EPSC Abstracts
Vol. 8, EPSC2013-242-2, 2013
European Planetary Science Congress 2013

Curvilinear, Interconnecting Vestan Gullies as Evidence for Transient Water Flow

J. E. C. Scully (1), **C. T. Russell** (1), A. Yin (1), R. Jaumann (2), H. Y. McSween (3), C. A. Raymond (4), V. Reddy (5,6), L. Le Corre (5,7).

(1) Dept. of Earth and Space Sciences, University of California, Los Angeles, CA, USA (jscully@ucla.edu), (2) DLR, Berlin, Germany, (3) University of Tennessee, Knoxville, TN, USA, (4) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, (5) Max Planck Institute, Katlenburg-Lindau, Germany, (6) University of North Dakota, Grand Forks, ND, USA, (7) PSI, Tuscon, AZ USA.

Abstract

Although the howardite, eucrite and diogenite (HED) meteorites have been interpreted to indicate a dry vestan crust, there is meteorite evidence for hydration in some HEDs and remote sensing evidence for localized hydration on Vesta. However, until now there has been no direct evidence for vestan hydration. Our results show that the walls of craters with pitted floors contain elongated curvilinear gully networks, which appear to have transported liquid water during a transient flow. These flows could have been released by impact heating from ice-bearing deposits buried within the vestan crust.

1. Introduction

1.1 Vesta & Dawn

NASA's Dawn spacecraft and its three instruments, the Framing Camera (FC), Visible and Infrared Spectrometer (VIR) and Gamma Ray and Neutron Detector (GRaND), have collected imaging, compositional and geophysical data. Vesta is a differentiated asteroid with no atmosphere [1] and the parent body of the HED meteorites [e.g. 2,3,4].

1.2 Indications of vestan hydration

Vesta's igneous differentiation [1], and the belief that igneous rocks formed in a vacuum are mostly anhydrous [5], has been used to support the notion that the vestan crust is dry. However, several lines of evidence suggest at least local hydration. Carbonaceous chondrite (CC) material is found in howardites [e.g. 6] and Vesta's dark material is interpreted to be CC [e.g. 7,8]. VIR detected a widespread, heterogeneously distributed 2.8 μm OH absorption [9]. Hydrogen was found by GRaND to correspond to the broad locations of CC dark material [10]. Pitted terrain, observed in some craters, is interpreted to form by the degassing of volatile-bearing material induced by impact heating [11]. Quartz veinlets and other minerals found in eucrite meteorites are interpreted to be deposited from aqueous solution [12, 13]. Apatites with relatively high OH contents in some eucrites suggest the presence of water in magmas [14]. Finally, thermal modeling suggests that water ice could be stable within the top few meters of regolith [15].

2. Types of gullies

Two types of gullies are classified: linear (L-type) gullies in 48 craters and curvilinear (C-type) gullies in 11 craters [16].

2.1 Linear gullies

L-type gullies tend to originate in alcoves below spurs of more coherent material near the crater rims. These rather linear and straight gullies rarely intersect and are sub-parallel to one another. In some cases L-type gullies are bounded by diffuse levees and end in lobate talus deposits. Morphology of the L-type gullies is consistent with a dry granular flow origin [17], as are the lunar gullies [18].

2.2 Curvilinear gullies

Some C-type gullies originate at the base of steep cliffs on crater walls, whereas others appear to stem from talus on crater walls. Individual gullies are curvilinear and sinuous. C-type gullies frequently intersect to form subparallel to dendritic networks. There is an association between craters containing C-type gullies and craters containing pitted terrain. In some cases the C-type gullies end in lobate deposits, which are occasionally overlain by pitted terrain [17]. C-type gullies are morphologically reminiscent of gullies in Meteor Crater on Earth [19] and to Martian gullies [e.g. 20]. Presently, the general consensus is that some type of liquid water erosion formed the Martian gullies [21].

3. Quantification of morphology

C-type gullies have a larger length to width ratio than the L-type gullies. Also, L-type gullies have fewer intersections and smaller junction angles than C-type gullies. Additionally, plots of stream order number vs. stream frequency and stream order number vs. stream length are consistent with those of sapping channel networks on Earth [22]. An initial channel has a stream order number of 1. When two order 1 channels merge, the resulting channel has an order of 2. Following this method higher order channels can also be classified [22].

4. Formation mechanisms

4.1 Impact melt

In our interpretation, it is unlikely that impact melt formed either gully type because the anticipated impact melt volumes on Vesta are low [23, 24] and morphology of impact melt differs sharply to that of the gullies [25].

4.2 Dry granular flow

Morphology and network geometry of L-type, but not C-type, gullies are consistent with dry granular flow. However, no mechanism is found to explain a dry granular flow process forming the morphology and network geometry of C-type gullies [16].

4.3 Transient water flow

We propose that subsurface water ice deposits, possibly delivered by ice-rich bodies and buried in the regolith, are the source of the water that carves the C-type gullies. A subsequent impact heats the ice-bearing deposits, which releases a water flow that carves the C-type gullies. Since water is stable as a gas at vestan surface conditions, the liquid water will evaporate and be lost from Vesta’s surface. Thus, the flow will be transient. Calculation shows that the required water volume will take longer to evaporate than the time necessary to form the C gullies. Loss of this water contributes to pitted terrain formation on crater floors.

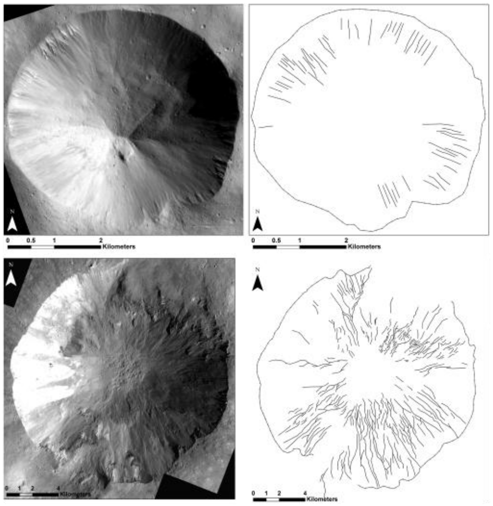

Figure 1: Unmapped (left) and mapped (right) images of L gullies in Fonteia crater (top) and of C gullies in Cornelia crater (bottom).

References

[1] Russell C. T. et al. (2012) Science, 366, 684.
[2] DeSanctis M. C. et al. (2012) Science, 336, 697.
[3] Prettyman T. H. et al. (2012) Science, 338, 242.
[4] McCord T. B. et al. (1970) Science, 168, 1445.
[5] Hasegawa S. et al. (2003) GRL, 30, 2123.
[6] Herrin J. S. et al. (2011) 42nd LPSC, 2806.
[7] Reddy V. et al. (2012) Icarus, 221, 544.
[8] McCord T. B. et al. (2012) Nature, 491, 83.
[9] DeSanctis M. C. et al. (2012) ApJL, 758, L36.
[10] Prettyman T. H. et al. (2011) Space Sci. Rev., 163, 371.
[11] Denevi B. W. (2012) Science, 338, 246.
[12] Treiman A. H. et al. (2004) EPSL, 219, 189.
[13] Warren P. H. et al. (2013) 44th LPSC, 2875.
[14] Sarafian A. R. et al. (2012) 43rd LPSC, 1175.
[15] Stubbs T. J. & Wang Y. (2012) Icarus, 217, 272.
[16] Scully J. E. C. et al. (2012) 45th AGU, P43E-03.
[17] Scully J. E. C. et al. (2013) 44th LPSC, 1578.
[18] Kumar P. S. et al. (2013) J. Geophys. Res. Planets, 118, 1.
[19] Kumar P. S. (2010) Icarus, 208, 608.
[20] Malin M. C. & Edgett K. S. (2000) Science, 288, 2330.
[21] Carr M. H. (2012) Phil. Trans. R. Soc. A, 370, 2193.
[22] Schumm S. A. et al. (1995) Geomorphology, 12, 281.
[23] Jaumann R. et al. (2012) Science, 336, 687.
[24] Schenk P. et al. (2012) Science, 336, 694.
[25] Scully J. E. C. et al. (2012) GSA, 152-12.