Revisiting the Geologic History of the Pathfinder Landing Site at Ares Vallis, Mars

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Abstract

Before NASA sent the Pathfinder lander and Sojourner rover to the mouth of Ares Vallis in 1997, they anticipated the discovery of Hesperian-age (3.6 Ga-3.0 Ga) sediments deposited from catastrophic outflows. When pictures came back, the rocks they discovered were large, boulder-size, angular and were largely inconsistent with transport by large floods. The origin of the deposits at the Pathfinder landing site remains controversial. This study aims to constrain the surface geology of the Pathfinder landing site using new high-resolution imagery and crater statistics. Context Camera (CTX) images along with High Resolution Imaging Experiment (HiRISE) images were used to map surface geology. Mars Orbiter Laser Altimeter (MOLA) elevation raster and Night Thermal Emission Imaging System (THEMIS) imagery were used. Multiple smooth terrains, at varying elevations, were identified in the region. Preserved geomorphic terraces, grooves, and streamlined islands from floods were also noted. Crater counts on all surfaces indicate early to late Hesperian model ages for craters with diameters (D) > 500 m, consistent with the timing of flooding in Ares Vallis. However, a resurfacing event occurred across all units, regardless of elevation, in the mid-Amazonian at ~950 Ma. This resurfacing likely had a large influence on the geology of the Pathfinder landing site and may have been caused by ~100 m of burial or erosion post-flooding.

Introduction

Ares Vallis is a catastrophic outflow channel that is approximately 1,500km long (Komatsu and Baker, 1997). The Pathfinder mission landed at 19.1°N, 33.2°W, the mouth of this massive channel to investigate evidence of fluvial materials deposited in either a sub-aqueous (posited northern ocean) or sub-aerial environment in the northern plain's basin of Chryse Planitia (Golombek et al. 1997). However, lander-based imagery indicated large, boulder-size, angular rocks that showed little evidence of water transport. It was argued that these rocks are instead fragments of basaltic bedrock ejected from nearby impact craters. However, both hypothesis remains controversial. The objective of this research is to analyze two areas near Pathfinder's landing site, one in a plains area of Ares Vallis and one in the channel of Ares Vallis to constrain the surface geology, near surface stratigraphy, and surface degradational history of the materials at the landing site.

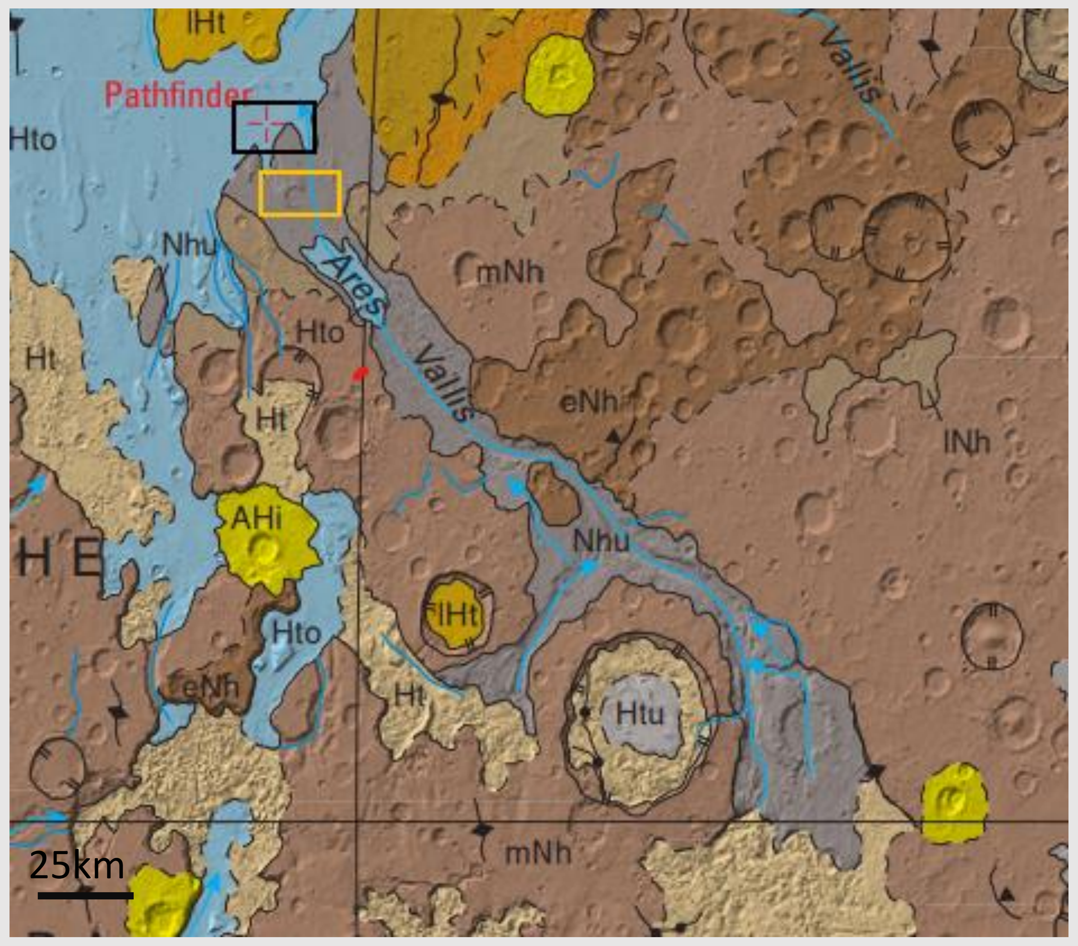

Figure 1: Global geologic map created by Tanaka et.al. (2014) zoomed in on Ares Vallis. The Black box indicates the plains region while the gold box indicates the channel region. The research area is located at 19.1°N, 33.2°W

Methodology

Two study regions were mapped using Context Camera (CTX) images at 6m per pixel and HiRISE images at 25 cm per pixel. Crater statistics were obtained from each identified geologic unit by counting all visible craters with D > 200 m. The crater data were plotted on a cumulative size frequency histograms using Craterstats2. Secondary chains or clusters were excluded. The crater statistics were used to not only determine age differences of geological units but to understand the timing and magnitude of crater resurfacing events. MOLA elevation data with grids of 463m were used to aid in the differentiation of geological units on the surface. THEMIS Nighttime images at 100 m per pixel were also used to differentiate geological units based on their thermal emission characteristics.

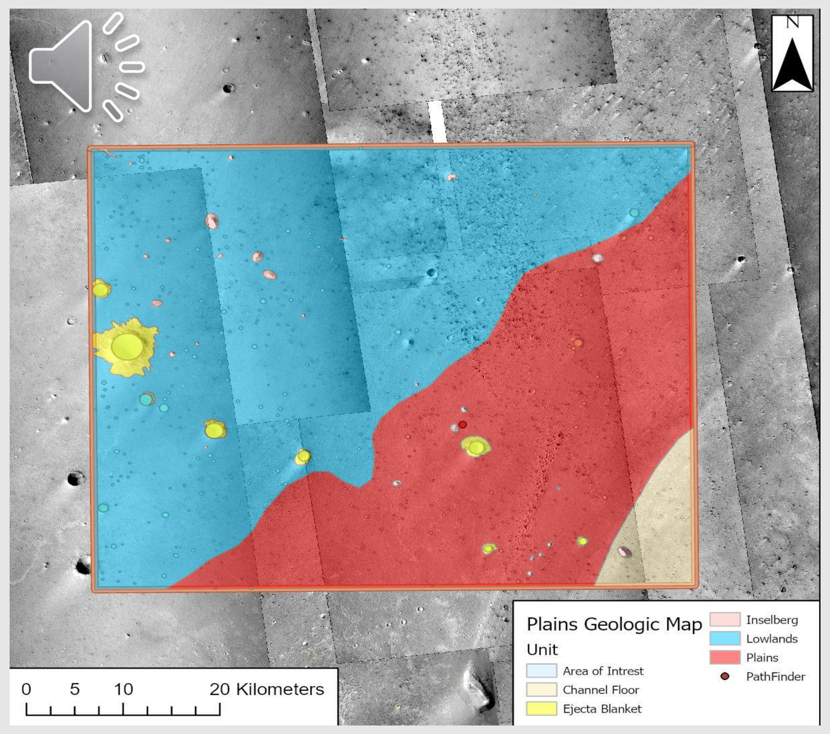

Figure 2: Geologic map of plains material constructed on CTX Imagery. Pathfinder is the dot.

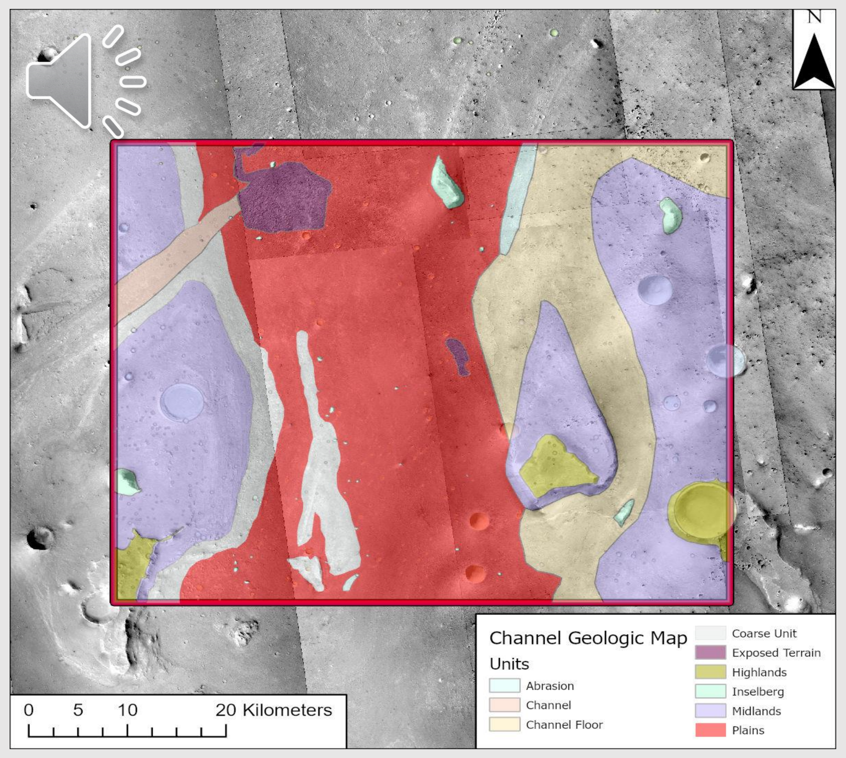

Figure 3: Geologic map of the channel region further south, constructed on CTX Imagery.

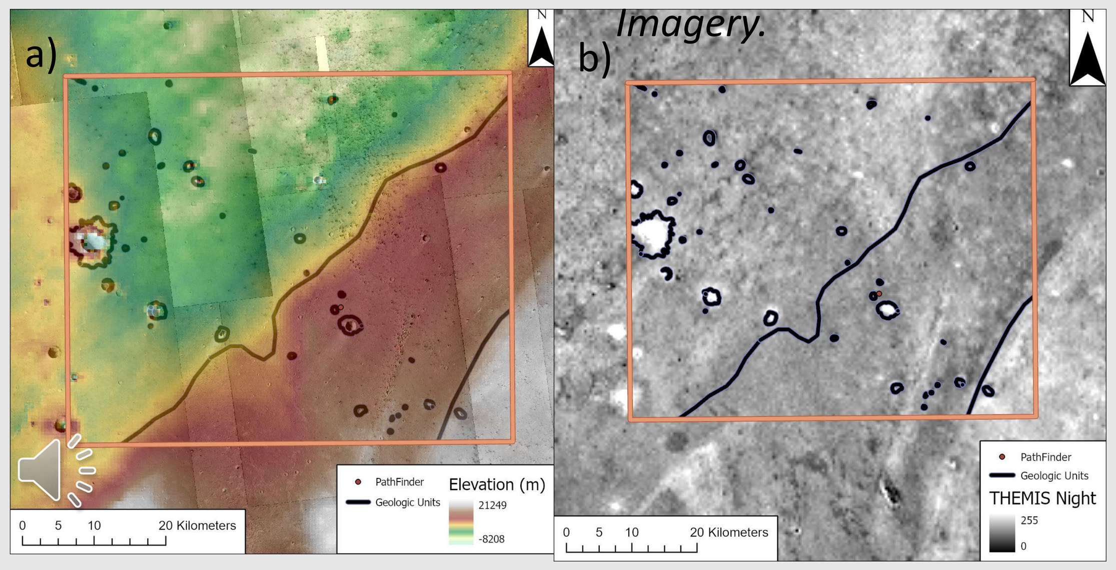

Figure 4: Both images are of the plains study area. Figure 4A is MOLA raster. Figure 4B is THEMIS Night raster. Both are overlain by geologic boundaries

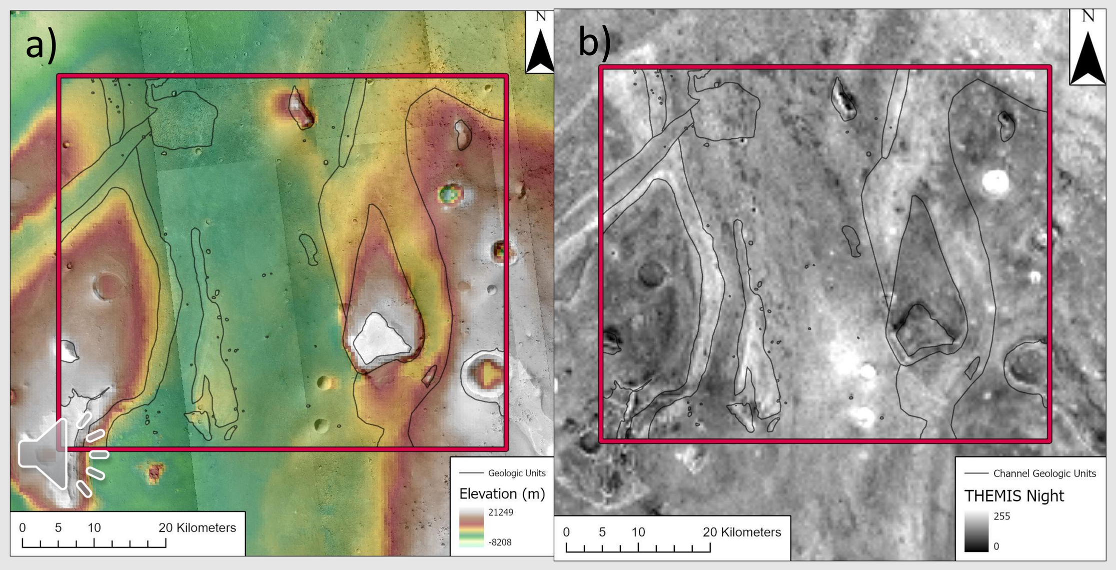

Figure 5: Both images are of the channel study area. Figure 4A is MOLA raster. Figure 4B is THEMIS Night raster. Both are overlain by geologic boundaries

Results

Craters larger than 500m in diameter on lowland, plains, and midland units follow a mid-late Hesperian crater production function that indicates a model age of 3.3 Ga to 3.7 Ga (Fig 5). At craters with a diameter less than 500m the lowlands, plains, and midland units show a kink in the production curve. This suggests a resurfacing event that removed or buried all craters smaller than 500m. Craters from 200m to 500m in size follow a middle Amazonian production function with model ages ranging from 930 Ma to 1.2 Ga (Fig.5).

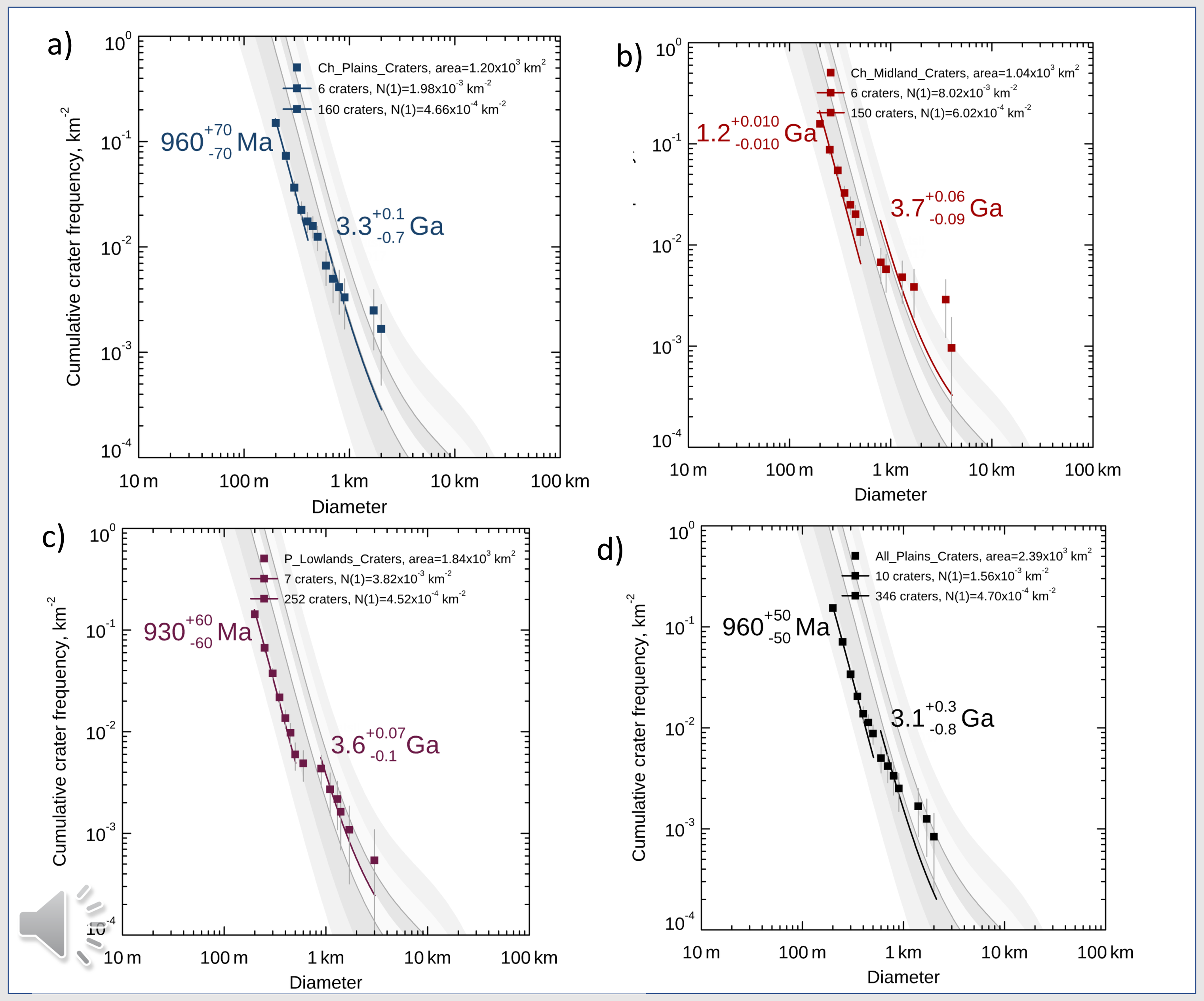

Figure 5: All graphs were created within Craterstats2. Each graph indicates a geologic unit 4a) Plains Unit in Channel area 4b)Midland unit 4c) Plains Unit in Plains study area 4d) All plains Unit

Discussion and Conclusion

There are two competing hypotheses for the Pathfinder landing site: (1) the landing site contains Hesperian-age fluvial deposits from Ares Vallis and (2) the landing site is covered by a Hesperian to Amazonian-age fragmented, basaltic lava flow (Golombek et al. 1997). Our data indicate that a major resurfacing event occurred at the Pathfinder landing site in the mid-Amazonian at ~ 950 Ma, well after Ares Vallis flooding (2.9 Ga, Warner et al. 2010). The magnitude of resurfacing indicates that ~100 m of material has either been eroded or buried here. Lava flow resurfacing remains a viable hypothesis for the materials at Pathfinder, however this hypothesis must account for resurfacing over a broad range of elevations. Resurfacing is seen both on the highlands and lowland plains channel units. A lava flow would have had to have covered midlands and flooded downslope onto the plain's unit. This resurfacing event could also represent late-stage flooding from Ares Vallis. However, this would extend flood activity to much later in Mars history than previously considered. Finally, broad-scale landscape erosion by eolian processes or exhumation of this surface should also be considered.

References

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