Planetary and Space Science 72 (2012) 44–52

Contents lists available at SciVerse ScienceDirect

Planetary and Space Science

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

A possible synoptic source of water for alluvial fan formation in southern Margaritifer Terra, Mars

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ARTICLE INFO

Article history:
Received 10 February 2012
Received in revised form
10 May 2012
Accepted 29 May 2012
Available online 7 June 2012

Keywords:
Mars
Alluvial fan
Margaritifer Terra
Precipitation
Mars Science Laboratory (MSL) rover
Climate

ABSTRACT

The morphometry and occurrence of crater-bound fans in southern Margaritifer Terra that were active from around the Hesperian–Amazonian boundary into the Early Amazonian is consistent with emplacement related to synoptic precipitation. Precipitation, possibly occurring as snow, may have been locally influenced by topography and (or) orbital variations. It is not known how much of the total sediment inventory in the fans relates to this late activity versus possible earlier events where water may have been available from alternate sources such as impact-related melting of ground ice. Winds may have concentrated late occurring precipitation into existing relief and (or) preexisting alcoves that facilitated physical weathering to produce fine sediments later incorporated into fans. Two of the craters containing fan deposits, Holden and Eberswalde, were finalists for the MSL landing site. Results suggest that exposed and accessible fan sediments at both crater sites may record a late period of colder, drier conditions relative to early Mars that was punctuated by ephemeral water-driven activity.

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1. Introduction

Alluvial deposits within impact craters on Mars have been studied to characterize the amount and style of runoff responsible for their formation and to constrain the climate in which they formed (Cabrol and Grin, 2001; Crumpler and Tanaka, 2003; Malin and Edgett, 2003; Moore et al., 2003; Irwin et al., 2005a; Moore and Howard, 2005; Weitz et al., 2006; Kraal et al., 2008; Grant and Wilson, 2011; Williams et al., 2011). Alluvial deposits on Mars are scattered across much of the cratered highlands (Irwin et al., 2005a; Di Achille and Hynek, 2010; Wilson et al., 2012), with apparent concentrations in southern Margaritifer Terra, southwestern Terra Sabaea, and southwestern Tyrrhena Terra (Moore and Howard, 2005).

Previous studies of intracrater alluvial fan deposits (e.g., Moore and Howard, 2005; Kraal et al., 2008) relied mostly on analyses of visible (VIS) and infrared (IR) images from the Thermal Emission Imaging System (THEMIS Christensen et al., 2004). With the increasing coverage of high resolution data from the High Resolution Imaging Science Experiment (HiRISE, McEwen et al., 2007a) and Context Camera (CTX, Malin et al., 2007) instruments on the Mars Reconnaissance Orbiter, however, it is possible to reevaluate the distribution, morphometry and setting of the deposits. These higher resolution data (~0.25–0.50 m pixel scale for HiRISE and 6 m pixel scale for CTX) were used to establish that fan surfaces in southern Margaritifer Terra were deposited near the Hesperian–Amazonian boundary or during the early Amazonian (Grant and Wilson, 2011) and enables more confident definition of relatively smaller-scale characteristics related to sources of runoff responsible for their emplacement.

This study explores relationships between the fans and their host craters in the context of the previously described distribution and age of the alluvial fans in the southern Margaritifer Terra region of Mars (Grant and Wilson, 2011) to understand the sources of water and climate enabling their formation.

2. Fan morphometry and characteristics of host craters

The study area in southern Margaritifer Terra extends from 20°S to 35°S between 320°E and 340°E (Fig. 1). Table 1 summarizes morphometry for craters with and without fans in the study area and while there are no clear trends in occurrence that can be used to uniquely characterize craters with fans, there are some intriguing attributes that may provide insight into their distribution. Some caution must by employed in interpretation of these data, however, because the observed distribution of crater-bearing fans may not reflect the entire regional population if some fans are masked by later mantling deposits (Grant and Wilson, 2011).

With these caveats in mind, all of the alluvial deposits occur at the downstream terminus of source valleys, most of which head

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0032-0633/$ - see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.pss.2012.05.020

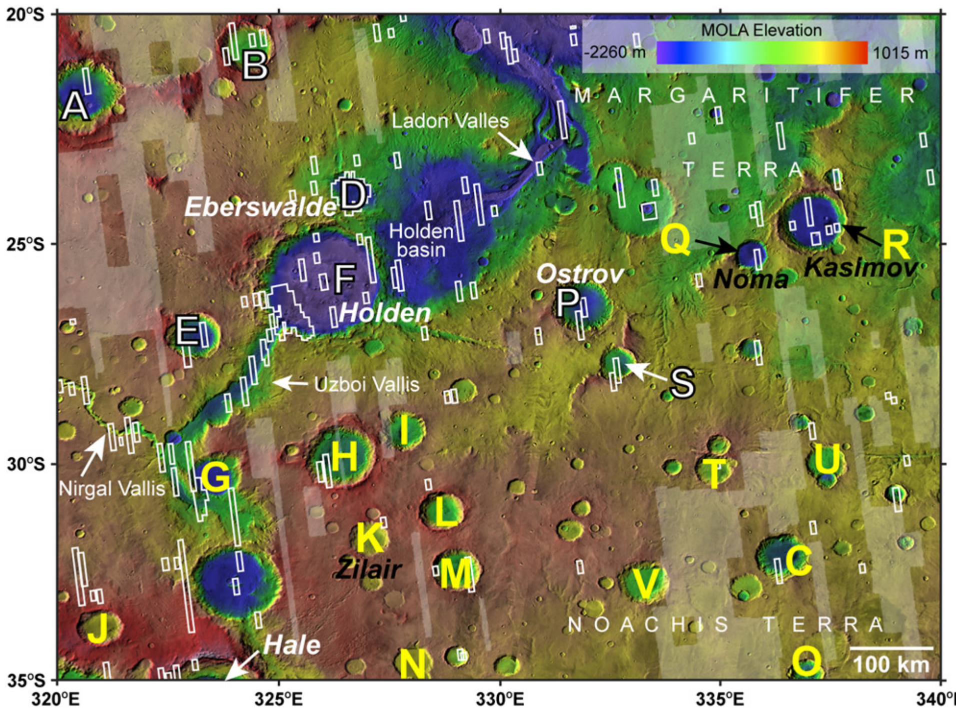

Fig. 1. Study area in southern Margaritifer Terra with place names discussed in text (modified from Grant and Wilson, 2011). Craters > 50 km in diameter with labels were included in the study; white and yellow labels indicate craters with and without fans, respectively (see Table 1). MOLA topography over subset of THEMIS global daytime IR mosaic. Shaded white indicates gaps in CTX coverage (as of 1/2012) and white boxes are HiRISE footprints (as of 1/2012).

Table 1
Characteristics of deposits identified within craters included in this study. Craters A through V correspond to labels in Fig. 1. Minimum elevation (Min. Elev.) is relative to MOLA datum. Crater depth for craters without fans is the difference between the average rim elevation around the crater and the lowest elevation of the crater floor. For craters with fans, the crater depth is the difference between the height of the rim(s) adjacent to the best-preserved fans and the lowest elevation of the crater floor. Interpreted playa surfaces are characterized by scabby, light toned deposits (LTD) that are typically higher in thermal inertia and occur on the crater floors. They are often somewhat circular in plan view and are located at the terminus of fluvial channels or fans.

Label (Fig. 1)	Crater Name	Lat. (°S)	Lon. (°E)	Diam. (km)	Min. Elev. (m)	Crater depth (m)	Location of fans	Nature of crater floor
A	None	21.8	320.6	99	–1800	3250	N (best), E, S, W	Playa (?), LTD, fans, central peak, landslide
B	None	20.65	324.28	69	–680	2810	N (best), S	Playa, LTD, fans
D	Eberswalde	23.76	326.7	65.3	–1500	1060	W (best), N, SW[a]	LTD, deltas
E	None	27.2	323.1	64	–1400	2405	N, E, W	Playa, LTD, fans, landslide
F	Holden	26.14	326	154	–2370	3233	N, S, W	Playa (?), LTD, fans
P	Ostrov	26.54	331.8	73	–1532	2059	N, S, E, W	Playa (?), fans, central peak
S	None	27.8	332.6	43	–1117	1678	N, E, S (best), W	LTD, fans
C	None	32.2	336.4	72	–1217	1651	None	Channels, playa (?) LTD, filled/mantled
G	None	30.4	323.55	58	–1500	2078	None	LTD, filled/mantled
H	None	29.9	326.4	80	–1072	2435	None	Playa (?), LTD, filled/mantled
I	None	29.4	327.9	55	–1052	1947	None	LTD, filled/mantled
J	None	33.8	321	50	–6	1497	None	Filled/mantled
K	Zilair	31.8	327	48	–228	1264	None	Filled/mantled
L	None	31.2	328.7	49	–919	2182	None	Filled/mantled
M	None	32.5	329	57	–880	1943	None	Filled/mantled
N	None	34.6	328	57	–23	834	None	Filled/mantled
O	None	34.8	336.9	38	–1164	1585	None	Channels, filled/mantled
Q	Noma	25.4	335.6	42	–1733	1695	None	Playa (?), LTD, channels, mantled
R	Kasimov	24.9	337.1	91	–1629	1975	None	Playa, LTD, channels, mantled
T	None	30.2	334.8	49	–448	1208	None	Channels, LTD, filled/mantled
U	None	30	337.4	47	–796	980	None	Filled/mantled
V	None	32.7	333.3	59	–759	1672	None	Channels, LTD, filled/mantled

[a] Largest fan delta on western side of the crater, smaller deposits elsewhere (see Rice et al., 2011).

in well-developed alcoves eroded into bounding crater walls. Valleys sourcing deposits in Eberswalde crater are the exception as they drain a basin extending well beyond the rim of the bounding crater, eroding into the continuous ejecta deposit associated with Holden crater (e.g., Pondrelli et al., 2008). Based on comparison to terrestrial fans (e.g., Ritter et al., 1995) the deposits (hereafter called "fans") vary in form, ranging from accumulations apparently emplaced subaerially or into only ephemeral or shallow standing water (Fig. 2) to those appearing steep fronted and more akin to fan deltas emplaced into deeper standing water (e.g., Eberswalde crater, Pondrelli et al., 2008). In most instances, the transition between fans to any inferred distal