Proxemy Research
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Closeout Report

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Proposal Title: Applications of MGS MOC and MOLA data to lava flows: Investigations of rheology, topographic influences and tectonic effects (Grant No. NAG5-11170)

Submitted to: Dr. Herb Fry
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PROPOSAL TITLE: Applications of MGS MOC and MOLA data to lava flows: Investigations of rheology, topographic influences and tectonic effects

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1. INTRODUCTION

Proxemy Research had a grant from NASA to perform science research using Mars Global Surveyor (MGS) data to study lava flows on Mars. This grant (NAG-11170) closed on August 14, 2004. Here we summarize the scientific progress and accomplishments of this grant. Scientific publications and abstracts of presentations are indicated in the final section.

This was a very productive grant and the progress that was made is summarized below. The Full Proposal originally identified three tasks related to applications of MGS data to lava flows. The specific tasks were: 1) Compilation of longitudinal and transverse flow thickness profiles for lava flows in a variety of volcanic and tectonic settings, 2) rheologic analyses of each lava flow based on thickness profiles determined in Task 1, and 3) Comparison of actual flow paths to those estimated from digital topography. A summary of the research and results is given below. A composite list of all scientific publications and most of the related abstracts appears in Section 3.

2. SUMMARY OF RESEARCH AND RESULTS

Primary Publications:


Over the life of this project, we have made tremendous progress toward achieving many of the goals in Task 1. We have collected numerous MOLA PEDR profiles, Viking context images and many high resolution MOC images for several volcanic regions. We have investigated several flows, including flows near Alba, Asraeaus, Elysium and the Tharsis region, and compiled data for the Mauna Loa 1984, 1 and 1A terrestrial lava flows (Table 1). The final months of this grant were spent collecting still more flow thickness data for numerous lava flows near the summits of Alba and Asraeaus Montes.

The process of deriving longitudinal flow thickness profiles directly from MOLA PEDR data turned out to be much more difficult than we had hoped when writing the original proposal. There are many reasons why this process is difficult. First, the topography for many of the flows we have looked at is is at a similar scale to much of the surrounding region. Thus, simply looking at the individual transects, it is not possible to "pick out" the lava flow. As a result, it is necessary to overlay the MOLA profiles onto some other product in order to verify that the features identified as
"lava flow" are indeed in the correct location.

Overlaying the MOLA profiles onto an image product is not a trivial task. Errors in Viking data geolocation mean that latitude and longitude references can differ from MOLA by a full degree. MOC data, while accurately georeferenced, are in a different coordinate system. Furthermore, high resolution MOC images generally only contain very small segments of the lava flows, which is of little use in finding the general location of the flow.

The approach we have taken is to use the gridded MOLA data set to help locate the lava flows. As the gridded data are derived from the MOLA data, the reference coordinates of both data sets are directly comparable. We then manually overlay the gridded data onto regional image data (usually Viking). We can then "see" the flow in the image data, and can identify the lat/lon location in the MOLA gridded data.

Table 1. Flows investigated as part of this project (numbers refer to internal identification system). Flows are listed in order of decreasing underlying slope. ML Flows are from the 1984 Mauna Loa eruption.

<table>
<thead>
<tr>
<th>Lava Flow</th>
<th>Length Studied (km)</th>
<th>Initial Thickness (m)</th>
<th>Front Thickness (m)</th>
<th>Channel</th>
<th>Slope (deg)</th>
<th>Viscosity Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML 1A Flow</td>
<td>13</td>
<td>5</td>
<td>13</td>
<td>Y</td>
<td>4</td>
<td>30x</td>
</tr>
<tr>
<td>ML 1 Flow</td>
<td>26</td>
<td>4</td>
<td>19</td>
<td>Y</td>
<td>4</td>
<td>100 - 400x</td>
</tr>
<tr>
<td>Elysium II</td>
<td>35</td>
<td>15</td>
<td>37</td>
<td>N</td>
<td>0.6</td>
<td>50x</td>
</tr>
<tr>
<td>Alba III</td>
<td>97</td>
<td>20</td>
<td>100</td>
<td>N</td>
<td>0.55</td>
<td>TBD</td>
</tr>
<tr>
<td>Ascraeus III</td>
<td>229</td>
<td>20</td>
<td>40</td>
<td>TBD</td>
<td>0.5</td>
<td>TBD</td>
</tr>
<tr>
<td>Alba I</td>
<td>95</td>
<td>40</td>
<td>130</td>
<td>N</td>
<td>0.4</td>
<td>30 - 60x</td>
</tr>
<tr>
<td>Tharsis I</td>
<td>111</td>
<td>39</td>
<td>69</td>
<td>N</td>
<td>0.35</td>
<td>TBD</td>
</tr>
<tr>
<td>Ascraeus V</td>
<td>145</td>
<td>20</td>
<td>30</td>
<td>Y</td>
<td>0.3</td>
<td>&lt; 10x</td>
</tr>
<tr>
<td>Alba V</td>
<td>143</td>
<td>45</td>
<td>108</td>
<td>N</td>
<td>0.16</td>
<td>TBD</td>
</tr>
<tr>
<td>Pavonis</td>
<td>175</td>
<td>30</td>
<td>55</td>
<td>Y</td>
<td>0.05</td>
<td>10x</td>
</tr>
</tbody>
</table>

This approach to deriving longitudinal flow thickness profiles is described in detail (with an example from Elysium) in Glaze et al. [2003]. With the availability of the 128 pixel/degree MOLA gridded dataset (we have this data set for the entire planet on CD-ROM), we can now use gridded data for the larger flows (i.e., thickness significantly greater than surrounding topographic variations). We have continued to use the Glaze et al. [2003] approach for smaller flows for which the gridded data are not sufficient.

The primary objective of the second task was to use the longitudinal thickness profiles derived in Task 1 to constrain physics models of flow emplacement. We have completed a detailed study of a flow northwest of Elysium [Glaze et al., 2003a] and on the plains north of Pavonis [Baloga...
et al., 2003]. These two lava flows represent two very interesting cases.

In the case of Elysium (Figure 1), the flow is $\sim 35$ km long and the thickness is on the same scale as the surrounding topographic variation. The flow appears to thicken with a concave up longitudinal flow surface. This is indicative of an exponential increase in the viscosity and the degree of thickening is consistent with a 50x increase over the length studied.

In the case of Pavonis (Figure 2), the flow is significantly longer (175 km) and shows very little evidence of thickening over the entire length. Thus the predicted viscosity increase is minimal. Even when we allow the flow to lose material to stagnant levees (which can mask a viscosity increase), we still see very little increase in viscosity over the length of the flow.

While the underlying slopes for these two flows differ by an order of magnitude, both are extremely low (both less than 1°). The primary difference between these two flows is the overall flow thickness and length. Baloga et al. [2003] suggest that the length of the Pavonis flow and the lack of viscosity increase are related. They suggest a dynamic regime featuring a balance between the formation of an outer skin and shedding of lava into stationary zones. Requirements for attaining such a regime include a thick flow, shallow slopes over extended distances, and pre-existing surface roughness that is small compared to flow thickness. This style of emplacement may explain why many of the long, thick sheet-like flows on the plains of Mars often exhibit an unexpected lack of thickening with distance.

Conversely, the Elysium flow must have experienced more disruption during flow allowing lava to cool and the viscosity to increase. This type of flow regime is more likely to produce shorter flows and multiple breakouts.

In addition to these two flows, we have also begun to investigate rheologic changes for the other six flows for which we have already derived longitudinal flow thickness profiles from the MOLA PEDR data. Table 1 shows the basic results for these flows, as well as results for the Mauna
Loa 1984 1 and 1A flows. Under our new MDAP grant, we plan to continue analyzing lava flow rheologies based on thickness data collected as part of this grant.

Progress was also made on comparisons of flow paths with digital topography. For these comparisons, we have used a new flow path prediction algorithm [Glaze and Baloga, 2003]. We have collaborated with Jim Zimbelman to present the results of a pathfinding study at the meeting of the Geological Society of America [Zimbelman et al., 2001]. As part of this study, we predicted the local gradient for a large lava flow that originates in the saddle between Pavonis and Ascreaus. This flow exhibits a systematic offset from the local topography. The preferred explanation at present is post-emplacement tectonism. Similar offsets have been identified for a large flow NW of Pavonis and for multiple flows south of Ascreaus.

In addition to the core activities described above, I have also been involved with several other MDAP and PGG scientists on collaborative projects related to this grant. These projects include a collaborative study with MDAP PI Mark Bulmer to explore surface block size distributions on volcanic deposits [Bulmer et al., 2004]. I have also collaborated with Steve Anderson and PGG PI Ellen Stofan on a study that uses MOC imagery and statistical techniques to study the spatial distribution of tumuli on pahoehoe lava surfaces [Glaze et al., 2005]. Collaborative efforts with PGG PI Steve Baloga have resulted in a new correlated random walk model for pahoehoe lava emplacement. This model can be used in conjunction with future MDAP efforts to use MGS data to constrain lava flow emplacement on Mars.

3. PUBLICATIONS AND ABSTRACTS FROM GRANT:

_Peer Reviewed Publications funded all or in part by this grant:_


_Abstracts related to this grant:_

_WPGC 04:_


LPSC 04:

LPSC 03:

LPSC 02:

AGU 01:

GSA 01:
4. TITLE AND SUBTITLE: Closeout Report

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11. SUPPLEMENTARY NOTES
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