Forum Comment

doi: 10.1130/G37491C.1

Long-runout landslides and the long-lasting effects of early water activity on Mars

Philip J. Shaller
Exponent, Inc., 320 Goddard, Suite 200, Irvine, California 92618, USA

Watkins et al. (2015) propose a clay-lubrication model to explain the extreme runout distances of long-runout landslides in Mars' Valles Marineris (VM) based on observations of the western margin of Ius Labes, one of the largest VM landslides. Their model proposes that the landslide "overrode and entrained the hydrated-silicate-bearing floor deposits, causing further loss of coherence and permitting the landslide outer zone to spread laterally while moving forward over the low-friction surface." While this model offers an attractive mechanism to explain the particular outcrops evaluated in their paper, it does not readily conform to the characteristics of long-runout landslides in other planetary settings, the engineering behavior of clays, or the properties of Ius Labes beyond the limits of their study area.

The study of long-runout landslides extends back to the late 19th century (Heim, 1882). The unusual characteristics of these landslides have spun off a host of hypotheses, as summarized by Shaller and Shaller (1996). Observations of long-runout landslides in Earth's oceans (Moore et al., 1989), on the Moon (Guest, 1971), Mars (Lucchitta, 1979), and Saturn's moon Iapetus (Singer et al., 2012) offer an opportunity to help clarify the issue, assuming these examples are placed into context with the phenomenon at large.

In this light, the geologic interpretations advanced by Watkins et al. would have benefitted from a more thorough survey of the relevant literature concerning terrestrial long-runout landslides, as the many morphological similarities between these mass movements on Earth and Mars suggest at least some commonality in mechanism (cf. Shaller, 1991). Among this admittedly voluminous literature, only one study, that of Watson and Wright (1969), cited any field evidence suggestive of a possible role for clay in the long-runout mechanism. This study, which described the Saidmerreh (Iran) landslide, added the proviso that the clay-bearing intervals be saturated to function as an adequate basal lubricant. On Mars, where liquid water is rare, clay lubrication is *a priori* a more remote possibility than on Earth. Clay lubrication of long-runout landslides is still more problematic for the Moon, which contains no clay (Carrier, et al., 1991). Similarly, Iapetus is too cold to host liquid water (NASA, 2007), which is necessary for clay formation (e.g., Ehlmann, et al., 2011).

Moreover, the engineering properties ascribed to the Martian clays by Watkins et al. do not account for the fact that these properties are extremely sensitive to both mineralogy and water content. The authors estimate the VM clay deposits to be 3.6 to 4.0 Ga older than Ius Labes. Clay deposits exposed to the Martian environment over geologic time scales are likely very dry (e.g., NASA, 2013). When dry and compacted, clays are a moderately strong and frictional material (e.g., claystone), with coefficients of friction that range from approximately 0.3 to 0.5 (NAVFAC, 1982). This compares with an apparent coefficient of friction (fahrböschung) of 0.06 for Ius Labes (Shaller, 1991). Coefficients of sliding friction this low are only rarely encountered in terrestrial clay beds, and only when they exhibit optimal mineralogy, a high degree of saturation, and are slowly sheared to residual strength (Watry and Ehlig, 1995). Dry clays are unlikely to have exhibited unusually low frictional properties in the conventional sense and would have been hard to incorporate into the landslide in significant quantities. On Earth, only relatively soft or weak materials are incorporated into long-runout landslides (Shaller, 1991).

Finally, the Ius Labes deposit itself provides evidence against a clay lubrication hypothesis. In most places, the light-colored unit interpreted by Watkins et al. to be the basal member of the debris apron is underlain by a lower, darker unit that also appears to be part of the landslide (unit 2 of Watkins et al.), based on the observations that the darker unit (1) has a distinct edge that obscures a neighboring, overridden landslide, and (2) preserves a few longitudinal grooves that are traceable upslope onto the light-colored layer.

It is hypothesized here that, instead of representing bulldozed chasma floor material, this exposure actually represents displaced wall rock and that the stratigraphy exposed at the margin of the debris apron is preserved from the headscarp area, a well-known phenomenon in terrestrial long-runout landslides (Shaller, 1991, and references therein that cite 24 published examples). This conclusion is supported by Google Mars™ imagery of the base of the chasma wall west of Ius Labes, which exhibits the same dark-over-light-over-dark stratigraphy of the landslide's debris apron.

In summary, long-runout landslides are rarely associated with clay deposits on Mars, Earth, or elsewhere. Any clay deposits overrun by Ius Labes were likely dry and would not be expected to exhibit notably low frictional properties. Instead of representing overrun basin deposits, the clay materials exposed along the tapered edge of Ius Labes are interpreted to represent displaced chasma wall material that maintained its relative stratigraphic position in the final deposit.

REFERENCES CITED

Carrier, W.D., III, Olhoeft, G.R., and Mendell, W., 1991, Physical properties of the lunar surface, in Heiken, G.H., Vaniman, D.T. and French, B.M., eds., Lunar Sourcebook: A User's Guide to the Moon: New York, Cambridge University Press, p. 475–594.

Ehlmann, B.L., Mustard, J.F., Murchie, S.L., Bibring, J.-P., Meunier, A., Fraeman, A.A., and Langevin, Y., 2011, Subsurface water and clay mineral formation during the early history of Mars: Nature, v. 479, p. 53–60, doi:10.1038/nature10582.

Guest, J.E., 1971, Geology of the farside crater Tsiolkovsky, in G. Fielder, ed., Geology and Physics of the Moon: Amsterdam, Elsevier, p. 93–103.

Heim, A., 1882, Der Bergsturz von Elm: Zeitschrift der Deutschen Geologischen Gesellschaft, v. 34, p. 74–115.

Lucchitta, B.K., 1979, Landslides in Valles Marineris, Mars: Journal of Geophysical Research, v. 84, B14, p. 8097–8113, doi:10.1029/JB084iB14p08097.

Moore, J.G., Clague, D.A., Holcomb, R.T., Lipman, P.W., Normark, W.R. and Torresan, M.E., 1989, Prodigious submarine landslides on the Hawaiian Ridge: Journal of Geophysical Research, v. 94 B12, p. 17,465–17,484.

NASA (National Aeronautics and Space Administration), 2007,Warm and Dry on Iapetus: http://www.nasa.gov/mission_pages/cassini/multimedia/pia10012.html (October 2015).

NASA (National Aeronautics and Space Administration), 2013, Curiosity's SAM Instrument Finds Water and More in Surface Sample: http://www.nasa.gov/content/goddard/curiositys-sam-instrument-finds-water-and-more-in-surface-sample/ (September 2015).

NAVFAC (Naval Facilities Engineering Command), 1982, Foundations and Earth Structures, Design Manual 7.2: Washington D.C., U.S. Government Printing Office, 279 p.

Shaller, P.J., 1991, Analysis and implications of large Martian and terrestrial landslides [Ph.D. thesis]: Pasadena, California, California Institute of Technology, 586 p.

Shaller, P.J., and Shaller, A.L., 1996, Review of proposed mechanisms for sturzstroms (long-runout landslides), in Abbot, P.L., and Seymour, D.C., eds., Sturzstroms and Detachment Faults, Anza-Borrego State Park, California: Santa Ana, California, South Coast Geological Society, Annual Field Trip Guidebook No. 24, p. 185–202.

Singer, K.N., McKinnon, W.B., Schenk, P.M., and Moore, J.M., 2012, Massive ice avalanches on Iapetus mobilized by friction reduction during flash heating: Nature Geoscience, v. 5, p. 574–578, doi:10.1038/ngeo1526.

Watkins, J.A., Ehlmann, B.L., and Yin, A., 2015, Long-runout landslides and the long-lasting effects of early water activity on Mars: Geology, v. 43, p. 107–110, doi:10.1130/G36215.1.