ORIGIN AND EVOLUTION OF THE PEACE VALLIS FAN SYSTEM THAT DRAINS INTO THE CURIOSITY LANDING AREA, GALE CRATER.

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Introduction: Alluvial fans are depositional landforms consisting of unconsolidated, water-transported sediment, whose fan shape is the result of sediment deposition downstream of an upland sediment point source. Three mechanisms have been identified, on Earth, for sediment deposition on a fan: avulsing river channels, sheet flows, and debris flows [e.g. 1-3]. Elucidating the dominant transport mechanism is important for predicting water sources and volumes to the fan, estimating minimum timescales for fan formation, and understanding the regional climate at the time of fan building. This is especially relevant at Gale Crater (5.3°S 137.7°E), which contains a large alluvial fan, Peace Vallis fan, within the vicinity of the Bradbury landing site of the Mars Science Laboratory (MSL) rover Curiosity. Understanding the location, size and evolution of past water reservoirs that formed the Peace Vallis fan will be necessary for both interpreting data collected by the Curiosity rover and providing insight to the regional and global environmental conditions on Mars when Gale's fan system was active. Here, we present an analysis of HiRISE and CTX imaging and topographic data to constrain the origin of the Peace Vallis fan.

Methodology: A detailed topographic analysis of the fan system at Gale was performed using two orbital datasets. For areas within the landing ellipse [4] and on Peace Vallis fan we used 1 m/pixel georeferenced Mars Reconnaissance Orbiter (MRO) HiRISE DEMs and orthophotos that were generated by the USGS Astrogeology Center in Flagstaff, Az. Outside of these areas we used data from the MRO Context Camera (CTX), which was provided by the MSL project. The CTX data, which has a resolution of ~6m/pixel, was used primarily to analyze the Peace Vallis catchment and gully system.

Geomorphic Observations from HiRISE and CTX Data: Peace Vallis fan is the only large (~80 km^2) low gradient fan within Gale Crater, and the main extent is located within several kilometers of Bradbury Landing (Figure 1). Prior mapping of Gale Crater [5] and our own additional observations show gullies, inverted channels, and steep small fans around the Gale Crater inner wall whose formation may have been coincident with Peace Vallis fan development. Peace Vallis

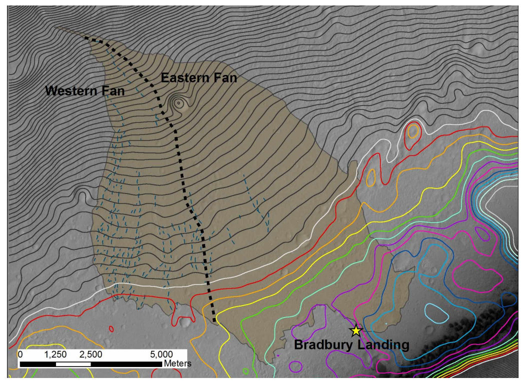

Figure 1: HiRISE image of Peace Vallis Fan with smoothed 5-m contours. The western and eastern fan portions are delineated (dashed line), as well as the topographic basin into which the fan enters (colored contours)

(~730 km^2) with prominent branching gullies. Peace Vallis, the feeder channel to the fan, is ~32-km in length and ~40-m wide. We estimate the volume of material removed from this gully system to be ~500 million m^3.

The fan itself is characterized by convex contours, which extend down into an enclosed basin, including the Bradbury landing site as well as the Glenelg region. The current fan volume is estimated to be ~650 million m^3, though the pre-eroded fan volume may have originally been close to ~790 million m^3, based on our topographic reconstructions. The fan's head is in a trough with a slope of ~7%, but the slope quickly drops to ~3% and then declines to ~1%, forming a concave up profile. In HiRISE imagery the main extent of the fan is characterized by a smooth, mottled surface [6], which was shown to correspond to a low thermal inertia unit [7], while the distal end of the fan is characterized by light to heavy fracturing and corresponds to a high thermal inertia unit.

There is, however, a clear distinction between the eastern and western fan system (Figure 2). The western fan is slightly steeper (1.5 versus 1.2%), smaller (25 versus 55 km^2), and more deflated (2.4 versus 0.6 meters) than the eastern fan. It also has numerous elongated, discontinuous ridges that are well expressed at the distal fan edge; we interpret these to be inverted channels. The eastern fan is much smoother, with subtle ridges that slope parallel to one another, which may be slightly inverted channels. Forty-three distinct inverted channels were mapped and over 150 cross-sections were created from the HiRISE data. The channels have average dimensions of 27 m in width and 2.5 m in deflation height, and the average channel segment length was 390 m. The lowest contours of the eastern fan show a steepening, or local convexity. The western fan terminates mostly on a local elevated ridge, while the eastern fan enters into a distinct enclosed basin (Figure 2). The distinct enclosed basin at the edge of the eastern fan is about 14.5 km long and 4.4 km wide with a maximum depth of about 30 m. Within the basin itself we observe the downstream, light-toned, wind scoured termination of the fan, as well as two elevated regions (referred to as rises in Figure 2) set about 20 m below the highest contour enclosing the basin. There are also two low regions, about 15 to 25 m below the local adjacent rise. We therefore estimate the basin to be ~35-40 m deep.

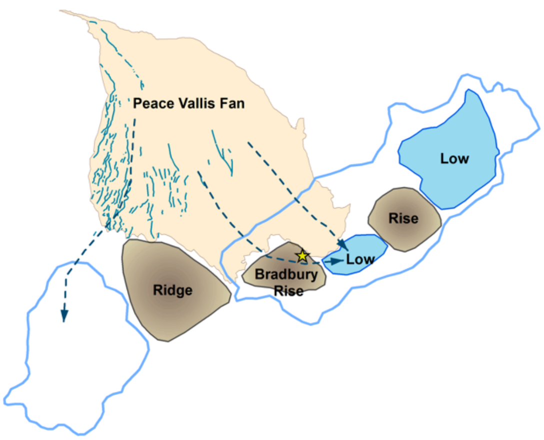

Figure 2: A schematic of the Peace Vallis fan system highlighting the local topographic rises and depressions at the distal end of the fan, as well as likely flow paths; the topographic lows (colored in blue) may record past fan-fed lakes.

Geomorphic Interpretations: Peace Vallis fan has characteristics consistent with terrestrial alluvial fans that are dominantly formed by fluvial, not debris flow, processes. Our fluvial interpretation is supported by the fan's low gradient slope, the lack of levee or lobate deposits, the presence of inverted channels, and the discovery of rounded gravels in clast-supported conglomerates on Bradbury rise [8]. Based on the morphology of the source canyon, any flows exiting the canyon would initially be forced to the southwest, which may have lead to preferential buildup of the western fan before the eastern fan. More extensive deflation of the western fan supports the hypothesis that the western fan is older, however, the differences between the western and eastern fan may also be due to changes in material or flow properties. We note that there is a correspondence between the upper and lower mapped fan units with the low and high thermal inertia. These data may reflect a change in material properties, such as grain size, as sediment was transported downslope [9]. The topographic data suggests that the fan built onto Bradbury rise and runoff would therefore have spilled to the topographic low to the east Bradbury landing. This topographically low region lies between two topographic rises and may hold a record of standing water fed from the fan (Figure 2).

With regards to timing, the approximate sediment balance between catchment erosion and fan volume suggest that the fan formed as a result of erosion of catchment material and subsequent deposition associated with avulsing river channels, pointing to a limited period of dissection of previously stored sediment in the headwaters. The clear preservation of the fan and source area indicates that fan formation was a relatively late-stage hydrological event that occurred early in Gale's history. Numerous authors [e.g. 10,11] have pointed to multiple lake levels within Gale Crater, the largest lake filling the crater itself, therefore construction of Peace Vallis fan likely post-dates these large lakes. Moore and Howard [12] hypothesize that large fan development on the southern highlands pre-dates the large pristine craters formed in the Late Noachian to Early Hesperian, but that the highly eroded craters prior to ~3.7 Ga are unable to provide the relief needed for fan formation, though newer work places the timing of fan formation into the Hesperian/Amazonian [13]. Since fan deposition there has been subsequent deflation, impact cratering, fracturing and tilting of outcrops.

Current Work: By applying conventional hydraulic and sediment transport models [e.g. 2,14-15] to the Peace Vallis fan system, we can infer past discharges, precipitation/snowmelt rates, and fan formation timescales, all of which will provide insight to the local environmental conditions during the fan's development.

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