Icarus 208 (2010) 86–100

Contents lists available at ScienceDirect

Icarus

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

Supraglacial and proglacial valleys on Amazonian Mars

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ARTICLE INFO

Article history:
Received 21 September 2009
Revised 24 February 2010
Accepted 28 February 2010
Available online 11 March 2010

Keywords:
Mars
Mars, surface
Mars, climate
Geological processes

ABSTRACT

Abundant evidence exists for glaciation being an important geomorphic process in the mid-latitude regions of both hemispheres of Mars, as well as in specific environments at near-equatorial latitudes, such as along the western flanks of the major Tharsis volcanoes. Detailed analyses of glacial landforms (lobate-debris aprons, lineated valley fill, concentric crater fill, viscous flow features) have suggested that this glaciation was predominantly cold-based. This is consistent with the view that the Amazonian has been continuously cold and dry, similar to conditions today. We present new data based on a survey of images from the Context Camera (CTX) on the Mars Reconnaissance Orbiter that some of these glaciers experienced limited surface melting, leading to the formation of small glaciofluvial valleys. Some of these valleys show evidence for proglacial erosion (eroding the region immediately in front of or adjacent to a glacier), while others are supraglacial (eroding a glacier's surface). These valleys formed during the Amazonian, consistent with the inferred timing of glacial features based on both crater counts and stratigraphic constraints. The small scale of the features interpreted to be of glaciofluvial origin hindered earlier recognition, although their scale is similar to glaciofluvial counterparts on Earth. These valleys appear qualitatively different from valley networks formed in the Noachian, which can be much longer and often formed integrated networks and large lakes. The valleys we describe here are also morphologically distinct from gullies, which are very recent fluvial landforms formed during the last several million years and on much steeper slopes (~20–30° for gullies versus ≪10° for the valleys we describe). These small valleys represent a distinct class of fluvial features on the surface of Mars (glaciofluvial); their presence shows that the hydrology of Amazonian Mars is more diverse than previously thought.

1. Introduction

Valleys resulting from water erosion provide critical clues to the distribution, abundance and state of H_2O throughout the history of Mars, and insight into martian climate history (Carr, 1996). Although early in Mars history, the climate may have been "warm and wet" (e.g., Craddock and Howard, 2002), the Amazonian climate appears to have been cold and hyperarid throughout, comparable in many ways to certain microclimate zones in the Antarctic Dry Valleys (Marchant and Head, 2007). During the Amazonian, observations and modeling suggest that water on the surface and in the near-subsurface has mainly been exchanged between major reservoirs at the polar caps, the regolith, and extensive glacial deposits at low-to-mid-latitudes (Forget et al., 2006; Madeleine et al., 2009).

In this paper, we review some of the morphologic evidence for cold-based glaciation at low-to-mid-latitudes on Mars and then introduce new evidence that calls for localized erosion from supraglacial and proglacial meltwater (Fig. 1). As an introduction, we begin with a brief overview of supraglacial meltwater streams and landforms on Earth. We refer to the erosional features as 'valleys' on Mars, instead of 'channels' as might be more typical on Earth, because of uncertainty that the features ever experienced bankfull conditions and the lack of observable channel bedforms (Mars Channel Working Group, 1983; see also Carrivick and Russell, 2006).

1.1. Surface melting of terrestrial cold-based glaciers and applications to Mars

Relative to meltwater production in association with wet-based glaciers, surface melting of cold-based glacier ice is minimal due to the very low ice temperatures and low sensible heat available for melting (e.g., Knighton, 1981; Fountain et al., 1998; Dyke, 1993; Skidmore and Sharp, 1999; Atkins and Dickinson, 2007; Swanger et al., 2010). Under optimal conditions, small amounts of seasonal melting may arise from preferred insolation geometries (e.g., Fountain et al., 1998) and from melting alongside solar-heated debris on the surface of otherwise relatively clean, cold-based glacier ice

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0019-1035/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.icarus.2010.02.021