Icarus 213 (2011) 443–450

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Preservation of layered paleodeposits in high-latitude pedestal craters on Mars

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ARTICLE INFO

Article history:
Received 3 November 2010
Revised 18 February 2011
Accepted 28 March 2011
Available online 7 April 2011

Keywords:
Mars, Polar geology
Mars, Climate
Cratering
Ices

ABSTRACT

An outstanding question in Mars' climate history is whether or not pedestal craters represent the armored remnants of ice-rich paleodeposits. We address this question using new high-resolution images; in a survey of several hundred high-latitude pedestal craters, we have identified 12 examples in which visible and/or topographically expressed layers are exposed on the marginal scarp of the pedestal. One example, located on the south polar layered deposits, preserves ice-rich layers that have otherwise been completely removed from the polar cap. These observations provide empirical evidence that the pedestal crater formation mechanism is capable of armoring and preserving ice-rich layered paleodeposits. Although layered exposures have not yet been observed in mid-latitude pedestal craters, high-latitude instances of discontinuous, partially covered layers suggest that layers can be readily concealed, likely through mantling and/or mass wasting processes along the marginal scarp. This interpretation is supported by the observation that high-latitude pedestals with exposed layers along their margins are, on average, taller than mid-latitude examples, and have larger, steeper marginal scarps, which may help to maintain layer exposures. These observations favor the interpretation that mid- to high-latitude pedestal craters represent the armored remnants of ice- and dust-rich paleodeposits, which occurred transiently due to changes in the climate regime. Preservation of fine-scale layering of ice and dust at these latitudes implies that the climate change did not involve regional melting conditions.

1. Introduction

Pedestal craters (Pd) on Mars were first identified almost 40 years ago in Mariner 9 data (McCauley, 1973), and have since been classified as an impact morphology characterized by a crater perched near the center of a plateau, surrounded by a scarp (Arvidson et al., 1976; Barlow et al., 2000). Early studies implicated a formation mechanism based on armoring of fine-grained target material during an impact event, followed by preferential eolian deflation of the non-armored intercrater terrain (McCauley, 1973; Arvidson et al., 1976), yielding pedestals surrounded by marginal scarps. Our recent analyses, however, offer evidence that the target material from which Pd form contains a significant fraction of ice (Kadish et al., 2008, 2009, 2010). These studies highlight the latitude-dependent (poleward of ~35°) distribution of Pd (Kadish et al., 2009; Mouginis-Mark, 1979), indicating a climate-related formation mechanism, as well as key physical attributes including sublimation pits in the marginal scarps of some Pd (Kadish et al., 2008). The resulting sublimation model for Pd formation posits that impacts occur into ice-rich targets during periods of higher obliquity, when mid to high latitudes were covered by thick deposits of snow and ice (Head et al., 2003; Levrard et al., 2004). The impact armors the proximal surface of the ice-rich deposit. During return to lower obliquity, the deposit sublimates, lowering the elevation of the intercrater terrain. Beneath the armored cover around the crater, however, the ice-rich deposit is preserved, yielding a pedestal. For a more detailed description of this model, see Kadish et al. (2009).

Climate models (e.g. Madeleine et al., 2009) have shown that ice-rich material can gradually accumulate (~10–20 mm/year) at mid to high latitudes under certain atmospheric and orbital/obliquity conditions. Madeleine et al. (2009) specifically identify the need for a relatively high dust opacity in order to form such deposits, which accumulate episodically on both short timescales, due to seasonal effects, and longer timescales, due to obliquity cycles. These types of deposits are similar to, but thicker than, the latitude-dependent mantle described by Mustard et al. (2001) and Head et al. (2003), and can lead to glaciation in parts of the midlatitudes (Head et al., 2010). Given the episodicity in accumulation, one might predict deposition of layers of dust and ice, similar to those observed in the polar layered deposits (e.g. Milkovich and Head, 2005; Plaut et al., 1988, 2007) and in more widespread latitude-dependent mantles (e.g. Head et al., 2003; Schon et al., 2009). If Pd formed from armoring of these ice- and dust-rich paleodeposits, which were subsequently removed from the intercrater plains during periods of climate change, then fresh exposures of the margins of the pedestals should reveal evidence of such layering. Here, we provide new evidence for the presence of such layers as identified through our analysis of high-latitude Pd (poleward of 65°) in

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0019-1035/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.icarus.2011.03.029