THE TIMING OF ALLUVIAL ACTIVITY IN GALE CRATER, MARS. J. A. Grant[1], S. A. Wilson[1], N. Mangold[2], F. Calef[3] and J. P. Grotzinger[3]. [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, 6th at Independence SW, Washington, DC, 20560 (grantj@si.edu), [2]Laboratoire Planetologie et Geodynamique de Nante, France, [3]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: Gale crater (D ~ 154 km, ~5°S, 138°E, **Fig. 1A**) formed in the Early Hesperian [1] or near the Noachian-to-Hesperian transition [2-5]. The surrounding region is incised by valley networks formed in the Late Noachian to Early Hesperian [6], but predate the crater [3]. The present appearance of Aeolis Mons within Gale, dubbed Mt. Sharp, evolved in the Late Hesperian to Early Amazonian [4], but initial deposition may have occurred earlier. The northern wall is flanked by crater fill that includes alluvium.

The Peace Vallis (PV) alluvial fan originates on the northern wall of Gale and consists of an upper fan (AF unit) and lower fan (BF unit) [7] (**Fig. 1B**). A cratered surface (CS) unit generally flanks the distal margin of the fan [7]. Topographic and mapping analyses suggest the lower fan contributes to PV fan form [8] and extends into the region explored by the *Curiosity* rover [7] (**Fig. 1B**). Sediments (~10-20 m) capping the AF unit are bound locally by outward facing slopes (**Fig. 1C**), and a distinct morphologic boundary exists between units AF and BF (**Fig. 1D**). Sinuous ridges ~0.5-2.5 m high on the AF unit [7] are distributary channels now standing in relief as a result of differential erosion [5]. By contrast, the BF unit lacks relict distributaries, appears more degraded, and larger craters expose layered sediments (**Fig. 1D**). Fans on the SW wall of Gale (**Fig. 1A**) are broadly similar in scale and morphology to the upper PV fan, superposing adjacent surfaces and preserving meter-scale features.

Mudstone outcrops examined by *Curiosity* in Yellowknife Bay (YB) near the distal end of the PV fan are consistent with deposition in a lacustrine setting and contain key elements that provide evidence of an ancient potentially habitable environment [7]. The age of the mudstone, however, is poorly constrained relative to deposition on the PV fan. This study establishes the timing of alluvial activity in Gale as it may relate to rocks explored in YB [7].

Methods: Geologic mapping and crater statistics are used to evaluate the relative ages of "crater fill" comprising Aeolis Palus, the AF, BF and CS units, and other fans in Gale. Areas used are based on prior mapping [7, 9], morphologic and (or) topographic data, and the juxtaposition of landforms. Crater statistics were compiled in ArcGIS using CTX data [10], excluding gaps in image data and secondary clusters. Relative and absolute ages were interpreted from reverse cumulative histograms using pseudo log bins and Craterstats software [11] based on the chronology function of [12] and production function from [13].

Results: Cumulative statistics for two crater fill areas (307 and 236 km^2, respectively) on Aeolis Palus match the expected production population [13] at diameters >250 m but are relatively deficient in craters <100-200 m (**Fig. 1E**). Craters >250 meters yield relative ages in the middle of the Hesperian and give a modeled absolute age of ~3.3 to 3.2 Ga, consistent with the inferred Early Hesperian age [e.g., 2].

Crater statistics for the AF unit (~49 km^2), BF (31 km^2) and CS units (15.5 km^2) [7] were compiled using very small areas, so caution is required when making interpretations. To provide further insight, the ages of other fans (areas 22 to 111 km^2, **Fig. 1A**) in Gale were analyzed. All of these alluvial surfaces are dominated by craters <100-200 m across, with the exception of a ~750 m crater on unit AF (**Fig. 1E**).

The cumulative plots for unit AF achieve a production population of craters ~250 to 90 m, yielding an Amazonian age (**Fig. 1E**). By contrast, plots for units BF and CS do not provide a good match to the expected production population at any significant diameter range. Plots for fans in southwest Gale yield Amazonian ages broadly comparable to the AF unit; combining with the AF unit improves the fit to the production population, yielding an age <2 Ga (**Fig. 1E**).

Discussion: Interpretation of statistics from the AF unit is complicated by a ~750 m crater (**Fig. 1C**). The up-fan rim is only 4 m high and ~100 m wide, whereas it is in the expected range [14] of ~20 m high and ~300 m wide on the down-fan side. This observation, in addition to its pristine rim, absence of ejecta, or influence on a relict distributary <1D to the SW argues the crater predates the exposed fan surface and is therefore excluded from the statistics.

Statistics for the larger craters on the crater fill indicate Aeolis Palus began forming shortly after the crater formed and ended in the Hesperian, likely ~3.3 to 3.2 Ga. Active processes included transport and deposition of alluvial sediments [9] and deposition of materials forming Aeolis Mons, which could have been more extensive before eroding to near its current extent during this period [15].

Preservation of the Hesperian age surface across Aeolis Palus crater fill is demonstrated by the uniform distribution of craters >200 m across the surface and constrains average post Hesperian erosion and (or) deposition to ~20-40 m based on a depth-to-diameter ratio of 0.2 for primary and 0.1 for secondary craters, respectively [14]. These results require that the current surface of Aeolis Palus and the expression of the PV fan were largely established in the Hesperian.

Crater statistics for craters <250 m on the upper PV fan and fans to the southwest are consistent with a possible later period of degradation approximately correlating with establishment of the current form of Aeolis Mons [4] in the Late Hesperian to Early Amazonian. Although relict distributaries confirm <5 m deflation, the absence of pedestal craters or depositional remnants and morphology of the fan indicates that possible late activity likely included alluvial deposition.

The boundary between the AF and BF units is consistent with AF as a younger, less eroded surface <20-40 m thick based on the uniform distribution of larger craters on the crater fill. This is compatible with the thin (meters-thick) nature of the PV fan inferred from its smooth expression, low outward facing margins, and the inferred ~15 m burial of the upslope rim of the ~750 m-diameter crater on unit AF. About 5 m of erosion is required to account for topographic inversion of putative distributary channels in the AF unit and is in agreement with a relative deficiency of craters <40 m.

By contrast, *Curiosity* measured 18 m of relief over a 450 m traverse on the lower fan [7], consistent with expected erosion of crater fill since the Hesperian. This implies the BF unit may be older and (or) comprised of significantly less resistant materials than unit AF.

Implications for Habitability: Crater counts indicate deposition of the crater fill occurred in the Hesperian and likely included rocks comprising the lower PV fan. Although uncertain, crater statistics for the lower fan are consistent with their being older. If the rocks in YB (unit BF) were emplaced in the middle of the Hesperian (~3.3-3.2 Ga), then the habitable environments they record occurred relatively late in Martian history and may not have been isolated [e.g., 15].

Crater counts and morphology on the upper PV fan suggest a possible younger period of alluvial activation in the Late Hesperian to Early Amazonian was responsible for 10-20 m deposition. Any late activity was perhaps concurrent with late alluvial activity elsewhere [16-18]. Based on morphology, it is unlikely any late alluvial deposition extended to the lower fan or YB, though evaluation of any potentially associated habitable settings requires more confident interpretation of the occurrence, timing, and extent of late activity.

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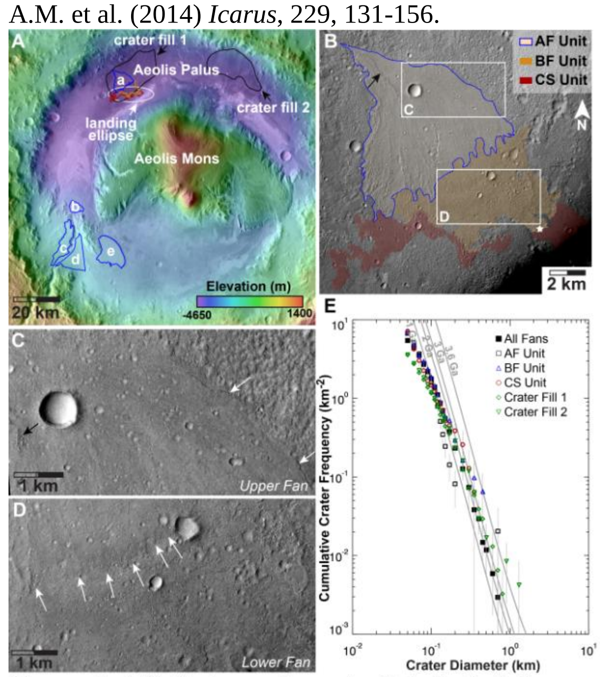

Figure 1. (A) Crater analyses in Gale included areas on Aeolis Palus (crater fill 1 and 2, black outlines), fans (blue outlines) including (a) AF unit, (b) SW floor fan, (c) SW upper fan (north), (d) SW upper fan (south), (e) SW floor fan lobe, and the BF (orange) and CS units (red). MSL landing ellipse is indicated. MOLA topography over THEMIS day IR. **(B)** Upper Peace Vallis fan (unit AF) and adjacent BF and more distal CS units of the lower fan. Black arrow is inverted distributaries; white star is YB. Subset of CTX G02_018854 _1754. **(C)** AF unit characterized by smooth surfaces bound by low, outward facing slopes (white arrows). Inverted distributary (black arrow) less than 1 crater diameter from the ~750m crater is unaffected by the crater ejecta, suggesting the crater may be partially buried by AF unit. **(D)** Morphologic contact between the AF and BF units (white arrows) differs from the thermophysical contact mapped in (B) [9,11]. Subset of HiRISE ESP_028269_1755. **(E)** Cumulative crater statistics for fans and other units mapped in (A).