THE ALLUVIAL FAN COMPLEX IN HOLDEN CRATER: IMPLICATIONS FOR THE ENVIRONMENT OF EARLY MARS. R. P. Irwin III[1], J. A. Grant[1], and A. D. Howard[2], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, 6th St. at Independence Ave SW, Washington DC 20013-7012, irwinr@si.edu, grantj@si.edu. [2]Department of Environmental Sciences, University of Virginia, P.O. Box 400123, Charlottesville VA 22904-4123, alanh@virginia.edu.

Introduction: Quantitative studies of large alluvial fans [1] and likely deltas [2–5], which were recently discovered in a subset of Martian impact craters, have yielded important contraints on the paleohydrology of early Mars [3,6]. Large alluvial fans are regionally clustered between 18° and 29°S, primarily in Late Noachian impact craters that maintain most of their original relief. Erosion of deep alcoves into the interior walls provided sediment to the fans and left irregular, embayed crater rims [1]. In contrast, most Noachian degraded craters transition abruptly from a gullied inner wall to a thick, low-relief floor deposit that contains no cone-shaped fans [7]; the rim maintained its circular form as the crater widened.

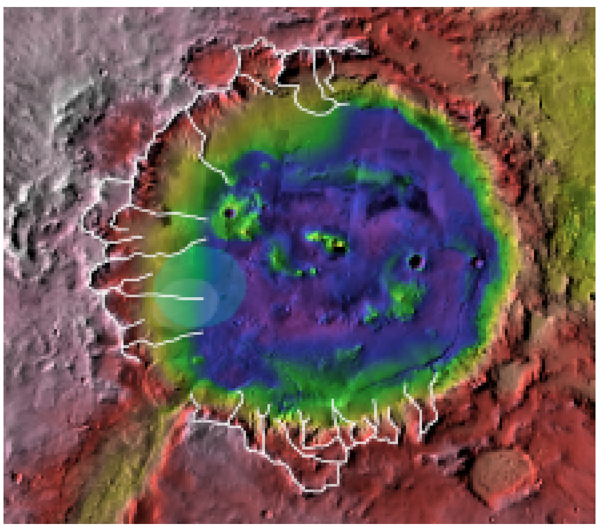

Fig. 1. Holden crater. White lines are divides between major alcoves and fans. Proposed MSL landing ellipses are shaded blue in west. Elevations given in text.

The alluvial fan complex in Holden crater (26°S, 34°W, 155 km diameter, Fig. 1) is the largest of these deposits recognized to date [1]. Its morphology provides insight to the local to regional paleoenvironment and potential past habitability in SW Margaritifer Sinus, where fluvial landforms are unusually well developed and/or preserved. The Late Noachian Holden crater interrupted the segmented Uzboi-Ladon-Margaritifer Valles system and excavated deposits from a larger, Early Noachian impact basin [8,9]. The crater contains at least a 150-m sequence of light-toned, layered deposits (LTLDs) that have laterally extensive beds of submeter thickness and high phyllosilicate abundance. Interleaved with and capping the sequence are alluvial fans derived from the crater wall (Fig. 2) and a late-stage flood deposit as water impounded in Uzboi Vallis (possibly derived from Nirgal Vallis) breached the rim and flooded the crater floor [9,10].

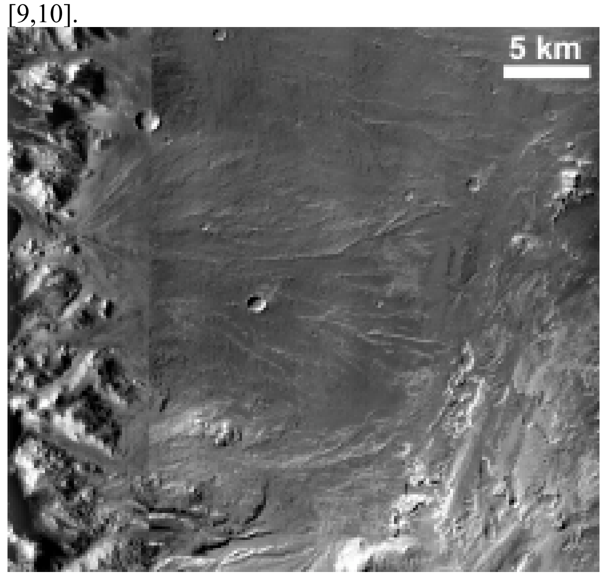

Fig. 2. Distributaries in SW Holden. LTLD outcrops in pits to the lower right, and Uzboi channels enter from the south. MRO context T01_000861_1531.

Observations:

Occurrence. Alluvial fans are concentrated along the high (~500–1000 m elevation) western rim of Holden crater, where they coalesced into a bajada >120 km long [1] (Fig. 1). Large fans are discontinuous along the lower (~0–500 m) southern rim and largely absent on the low-relief (~–1000–0 m) eastern rim [1]. Slopes of ~2.5–3 km relief above the crater floor (at ~–2200 m) were most favorable for fan development, which was inhibited where relief was ~1.5–2.5 km.

Complexity. The alluvial fans display relatively simple topographic profiles with little evidence of fan segmentation, although shallow trenches are observed in several fan heads. Negative-relief channels extending from a fan head to its toe are observed only along the eastern periphery of the bajada (both its northern and southern ends), where headward extension of source alcoves captured drainage from outside the crater rim, or where water from Uzboi Vallis overtopped the rim. The few contributing surfaces outside the crater rim are sparsely dissected, suggesting that most of the sediment was derived from the alcoves.

Alcove morphology. The source alcoves are highly variable in width and depth. Some are incised up to 10 km headward into and ~1 km below the rim. The deeper alcoves are near the highest areas of the crater rim and appear to favor irregularities in topography and structure. The alcoves are among the most densely dissected surfaces on Mars, with valley density up to 0.5–0.7 km/km^2 in the longer alcoves. Alcove slopes reflect combined mass wasting and fluvial incision.

Distributary channels. Most fans exhibit positive-relief distributary channels that presumably reflect the last major intervals of flooding on the fan surface, followed by aeolian deflation. Some individual distributaries can be traced up to 20 km downslope (Fig. 2). Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) imaging shows some inverted paleochannels with small concentrations of meter-scale boulders similar to those on the nearby Ebwerswalde delta [11], although most of the exposed channel surfaces show no rocks at full resolution (27 cm/pixel), and interchannel surfaces are composed primarily of sand. One of the larger alcoves in the SW quarter of the crater has a prominent fan-head trench and inverted paleochannels that are ~100 m wide despite the small contributing area of ~150 km^2. Using the continuity and Darcy-Weisbach relationships with gravity = 3.72 m/s^2, slope = 2°, and friction = 0.1, floods of ~1.5 m depth in these channels (barely enough to submerge the largest boulders transported) would require flash floods of ~600 m^3/s equivalent to ~1 cm/hr of runoff from contributing surfaces. The method used by [6] gives a similar result.

Base-level control. Fans along the northwestern wall of Holden crater (~320–360° azimuth from the center) have steep frontal scarps that likely reflect either basal erosion or depositonal base-level control, as tectonic scarps are expected to be straighter. The toes of these fans stand at ~–1850 m, and a lower bench projects from the central part of the scarp at –2000 m. Some small fans along the southern rim have toes at –1850 m, whereas the highest LTLD outcrops occur at –2000 m along the southern rim. A prominent fan along the southern wall has a frontal scarp, above which the toe occurs at –2160 m.

The frontal scarps of fans may indicate past lake levels but are interpreted conservatively. LTLDs are exposed in the frontal scarp of the largest southern fan, suggesting that the scarp may represent deflation of LTLDs inward of the armoring alluvial gravels rather than base level control from a lake at –2160 m [4]. It is also unclear why the frontal scarp of the northwestern fans was not deeply dissected with falling lake level, because most other fans prograded to the crater floor at variable elevations of –2000 to 2250 m without developing a frontal scarp. The proximity of fans with and without frontal scarps argues against late-stage basal erosion of fan toes. One fan, which has the largest source alcove and lowest gradient (1.5°) of any in the crater, crossed this scarp and prograded onto the crater floor at –2150 to –2250 m elevation.

Implications for Paleoenvironment: Restriction of LTLDs below –2000 m suggests that a paleolake fell from that level (fans with frontal scarps may suggest earlier levels as high as –1850 m, but with less confidence) to shallow conditions before the Uzboi entrance breach developed and temporarily recharged the lake [10]. Development of alcoves required kilometers of precipitation over time with occasional higher-magnitude events to transport boulders. No evidence for debris flows or catastrophic flooding (by terrestrial standards) is observed [1], however. A positive influence of slope and topography on runoff production is suggested. Despite this capacity to erode, the lack of dissection on most fan surfaces suggests that sediment production in the alcoves remained high relative to transport capacity, up to the permanent transition to dry conditions around the Noachian/Hesperian (N/H) transition. The development of inverted paleochannels by aeolian deflation of interdistributary fines suggest that much of the sediment load was fine-grained, requiring an effective but unknown weathering process in the alcoves. Channel continuity attests to the lack of later fluvial erosion of the fan surface [1], which creates discontinuous inverted channels on Earth. In contrast, the Pleistocene/Holocene transition from cool, humid to warm, arid conditions in Nevada led to reduced sediment supply and an increase in the magnitude of the dominant floods, which led to dissection of some alluvial fan and delta surfaces.

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