POSSIBLE GEOMORPHIC AND CRATER DENSITY EVIDENCE FOR LATE AQUEOUS ACTIVITY IN GALE CRATER.

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Introduction: Gale crater formed by impact in the Early Hesperian [1-3] and preserves a record of geologic activity that included deposition into a paleolake on the crater floor [e.g., 4-6] and evolution of geomorphic features/surfaces on Aeolis Palus and Aeolis Mons/Mt. Sharp [e.g., 1, 3, 7-14] (Fig. 1). The bulk of water driven geomorphic activity associated with evolution of the crater interior was confined to the first 0.3-0.4 Ga after the crater formed [7-8, 11] with eolian degradation dominating subsequent activity [12]. However, recent work on the formation age of secondary jarosite in mudstones on the crater floor concludes that some aqueous activity likely occurred <3.0 Ga [15]. Examination of geomorphic surfaces in the crater reveals some whose superposition relations, preservation scale, and crater densities may be consistent with such late aqueous activity [7, 11].

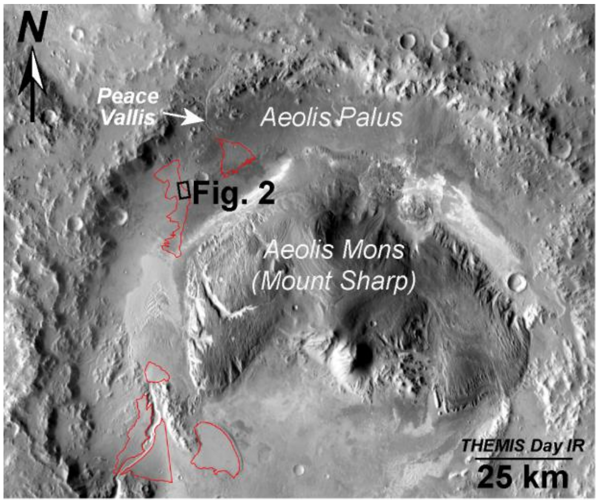

Fig. 1. Alluvial fans in Gale crater (outlined in red) superpose broader Aeolis Palus and retain morphology indicative of relatively young age and little erosion.

Superposition Relationships: There are a number of alluvial fans on the flanks of Aeolis Palus and along the western wall of Gale [e.g., 8] that clearly superpose broader surfaces [e.g., 14]. For example, a surface we interpret as alluvial covers ~90 km^2 in the northwestern corner of the crater (Figs. 1 and 2) is apparently mantled by ejecta on its western side from a crater farther to the west. The exposed surface is smoother (at 10s to 100s of m scales), darker-toned, and clearly embays rougher and relatively brighter-toned surfaces to the east. And on the upper Peace Vallis fan (Fig. 1), a broadly similar smoother and darker alluvial surface sits on a rougher, relatively brighter, and lower surface. Although superposition of these surfaces and other alluvial surfaces in Gale (Fig. 1) is not indicative of absolute age, it does confirm they are among the youngest primary depositional surfaces in the crater.

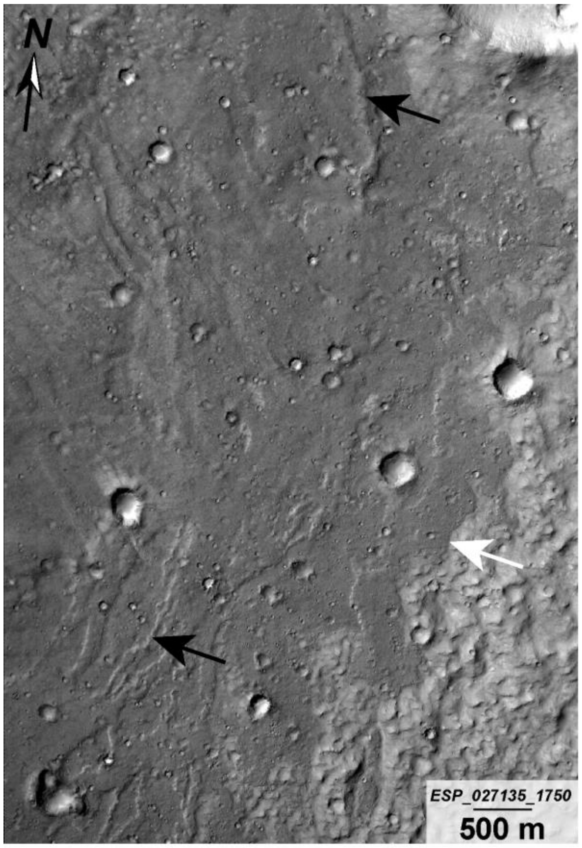

Fig. 2. Surface on the northwestern wall of Gale (Fig. 1 for context) shows embayment relations with Aeolis Palus and retains distributary channels, see also [14].

Preserved Small-Scale Morphology: These same alluvial surfaces (Fig. 1) preserve well-defined channels [8] that often transition to variably sinuous ridges [7] and are up to ~100 m wide, ~10s of m deep/high, and sometimes km in length [8]. These features are interpreted as distributary channels [e.g., 7, 8] and their preservation contrasts with adjacent, degraded surfaces (Fig. 2). Moreover, the edges of the fan surfaces show embaying relations with the surrounding terrain, with little evidence of erosional modification (e.g., lack of isolated remnants, Fig. 2). Preservation of these features could reflect greater induration leading to lesser erosion over time, but examination of craters on these same surfaces does not reveal increased blocks in the ejecta that would support this conclusion. Hence, their expression may be most consistent with a relatively young age, but without implication for absolute age.

Preserved Crater Densities: The size-frequency of craters on the alluvial fans may help to constrain their absolute age. However, crater statistics derived from small areas can be fraught with uncertainty because larger, more rarely occurring craters that accurately reflect the age may be distributed at scales too large to be sampled [e.g. 16-19]. In spite of this, careful mapping may enable the combination of small, but similar morphological units into a larger cumulative area, thereby enabling extraction of potentially useful age information [20, 21]. For example, carefully chosen surfaces on Aeolis Palus covering hundreds of km^2 yield interpreted ages (Fig. 3) [7] the same as ages derived from much larger surfaces [3, 8].

Although individual alluvial fans in Gale (Fig. 1) are too small to yield meaningful ages, combining their areas totals ~400 km^2 and yields an age interpretation that may be more robust [20, 21]. The basis for this is similarity in their morphology, superposition relationships, and common scale of preserved morphology.

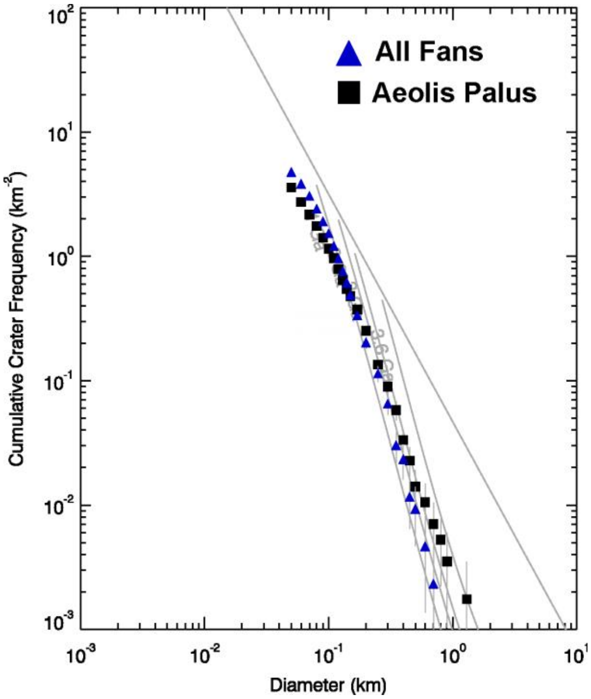

Fig. 3. Cumulative crater densities for the combined areas of alluvial fans and Aeolis Palus. Both rely on comparable, relatively small areas, but the interpreted ~3.2 Ga of Aeolis Palus is confirmed by larger areas [3, 8] and the interpreted age of the fans is <3 Ga.

A plot of the combined areas of the alluvial fans (Fig. 3) shows a good match to the expected production population on a surface ~1.4 Ga. Moreover, comparision between the crater densities on alluvial fans and those on broader Aeolis Palus show a clear distintction: the fans are younger (Fig. 3). Although the interpreted age of the combined fan surfaces incorporates uncertainty, when placed in the context of their superposition relations and morphology, a reasonable interpretation is that they represent a relatively young aqueous-driven surface within Gale. In at least some instances, the local occurrence of the interpreted younger fan surfaces (e.g., upper Peace Vallis) are mostly confined to locales above the crater floor and transition down slope to more degraded and possibly older surfaces [7]. Hence, the alluvial surfaces may have been shaped by relatively small discharges of water that largely infiltrated before reaching the lower wall and floor of the crater. Such a scenario, while speculative, could have sourced groundwater responsible for the diagenetic formation of jarosite in Gale interpreted to have occurred less than 3 billion years ago [15]. Late aqueous activity would have been contemporary with late activity on alluvial fans elsewhere on Mars that may have been triggered by snowmelt [21, 22]. If this model is accurate, late aqueous activity in Gale may have been associated with the establishment of habitable environments fairly late in Mars history.

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