151-163 EVIDENCE FOR WATER ON VESTA: COMPARING THE GEOMORPHOLOGY OF DEBRIS FLOWS IN CRATERS ON EARTH, MARS, THE MOON, AND VESTA. Dylan Daneman, Cheng "Steven" Huang, Audrey Mills, John Shaughnessy, Zyris Zacha, Holly Bensel (Mentor), Dr. Ryan Watkins (Advisor), St. Mary's School, 816 Black Oak Drive, Medford, Oregon, 97504

Background Work and Motivation: The protoplanet Vesta was previously believed to be predominately dry, lacking volatiles, and rich with basalts. However, using images from the Dawn mission, Dr. Jennifer Scully, et al. [1] published a paper in 2015 describing evidence of fluvial debris flows in multiple young Vestan craters. Based on data from Dawn, Vesta may have had brief flows of material mobilized by water on its surface.

Specific Question or Relationship: The focus of this study is the result of work done by Dr. Scully [1] in her 2015 paper, which presented the idea that Vesta had wet debris flows similar to those formed on Earth and Mars. Specifically, we wanted to address if Vestan debris flows exhibit morphologies with debris flows found on Earth and Mars that indicate the influence of a liquid as described by Dr. Scully.

General Topic: Debris flows occur on all of the inner solar system bodies, and are a geologic phenomenon in which rocky material flows downhill under the force of gravity. In accordance with an article written by Kokelaar [2], debris flows are divided into two categories: wet and dry. Wet flows contain volatiles and liquids that influence the mass wasting processes and deposits on planetary bodies, such as gullies on Mars. Volatiles and liquids are absent from dry flows, with the example of granular flows on the Moon. Dry flows are a type of mass wasting that results in dry, rocky material moving downhill. The focus of this research is the comparison of granular flows, rock falls, talus slopes, linear gullies, and flow melts. By definition in this project, wet flows involve liquid. The flow styles encountered in this study are alluvial fans, curvilinear gullies, pitted terrain, and braided streams.

Methods: The purpose of our research was to study debris flow geomorphologies on Earth, Mars, the Moon, and Vesta. On Earth, these features have been studied extensively and the mechanisms that form them are well-understood. The understanding of debris flows on Earth can be applied to other solar system bodies such as the Moon, Mars, and Vesta. Using image analysis tools including JMARS, Vesta Trek, Mars Trek, and LROC Quickmap, we observed different debris flow types in craters. After analysis, we compared these images to better understand the mechanism of their flow style, wet or dry. Once a crater was found using the aforementioned tools, the name and location were used to find higher resolution images on NASA's Photojournal [3] (cite).

Results: From our observations and comparisons of images from the Moon, Mars, Earth, and Vesta, we found that all four of these bodies share many similar styles of mass wasting. When we observed dry flows compared to wet flows, we noticed two main differences: texture and flow direction. Dry flows appear to have a rough texture due to unsorted material. Wet flows appear smoother as a result of liquid moving the materials. Dry flows also tend to move straight downhill whereas wet flows are curvilinear. Of particular interest, our analyses revealed that Vesta does have curvilinear valleys, pitted terrain, and alluvial fans; all of which point to the presence of a liquid that is at least transient in nature.

Conclusions: Based on our study of debris flow geomorphologies on Earth, Mars, the Moon, and Vesta, there is clear evidence that several Vestan craters contain debris flows formed in combination with a liquid. Our research supports Dr. Scully's [1] contention that there is "evidence that transient water flowed on the surface, in a debris-flow-like process, and left distinctive geomorphologic features."

Sources:

[1] Scully, J.E.C., et al. (2015) *Earth and Planetary Science Letters, Volume 411,* pages 151-163
[2] Kokelaar, B.P., et al. (2017*) Journal of Geophysical Research: Planets, Volume 122, Issue 9,* pages 1893-1925
[3] NASA Photojournal, https://photojournal.jpl.nasa.gov/

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Lunar quick maps JMARS
Vesta Trek Mars Trek
Dr. Scully's meeting with us and her conference lecture presentation
#2
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017JE005320
#1
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Nasa photojournal https://photojournal.jpl.nasa.gov/

Don't plagiarize this: Protoplanet Vesta, visited by NASA's Dawn spacecraft from 2011 to 2013, was once thought to be completely dry, incapable of retaining water because of the low temperatures and pressures at its surface. However, a new study shows evidence that Vesta may have had short-lived flows of water-mobilized material on its surface, based on data from Dawn.

Also this: Debris flows are geological phenomena in which water-laden masses of soil and fragmented rock rush down mountainsides, funnel into stream channels, entrain objects in their paths, and form thick, muddy deposits on valley floors. They generally have bulk densities comparable to those of rock avalanches and other types of landslides

Tis useful, but don't steal stuffs kids/ . Thank you for coming to my Ted Talk.
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Lunar avalanches only involve dry granular movement. Thus, this study benchmarks, in new detail, what flow processes and flow‐deposit morphologies occur in the absence of liquid and gas and without reworking due to them. More widely, granular avalanches are a key comparative planetary process and their deposits on planetary surfaces should be considered important targets for further study and future exploration to fully understand their sedimentological evolution and activation trigger(s). The presence or absence of atmospheres and their differing phases of surface volatiles may influence and yield contrasting mass‐wasting processes and deposits on other planetary bodies including Mars (i.e., "gullies" and recurring slope lineae) [Treiman, 2003; Barnouin‐Jha et al., 2005; Bart, 2007; McEwen et al., 2014; de Haas et al., 2015; Schmidt et al., 2017], Mercury [Brunetti et al., 2015], asteroid 4 Vesta [Otto et al., 2013; Krohn et al., 2014; Williams et al., 2014] and even comet 67P/Churyumov‐Gerasimenk [Pajola et al., 2017]. Additionally, the potential effect of extreme diurnal or other temperature variations on granular movement warrants consideration [e.g., Molaro and Byrne, 2012; Molaro et al., 2017].

Wet flow is the presence of volatiles nad liquids that may influence the mass wasting processes and deposits on planetary bodies, such as gullies on Mars.. Dry flow is the absence of volatiles or liquids such as granular flows on the Moon.

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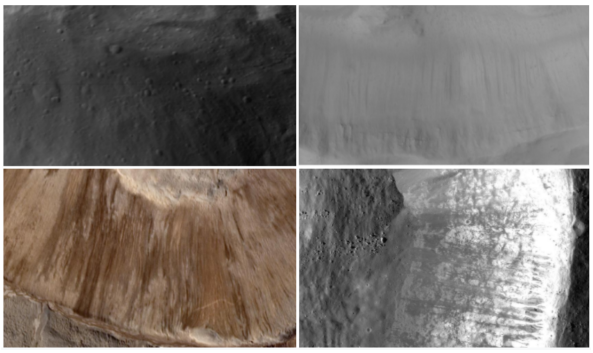

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