) were surveyed.

Methods: In this investigation, a general distinction is made between landslides and slumps using two characteristic features: a rupture surface, and a displaced mass of sediment or rock. Landslides exhibit translational movement resulting in a planar rupture surface, while slumps exhibit rotational movement resulting in a spoon shaped rupture surface.

We employed a method used by Hampton and Lee [1] to summarize the mobility of submarine landslides to calculate the diagnostic parameters of VM mass movements. Although this model is based only on friction, and does not consider water interactions, it integrates the fundamental qualitative characteristics of basic mass movements. The parameters measured for each individual mass movement (Figures 1 and 2) include: area, height (H), travel distance (S), lateral displacement (L), runout thickness, headscarp height (HH), headscarp slope, and runout deposit length (RODL). We used these calculated values to compare landslides and slumps, and to present a comparison between Martian slides and terrestrial submarine landslides.

Data and Discussion: *Correlations.* We determined the relationships between mass movement variables by applying a correlation function (the covariance of two data sets divided by their standard deviation). When parameters for all VM mass movements (both slides and slumps) were considered, we found that the further a displaced mass of material traveled, the greater the total area of movement. This too is true when comparing total area and lateral displacement values of just slides. In the case of slumps, a weak to no correlation between these parameters is displayed due to the characteristic morphology of slumps, which is constrained by the geomorphology of the VM region (i.e. trough and valley features, as well as interior deposits).

Based on the amount of potential energy in a movement that starts at a high elevation, and the mechanics of consolidated material, a positive correlation between height and runout thickness is to be expected. This is true for VM slides; presumably, the higher the initial point of failure, the more potential energy or force available to be transferred to material upon failure. This concept can also be applied to explain why lateral displacement increases with headscarp height. These findings are in accord with Lucchitta [2] and Locate and Lee [3]. An increase in height leads to increased thickness, because although the potential energy of the movement is high, a dense material is less likely to flow than a less dense material. Given this information, the material is probably very consolidated.

Despite the constraining morphology of VM troughs, movement geometry should support a correlation between area and lateral displacement. Our data, however, show that for VM slumps there is a weak correlation between total area and the distance traveled by failed material. Our data suggests that headscarp and deposit region slopes play a larger part in governing movement distances in the case of slumps more than they do with slides. This finding is in accord with Hampton and Lee's [1] theory that the potential energy afforded to displaced material may be controlled by the shear strength of slope forming materials.

H/L Ratios. Height to lateral displacement ratios are essential to comparisons made between current and previous studies. McEwen [4] and Lucchitta [5] used H/L ratios found on Mars to conclude the type of debris flows (dry or wet) from which the distance traveled by displaced material originates. Conclusions like these are based on the relationship between H/L ratios and the corresponding volumes of the mass movements being studied. Determination of individual slump and slide volumes is beyond the scope of this investigation., however, general H/L ratio comparisons offer implications on initial failure mechanisms in terms of potential energy and failure rheology similar to those one would expect to obtain from volume measurements. Despite differences in regional locality, values found for defined parameters of slumps and slides were comparable. Based on H/L values alone, slumps may initiate with greater potential energy than slides. This is to be expected since the initial failure of slumps occurred at higher elevations than slides.

Martian landslides vs. submarine landslides. Because of their massive size, gravity conditions, properties of buoyancy, and low diffusion, submarine landslides may be the best "terrestrial" analogue to Martian mass movements. Submarine landslides (ranging from 1.2 to 5.0 km in height and 4 to 230 km in lateral displacement) most comparable in size to the VM landslides surveyed were chosen for our comparison.

Gravity aside, the relationship between H/L ratios of VM slides and some submarine landslides suggests that the mechanisms that drive the morphologies of both of these types of mass movements may be similar (Figure 3). In order to draw conclusions, however, it is important to consider how gravity and buoyancy compare on Mars and underwater. Normal stress on Earth is 2.65 times that on Mars. Assuming the average density of rock to be 2.7 kg/m^3, and the density of water to be 1kg/m^3, we calculated the normal stress acting on materials underwater to be 1.67 times that on Mars. Based on this value, Martian landslides should have shorter runouts than submarine landslides; this is not the case. On average, Martian landslides are longer than submarine landslides. To explain this deviation from the expected, an additional variable (i.e. one that can make slide material less dense, less consolidated) is affecting the normal stress. Fluidization of materials due to water [6] or acoustic fluidization [6,7] may be the driving force.

Conclusions: Our research indicates that despite the similarity in parameter values for slides and slumps, the forces initiating slumps may be higher in potential energy than those initiating slides. When comparing Martian slides and submarine landslides, the height vs. lateral displacement (H/L) ratios for over half of the submarine landslides selected plot along the Martian landslide H/L trendline (Figure 3). According to the relationship between normal stress underwater and normal stress on Mars ($\sigma_W = 1.67 * \sigma_M$), Martian landslides should have shorter runouts than submarine slides. Fluid or acoustic fluidization may be driving long runouts on Mars.

An obvious driving mechanism of mass movements is gravity. The role of liquid water within the Valles Marineris region of Mars is not clearly understood, and, thus, remain debated. Recent studies [8,9,10] support the need for continued investigation of the mechanisms driving mass movements on Mars, and further comparison between submarine landslides and Martian landslides.

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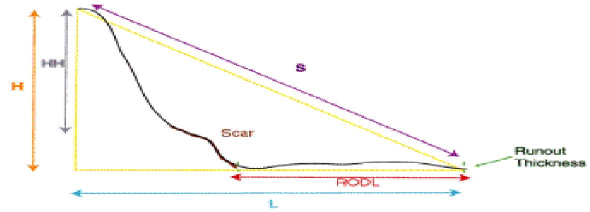

Figure 1. Depiction of landslide parameters measured. Adapted from Hampton and Lee, 1996.

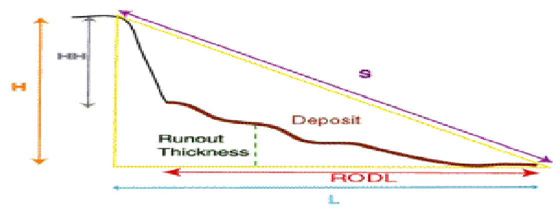

Figure 2. Depiction of slump parameters measured. Adapted from Hampton and Lee, 1996.

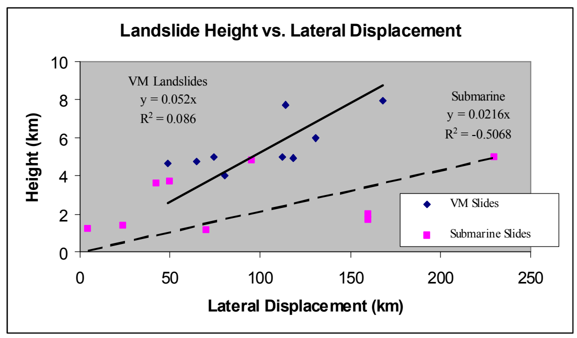

Figure 3. Comparison between H/L ratios of VM slides and selected landslides. In general, VM slides exhibit higher H/L ratios. However, over half of the submarine slides plot along the VM trendline. This suggests that VM slides and submarine slides may have similar dynamic rheologies.