# MECHANCAL AND FLOW MODEL CONSTRAINTS ON THE ORIGINS OF PLATY FLOWS ON MARS: LAVA, FROZEN SEA, OR SOMETHING RATHER MUDDY?

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**Introduction:** The Mars Global Surveyor, Mars Express, and Mars Odyssey Missions have returned images and topography for "platy" surface textures for materials that appear to be the either material flowing downhill through topographically constrained channels into low-lying areas[1-30]. As noted previously [e.g. 29, and many others], the platy materials are typically characterized by plates separated by ridges or troughs at scales of hundreds of meters to tens of kilometers, [e.g. .2, 5, 6, 9, 11, 14, 15, 16-30]. These flow surfaces are within geologically young regions with relatively fresh topographic expressions, and they appear relatively young (<10's m.y., and possibly recent) in terms of apparent relative dust cover and crater counts [e.g. 25]. The platy flows are within major resurfacing units for extensive regions of Mars, (Cerberus, Elysium, Amazonis, etc…) [26], and thus the question of their origins has wide implications for recent martian geologic history. Their origins are the subject of spirited ongoing discussions, and they have been variously interpreted as the signature of a recent 50 meter deep frozen ocean [e.g. 14, 15, 30] or lava, mud, and/or ice flows [e.g. 13, 16, 29 and others]. This study considers combined high resolution image and topography data as constraints on mechanical and process models for the lava and frozen sea origins. The platy surfaces are found within regions with mapped volcanic vents and flows [e.g. 11, 21, 29, and others] as well as probable fluvial [e.g. 5, 29, 34] and many others], hydrovolcanic [e.g. 1] and mud lake [32] or pingoes or permafrost [e.g. 33] features.

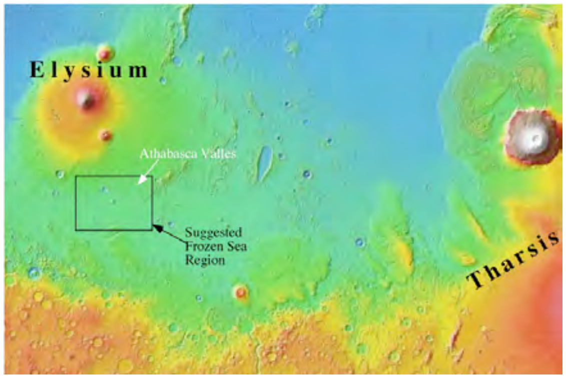

Fig. 1. Location map for the platy flow region proposed as frozen sea by Murray et al. [30]. Background is MOLA topography.

**Methods and Results:** We use several modeling approaches here, including 1) analysis of reported platy terrain boundaries as possible shorelines, 2) mechanical strength of surfaces from plate dimensions, and 3) the flow of a thin brittle surface over a viscous layer. Model assumptions were made so as to maximize consistency with and thus inclusion of both proposed frozen sea and viscous fluid (lava/mud) origins interpretations.

*Platy Terrain Boundaries as Shorelines:* Figure 1 shows the location of region suggested [14,15,30] as a possible frozen sea deposit. Using the image-based shoreline locations mapped in [30], we regularly sampled corresponding MOLA elevations for the MOLA proposed shoreline every few tens of km in 128 and 256 pixel per degree gridded topography data (checked with MOLA profile data) as a function of distance along the shoreline. Figure 2 these image-mapped shoreline elevation points with error bars compared to our best-fit MOLA constant elevation contour fit to the same shoreline (horizontal line) plus or minus one standard deviation. The first result to note is that the proposed shorelines are quite far from a constant elevation. The image-based mapping of [30] results in a shoreline with corresponding MOLA elevations ranging over about 130 meters (error bars of about 10 meters). Since this is a young area, we expect minimal subsequent tectonic deformation. The best fit nearest MOLA constant elevation contour fit to the same proposed shoreline (horizontal line in fig. 2) plus or minus

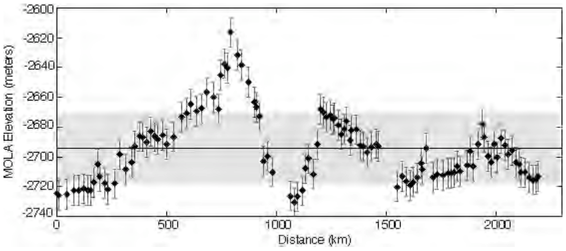

Fig. 2. MOLA Elevation of the proposed frozen sea shoreline of Murray [30]. Data points are MOLA elevations with error bars of the shoreline every few tens of km. Gray shaded box with thin horizontal center line shows sampled mean shoreline elevation from locations image based mapping (after [30]) and one standard devia-

one standard deviation is outside the error bar range of most of the proposed shoreline elevations. The second result to note is that the above best fit nearest MOLA constant elevation contour does not form a closed basin, and that there is no closed topographic basin that appears to be a reasonable approximation of the proposed shorelines. While this is very likely inconsistent with a frozen sea origin, it is quite possible with a lava or other very viscous (mud?) flow origin.

*Mechanical Strength Modelling:* The minimum thickness of the plates is estimated from registered THEMIS and MOLA profile data (see companion abstract [31]). For example, for the region in [31], a typical plate relief above the base of the surrounding trough is about 1.5 meters (range of 1.5–5.5 m) with meter-scale roughness of the same order as plate thickness. This is used as a minimum plate thickness (mechanical), and it is allowed to vary upwards by an order of magnitude to allow for partial plate burial (e.g. [14] assuming an ice origin, and the maximum range (1-100 m) of typical local fllava ow thicknesses positively identified as emanating fromvolcanic vents [21].

*Flow and fracture of a thin brittle surface over a viscous layer:* Here, we model apparent plate thickness as above as the assumed thin skin brittle crust for an underlying fluid or viscous layer, and estimate resulting fluid layer thicknesses required under either ice or lava flow conditions and compare these to observed local lava flow thicknesses as well as proposed frozen ocean depths from reported models (e.g. 14, 15, 30, 33]. Preliminary results indicate that typical basaltic lava parameters easily produce the observed plates, while it is difficult (and perhaps impossible, depending on assumptions) to produce ice plates.

**Conclusions**: While the interpretation of platy surface units as remnants of a frozen martian sea [e.g. 15] has received substantial press, and certainly has some (primarily image-based) supporting evidence, we find that despite making assumptions designed to favor ice interpretations (to avoid a lava-bias), the quantitative modeling here combining topographic, thermal, and image constraints has multiple significant difficulties producing results consistent with an interpretation of frozen sea ice, including but not limited to: 1) Mapped shoreline elevations ranging over a wide elevation range, 2) a lack of a closed topographic basin to contain the proposed ocean, 3) proposed plate thicknesses and proposed ocean depths difficult (or impossible) to produce with brittle plate failure and thin skin models. While remapping boundaries may rectify some issues, these problems need careful attention before a frozen ocean model can be said to be equally plausible with a viscous fluid (lava or mud) set of models. Until then, we suggest that a viscous fluid (lava/mud) such as that shown in fig 3 may be a more likely interpretation than a frozen ocean.

**References:** [1] Berman, D.C., & W.K. Hartmann (2002) Icarus, 159, 1-17. [2]Burr, D.M., et al. (2004) Icarus 171, 68-83. [3] Burr, D.M., et al. (2002), Icarus 159, 53-73. [4] Burr, D.M., et al. (2002) LPSC XXXIII, Abstr.#1047. [5] Burr, D.M., et al., (2002) GRL 29, 13-1. [6] de Pablo, M. A., Fair, & A. G., Marquez, A (2004) 35th COSPAR Sci. Assem. 425. [7] Fagents, S.A. & Baloga, S.M., (2003) LPSC XXXIV Abstr.#1788. [8] Fuller, E.R. & J.W. Head, (2002), JGR 107, 10.1029/2002JE001842. [9] Gregg, T.K.P. & S.E.H. Sakimoto (2000) LPSC XXXI #1758. [9] Head, J.W., M.A. Kreslavsky, & S. Pratt, (2002) JGR 107, DOI 10.1029/2000JE001445. [10] Keszthelyi, L., A.S. McEwen, & Th. Thordarson (2000) JGR 105, 15,027-15,050. [11] Keszthelyi, L., Burr, D.M., McEwen, A.S, (2004) 2004, LPSC XXXV Abstr.#1657. [12] Manga, M, (2004), GRL 31, L02702. [13] McEwen, A., et al., (2002) AGU, Mtng. 2002, Abstr.#P11B-09. [14] Murray, J.B., et al. (2005) Nature 434, 352-356. [15] Murray, J.B., ., et al. (2005) LPSC Abstr.#1741. [16] Rice, J.W et al, (2003) LPSC XXXIV, Abstr.#2091. [17] Rice, J.W., et al, (2002) LPSC XXXIII Abstr.#2026. [18] Rice, J. W. et al, (2002), AGU Mtng. Abstr. [19] Russell, P.S. & J.W. Head, (2003) JGR 108(E6) ,CiteID 5064, DOI 10.1029 [20] Sakimoto, et al. (2001) AGU, Mtng. Abstr.#P22A-0537. [21] Sakimoto, S.E.H. & Gregg, T.K.P. ( 2004) LPSC XXXIV Abstr.# 1851. [22] Tanaka, K.L., et al. (2003) JGR 108, 20-1. [23] Williams, R. M. E., & M. C. Malin, (2004) JGR 109 10.1029/2003JE002178. [24] Williams, R.M., & R.J.Phillips, M.C. Malin, (2000) GRL 27(7) 1073. [25] Hartmann, W.K. & D.C. Berman, (2000) JGR 105 15,011-026. [26] Tanaka, K.L., (1986) JGR 91, E139-158.[28] Glaze et al.,(2003) Icarus 165 26-33, [29] S.E.H. Sakimoto, (2006) LPSC Abstr.#2384, [30] J.B. Murray et al., (2006) LPSC Abstr. # 2293, [31] A.L. Fagan and S.E.H. Sakimoto (2006) LPSC Abstr. (This volume)., [32] K. J. Kossacki et al., (2006) Icarus, V 181(2), pp 363-374, [33] D.P. Page and Murray (2006) Icarus, V 183(2), p. 46-54. 10.1016/j.icarus.2006.01.017, [34] L. Keszthelyi et al., (2006) LPSC Abstr. #2245.

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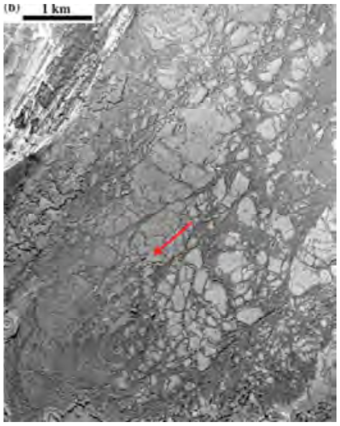

Fig. 3, Example of platy lava flow within the Eastern Snake River Plains (air photo).