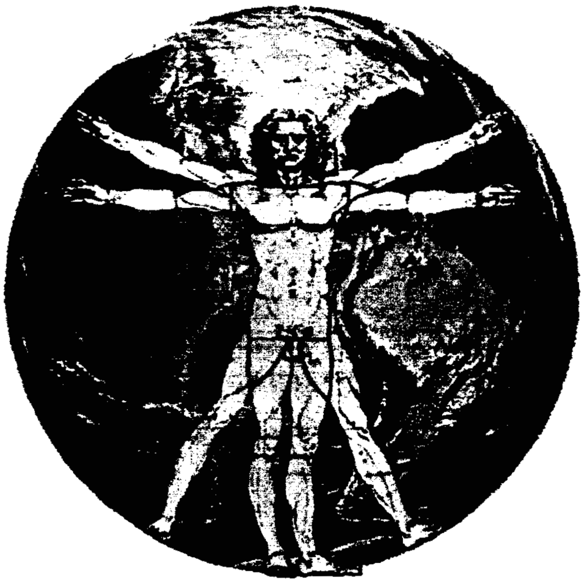

Proxemy Research
Grant NAG5-11170
Closeout Report

Author: Dr. Lori S. Glaze

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
NASA Headquarters

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

AUTHOR: Dr. Lori S. Glaze

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:

Glaze, L.S., S.M. Baloga and E.R. Stofan (2003) A methodology for constraining lava flow rheologies with MOLA. Icarus, 165:26-33.

Baloga, S.M., P.J. Mouginis-Mark and L.S. Glaze (2003) Rheology of a long lava flow at Pavonis Mons, Mars. J Geophys Res/Planets, doi:10.1029/2002JE001981.

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, Ascraeus, 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 Ascraeus 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 propsal. There are many reasons why this process is difficult. First, the topography for many of the flows we have looked at 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.

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

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 ~ 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.

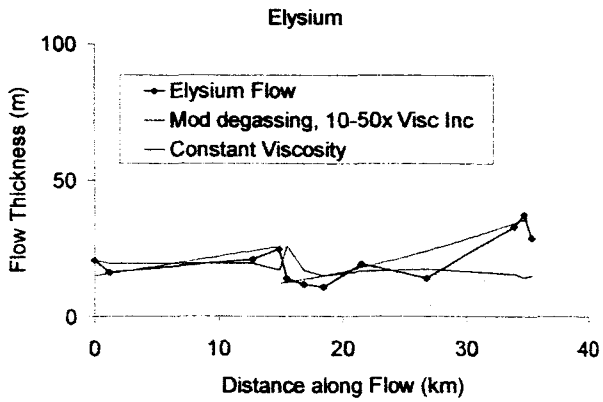

Figure 1 Longitudinal flow thickness profile and theoretical estimates of flow thickness based on a model that incorporates a viscosity increase and concurrent degassing [Baloga et al., 2001].

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.

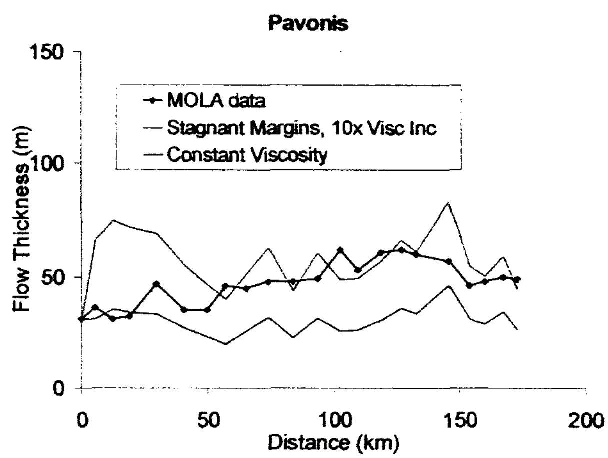

Figure 2 Longitudinal flow thickness profile and theoretical estimates of flow thickness based on a model that removes material to stationary margins during flow [Baloga et al., 1998].

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 Ascraeus. 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 Ascraeus.

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:

Glaze, LS, SW Anderson, ER Stofan, SM Baloga and SE Smrekar (2005) Statistical distribution of inflation features on lava flows: Analysis of flow surfaces on Earth and Mars. Geol Soc Am Bull (revised).

Bulmer, MH, LS Glaze, S Anderson, and KM Shockey (2004) Distinguishing between primary and secondary emplacement events of blocky volcanic deposits using rock size distributions. J Geophys Res/Solid Earth (in press).

Glaze, L.S., S.M. Baloga and E.R. Stofan (2003) A methodology for constraining lava flow rheologies with MOLA. Icarus, 165:26-33.

Glaze, L.S. and S.M. Baloga (2003) DEM flow path prediction algorithm for geologic mass movements. Environmental and Engineering Geoscience, 9:225-240.

Baloga, S.M., P.J. Mouginis-Mark and L.S. Glaze (2003) Rheology of a long lava flow at Pavonis Mons, Mars. J Geophys Res/Planets, doi:10.1029/2002JE001981.

Baloga, S.M. and L.S. Glaze (2003) Pahoehoe transport as a correlated random walk. J Geophys Res, 108:10.1029/2001JB001739.

Abstracts related to this grant:

WPGC 04:

Glaze, LS, and SM Baloga (2004) Simulation of complex pahoehoe flow fields. EOS Transactions AGU, 85 (28), West Pac Geophys Suppl, Abstract V42A-02.

Baloga, SM, LS Glaze, and S Rowland (2004) Modeling random influences on the style of pahoehoe emplacement. EOS Transactions AGU, 85 (28), West Pac Geophys Suppl, Abstract V42A-01.

LPSC 04:

Glaze, LS, SM Baloga, PJ Mouginis-Mark and J Crisp (2004) A model for variable levee formation rates in an active lava flow. Proceedings of the Thirty-fifth Lunar and Planetary Science Conference, CD-ROM. Paper # 1036.

Shockey, KM, LS Glaze and SM Baloga (2004) Analysis of Alba Patera flows: A comparison of similarities and differences. Proceedings of the Thirty-fifth Lunar and Planetary Science Conference, CD-ROM. Paper # 1154.

LPSC 03:

Anderson, SW, L Glaze, E Stofan and S Baloga (2003) The Spatial Distribution of Lava Flow surface features on Earth and Mars. Proceedings of the Thirty-fourth Lunar and Planetary Science Conference, CD-ROM. Paper # 1080.

Baloga, SM, LS Glaze, DA Crown (2003) Scaling of Pahoehoe Flow Field Features. Proceedings of the Thirty-fourth Lunar and Planetary Science Conference, CD-ROM. Paper # 1437.

Bulmer, MH, L Glaze, KM Shockey, OS Barnouin-Jha and W Murphy (2003) Insights into the Emplacement of Rock Avalanches on Mars. Proceedings of the Thirty-fourth Lunar and Planetary Science Conference, CD-ROM. Paper # 1225.

Glaze, LS, SM Baloga, ER Stofan, PJ Mouginis-Mark, KM Shockey and S McColley (2003) Rheology Comparisons for Several Martian and Terrestrial Lava Flows. Proceedings of the Thirty-fourth Lunar and Planetary Science Conference, CD-ROM. Paper # 1315.

LPSC 02:

Glaze, LS, ER Stofan, SM Baloga, SM McColley, S Sakimoto and D Mitchell (2002) MOLA constraints on lava flow rheologies. Proceedings of the Thirty-third Lunar and Planetary Science Conference, CD-ROM.

Baloga, SM, LS Glaze and JA Crisp (2002) Channelized lava flows with density changes during emplacement. Proceedings of the Thirty-third Lunar and Planetary Science Conference, CD-ROM.

Bulmer, M, L Glaze, S Baloga, OS Barnouin-Jha, W Murphy, and G Neumann (2002) Modeling mass movements for planetary studies. Proceedings of the Thirty-third Lunar and Planetary Science Conference, CD-ROM.

AGU 01:

Glaze, LS, SM Baloga, ER Stofan and SM McColley (2001) New Constraints on Martian Lava Flow Rheologies From MOLA. Fall Meeting of the American Geophysical Union, abstract #P31B-06, CD-ROM.

Barnouin-Jha, OS, M Bulmer, S Baloga and L Glaze (2001) Estimating flow properties of quasi-newtonian mass-movements. Fall Meeting of the American Geophysical Union, abstract #P22D-03, CD-ROM.

GSA 01:

Zimbelman, JR, LS Glaze, SM Baloga and HH Miyamoto (2001) Comparison of finite difference method and computational calculus approaches in simulating lava flow paths on Mars. Proceedings of the Geological Society of America.

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13. ABSTRACT *(Maximum 200 words)*

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