EPSC Abstracts
Vol. 11, EPSC2017-396, 2017
European Planetary Science Congress 2017

Landslides on Ceres Reveal Hidden Ice

B. E. Schmidt(1*), K. G. Hughson (2), H. T. Chilton(1), J. E. C. Scully(3), T. Platz(4), A. Nathues(4), H. Sizemore(5), M. T. Bland(6), S. Byrne(7), S. Marchi(8), D. P. O'Brien(5), N. Schorghofer(9), H. Hiesinger(10), R. Jaumann(11), J. Lawrence(1), D. Buczowski(5), J. C. Castillo-Rogez(3), M. V. Sykes(5), P. M. Schenk(12), M. C. DeSanctis(13), G. Mitri1(4), M. Formisano(13), J-Y Li(5), V. Reddy(5), L. LeCorre(5), C. T. Russell(2), C. A. Raymond(3) and the Dawn Science and Operations Teams. 1. Georgia Tech 2. UCLA 3. JPL 4. Max-Planck. 5.PSI. 6. USGS. 7. Univ. Arizona. 8. SWRI. 9. Univ. Hawaii. 10. Westfälische Wilhelms-Universität,. 11. DLR. 12. LPI. 13. INAF. 14. Universite de Nantes.

Abstract

We analyzed Dawn Framing Camera clear filter images of landslides on Ceres. Here we describe morphological evidence for an ice-rich substrate on Ceres based on both the geomorphology of landslide deposits and the characteristics of their failure scarps. Most of the results discussed here are reported in [1].

1. Introduction

Among the most compelling pre-Dawn questions about Ceres was in regards to the possibility of subsurface ice. Although unlikely on its surface, ice can last in Ceres' subsurface over billions of years if protected by an insulating layer; the necessary burial depth may be less than 1 m above ~40° latitude. We adopt the term "ground ice" to describe silicate material rich in ice, or silicate-covered ice deposits. The geomorphology of surface features can be related their material properties. In particular, landslides are found on planetary surfaces across the solar system, and are prevalent on ice rich bodies. On Ceres, these features have been observed associated with a surprising number of impact craters.

Across Ceres' surface there is evidence for mass wasting that operates in a very different manner from that on Vesta. Noted examples include scalloped and "breached" craters that are characterized by mass wasting by which recession of crater walls occurs in asymmetric patterns. Often contacts between craters are completely degraded, leaving behind lobate, or fan-shaped deposits.

2. Landslide Morphology

Arguably the most intriguing mass wasting features on Ceres manifest as flows with varying characteristics that originate at crater rims. In a survey of 20-35 km craters on Ceres (a good subset of features not strongly influenced by relaxation or secondary populations), a surprising number possess mass wasting features that extend 10's of km from their sources—over 20% contain such flows. The number of flows also varies with latitude, with a strong trend in the areal coverage of the surface by landslides that peaks above 60 degrees latitude. This poleward positive trend suggests that whatever is controlling the behavior of large mass wasting features on Ceres also varies with latitude. Thus, we consider ice as a likely culprit. Moreover, the style of mass wasting also changes over the surface of Ceres. We have identified three classes of flows that can be separated by their geomorphological characteristics. We refer to these as Type 1, 2, and 3

Type 1 flows are thick, tongue-shaped, lobate, and voluminous flows of up to hundreds of meters thick. Type 1 flows occur at a wide range of scales, from hundreds of meters to several kilometers long and tens to hundreds of meters thick. The always have one or more elongate trunks as wide as their source, often with longitudinal furrowing, with broad steep snouts and distal ramparts. Several high latitude craters feature long, thick flows that emanate from deep failures along degraded or slumping crater rims. In many of these cases, a small impact into the rim of a larger, older crater has destabilized material in and exterior to the crater rim. These flows may be consistent with downslope motion of relatively cohesive, ice-rich or ice-cemented material. Type 1 flows are only found above 50 degrees latitude.

Type 2 landslides are pervasive thinner (10's of m), spatulate, sheeted flows that initiate near crater rims at the exteriors of craters. The deposits of these features have circular to lobate toes, and from single broad or fan-shaped sheets to multiple sheets diverted by topography. Type 2 flows generally blanket lowgrade relief, but have impressive length despite their shallow slopes, characteristic of long run out landslides observed on other bodies such as Mars and Iapetus. The length and low slope angle of these flows suggests that friction reduction may help to explain these features, which requires ice but could also involve clays. Type 2 flows are found across the surface, though they are largely found above 30 degrees latitude, extending to 70 degrees. These are shallower features, perhaps restricted to forming within regolith.

Rare cases of cuspate, sheeted flows are observed extending outward from crater rims of extremely large impacts. In these features, thin broad sheets of smooth material terminate in layered sets of lobes or cusps. These flows are generally wider than the Type 2 flows and thinner than Type 1. Their acute lobes, absence of deep furrows, and textures--relatively smooth but occasionally hummocky—are similar to the morphology of fluidized ejecta blankets in Martian rampart craters and those on Ganymede that form by impacts into ice-rich ground. These flows may be consistent with melted material derived from the impact or post-impact melting. These are found in ~10% of craters below 50 degrees latitude and never at the poles.

3. Implications

Below, The geomorphology of Ceres' landslides is indicative of flow that occurs due to the presence of ice in the surface and shallow subsurface. These flow types are morphologically analogous to ice-rich flows found on Earth, Mars and the icy satellites. Importantly, no similar flow morphologies or fluidized materials were found on Vesta, which shares a comparable impact environment to Ceres. This indicates that the primary difference in impact response derives from target compositional differences. Material on Ceres appears weaker, more deformable, and flows more rapidly, than that on Vesta, which we interpret as evidence for ground ice. The increase in number of these flows towards the poles is evidence that Ceres' subsurface contains ground ice and that the ice is most abundant near the poles. Further, we characterize Type 1 and Type 2 as landslides, where Type 1 are relatively deeper failures, and Type 2 are shallower regolith-dominated features. Type 3 flows are most likely formed as either fluidized ejecta or by melting during the impaction.

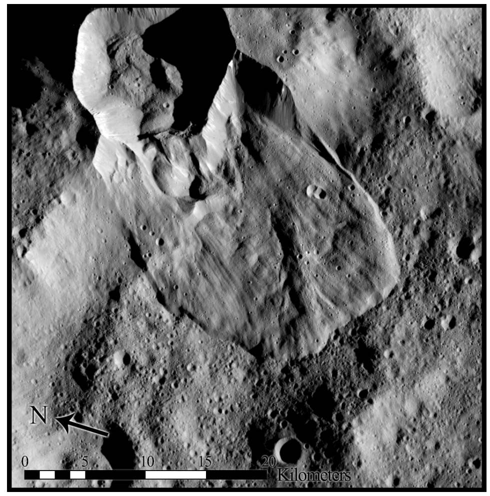

Figure 1: Type 1 landslide in Ghanan crater.

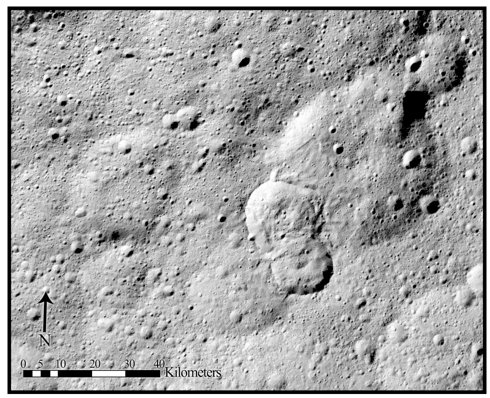

Figure 2: Type 2 landslide.

Acknowledgements

We acknowledge support from the Dawn mission, and the Framing Camera and mission operations team. Congratulations to Dawn on its 10th anniversary of launch!

References

[1] Schmidt, B. E. et al., (2017). Geomorphological evidence for ground ice on dwarf planet Ceres. Nature Geoscience 10, 383-343.