A SYNOPTIC SOURCE OF WATER FOR LATE ALLUVIAL FAN ACTIVITY IN SOUTHERN MARGARITIFER TERRA, MARS?

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Introduction: Alluvial deposits on Mars provide an important record of the environmental conditions enabling their formation [1-10]. A recent study of alluvial fans within large craters in southern Margaritifer Terra [10] using crater statistics coupled with regional stratigraphic context showed that deposition of exposed surfaces occurred relatively late in Martian history, within the latest Hesperian or well into the early Amazonian. These fans (Figure 1) typically display well developed alcoves and incised walls, and fan surfaces preserve distributary channels standing ~10-15 m in relief (via inversion of topography) [5, 8, 10]. Deposits within Holden and Eberswalde craters, included in the analysis, were considered as final candidate landing sites for the Mars Science Laboratory [11]. Hence, understanding whether the source of water associated with fan development is related to local impact events [e.g., 12-15] versus synoptic climatic events [e.g., 10, 16] has implications for the nature of late water activity and potential habitability of Mars.

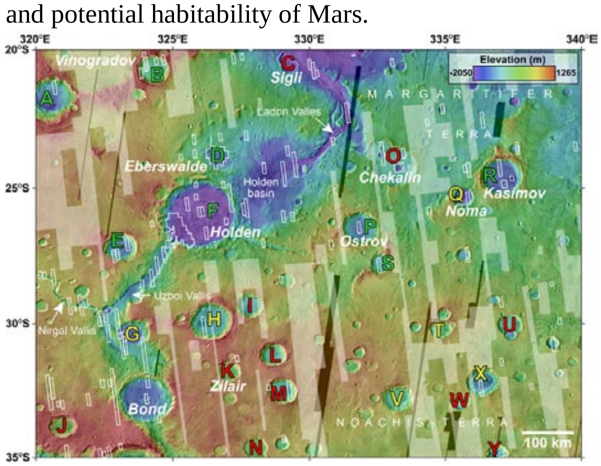

Figure 1. Craters >50 km across in southern Margaritifer Terra containing alluvial fans (green labels), older and possibly water-lain floor deposits (yellow labels), or other mantling deposits (red labels). See [10] for more details. MOLA over THEMIS daytime IR. Shaded white and black indicate gaps in CTX and THEMIS coverage, respectively. White boxes are HiRISE footprints. North is up.

Possible Impact-Related Water Sources: Various studies [e.g., 12-15] have suggested that water released during and after crater formation combined with heat generated by the associated impact may be sufficient to cause runoff within and around newly formed craters, thereby incising valleys and contributing to the formation of fluvial and alluvial landforms. Such local sources of water could contribute to valley and fan formation without requiring broader scale changes in climate relatively late in Martian history.

Valleys incised into the ejecta surrounding nearby Hale crater (35.7S, 323.6E) were interpreted as an examples of such local activity [13]. Because the impact responsible for Hale crater likely formed in the Amazonian or near the Hesperian-Amazonian boundary, its formation may overlap with nearby fan formation and represents one possible mechanism for triggering fan development [e.g. 12, 13]. Hale does not appear responsible for the alluvial fans, however, because: most associated valleys appear confined to the ejecta, whereas some alluvial fans are in craters 700-800 km away; craters containing fans occur at a range of azimuths from Hale and may not be consistent with downwind transport of volatiles under prevailing winds [e.g., 14]; and many craters bearing older floor deposits and mantling deposits are closer to Hale than those containing fans [10] (Figure 1).

The impact forming Holden crater, dating to the middle-to-late Hesperian [17], is another potential local source of water and heat that may have triggered fan formation. However, like at Hale, craters bearing alluvial fans occur up to hundreds of km away from Holden and are found at a range of azimuths (though there is a general paucity of fan-bearing craters south of Holden). Some valleys incising the ejecta around Holden source the Eberswalde delta complex [15], but estimates of the range in expected discharge from these valleys may be difficult to reconcile with the emplacement of the delta [18] and many of the mapped fan deposits are unrelated to these valleys or Holden's ejecta. While some alluvial deposition nearby (e.g., in Eberswalde) and within Holden could be related to the Holden impact [14, 15], there is additional evidence from the rim and fans around Holden that there was a gap in time between the Holden impact and when exposed fan materials were emplaced.

At least six degraded craters on the relatively high relief rim of Holden (Fig. 2A) suggest a gap in time between the Holden impact and latest fan activity. In addition, fans flanking the north, southwest, and south walls of Holden record evidence for multiple periods of formation, thereby suggesting any activity driven by crater formation was followed by an even later period of fan emplacement (Figs. 2B-D). Finally, the surfaces of most fans found over a broad area in southern Margaritifer Terra (Fig.1) all appear to be about the same age [10], dating to the latest Hesperian at most and likely post-date the Holden impact [17].

Possible Synoptic Water Sources: A latest Hesperian or Amazonian emplacement age for the surface materials in such widely distributed fans likely requires precipitation (rain or snow [5, 16]) relatively late in Martian history, after most precipitation-driven fluvial activity ended [e.g., 5, 19, 20]. Late intervals of water-driven erosion on Mars have been suggested [e.g., 20, 22-25] and a possible source of water includes precipitation derived from redistribution of outflow channel discharge [e.g., 22, 24, 26] into the highlands [27]. Hence, the alluvial fans may record a period of late, widespread water-driven degradation, perhaps accentuated by volcanic activity, topography, and/or orbital variations, and possibly enabled at least locally habitable conditions relatively late in Martian history.

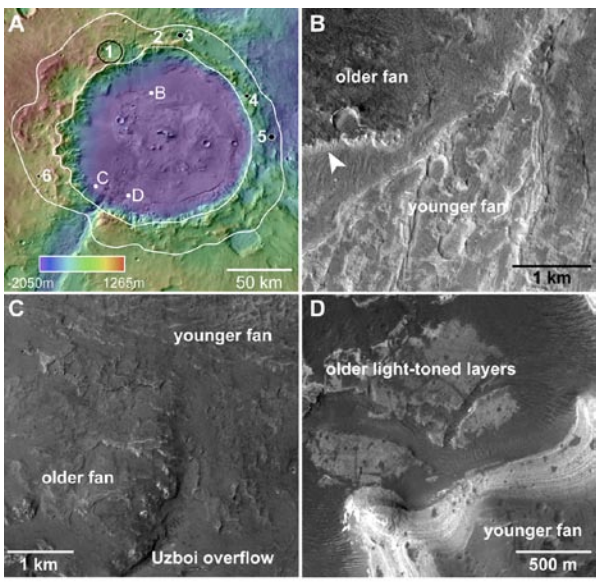

Figure 2. A) Holden crater with approximate extent of high-relief rim indicated by solid white lines (~ 18,000 km^2). At least six craters on the rim of Holden are degraded, suggesting a significant gap in time after the Holden impact to allow these craters to accumulate before being modified by fluvial activity. Diameters of degraded craters: crater 1 (19.3km); crater 2 (1.6 km); crater 3 (5 km); crater 4 (3.9 km); crater 5 (5.4 km) and crater 6 (2.7 km). MOLA topography over subset of THEMIS daytime IR global mosaic. Locations B, C and D show additional morphological evidence for multiple epochs of fan formation. (B) Arrow head indicates crater wall excavated into older fan that was later filled by younger alluvium. Subset of HiRISE image ESP_012676_1545. (C) Older fan materials are cut by Uzboi overflow channel and later filled by younger fan sediments (top). Subset of HiRISE image ESP_019889_1530. (D) Light-toned layered deposits on the floor of Holden were cut by fractures before later burial by younger fan deposits. Subset of HiRISE image PSP_003077_1530.

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