Vaduz, an unusual fresh crater on Mars: Evidence for impact into a recent ice-rich mantle

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[1] A fresh, 1.85 km diameter impact crater in the midlatitudes of Mars (38°N) named Vaduz exhibits distinctive crater-related geological subunits (facies) extending up to ~15 radii from the rim crest and perched >10 m above the adjacent plains. Knobby terrain fringing and underlying the facies is interpreted as degraded thermal contraction crack polygons, consistent with an ice-rich mantle buried by ejecta. The almost complete regional disappearance of this ice-rich unit, and consequent lowering of regional topography by over ten meters, is interpreted to mean that the ice-rich mantle was formed by climate-related deposition of snow, ice, and dust during recent periods of high obliquity. Transition to lower obliquity, and the attendant poleward retreat of the mantling unit, is the most likely cause of the regional loss of the ice-rich layer. The depth of this crater, relative to the thickness of the ice-rich unit, indicates that the impact event excavated bedrock and that Vaduz can be classified as an excess ejecta crater. Excavated silicate regolith and fragmented target debris appear to have been an important factor in the armoring mechanism. **Citation:** Schaefer, E. I., J. W. Head, and S. J. Kadish (2011), Vaduz, an unusual fresh crater on Mars: Evidence for impact into a recent ice-rich mantle, *Geophys. Res. Lett.*, *38*, L07201, doi:10.1029/2010GL046605.

1. Introduction

[2] Since ~5 Ma, high obliquity (spin axis inclination) excursions have produced multiple subtle ice ages, with stable ground ice [*Mellon and Jakosky*, 1995] and ice-rich deposits [*Head et al.*, 2003] extending to ~30°. In the most recent history, decrease in the amplitude of obliquity has caused surface and near-surface ice stability to migrate poleward to the high midlatitudes and poles [*Mellon and Jakosky*, 1995; *Head et al.*, 2003].

[3] At issue is whether the migration and emplacement of volatiles during recent ice ages has taken place solely by vapor diffusion and ice deposition into preexisting regolith pore space [*Mellon and Jakosky*, 1995] or whether there was also surface deposition of ice, snow, and dust to create mantling layers. For example, several workers have described evidence for a recent ice-rich, latitude-dependent mantle, meters to tens of meters thick, currently preserved under a sublimation lag [*Mustard et al.*, 2001; *Kreslavsky and Head*, 2002; *Head et al.*, 2003; *Schon et al.*, 2009].

[4] Impact craters on Mars show a wide variety of morphologies [*Barlow et al.*, 2000], and some appear to have excavated into ice-rich units. Two such types are pedestal craters (Pd) and excess ejecta craters (EEC); both are elevated above their surroundings, a configuration generally attributed to local preservation of an underlying ice-rich unit that has been regionally removed [e.g., *Barlow*, 2006; *Black and Stewart*, 2008; *Kadish et al.*, 2009]. Pedestal craters (Pd) generally occur in the center of a circular plateau (pedestal) that is typically tens to several hundreds of meters high; the margins of the pedestal extend well beyond the typical radial extent of the continuous ejecta deposit of the central crater [*Kadish et al.*, 2009]. The observed depth of a pedestal crater is typically less than the height of the pedestal [*Kadish et al.*, 2009]. Excess ejecta craters (EEC) are characterized by a crater that excavates through the ice-rich substrate into the subjacent regolith and bedrock and deposits ejecta on the surroundings; the ejecta becomes perched after regional removal of the ice-rich substrate [*Black and Stewart*, 2008]. The armoring mechanism involved in Pd and EEC is debated [see *Kadish et al.*, 2009].

[5] In this analysis, we document a very fresh midlatitude impact crater (Figure 1), Vaduz, characterized by distinctive and extensive crater-related geological subunits (facies) that are perched over ten meters above adjacent plains on a substrate with a knobby surface texture. Together, these deposits provide insight into the nature, distribution, and timing of ice-rich mantles and the mechanisms for armoring and preserving these mantles during recent climatic history.

2. Crater Characterization

[6] Located at ~38.2°N, 15.8°E, just west of Mamers Valles near the dichotomy boundary, Vaduz is a 1.85 km diameter crater characterized by a number of distinctive facies (Figure 1) and is extremely fresh, with very few superposed impact craters; there is also no evidence of related secondary craters out to a search distance of ~40 R (radii from the rim crest). The crater has minimal infilling, and the rim crest is sharp.

[7] Six geomorphic units are associated with Vaduz and overlie the background Hesperian ridged plains (Hr) [*Skinner et al.*, 2006] (Figure 1). From the center outward, these are *crater interior* (CI), *crater rim* (CR), *lobate facies* (LF), *smooth facies* (SF), *radial facies* (RF), and *knobby terrain* (KT). We use "crater facies" to denote the *lobate*, *smooth*, and *radial facies* collectively.

[8] The outer margins of the *lobate* and *smooth facies* have lobateness values (Γ = (outer perimeter) / $[4\pi \text{ (area)}]^{1/2}$) of 1.24 and 2.61, respectively. This differs from pedestal craters, which are generally very circular, having an average Γ

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