A NASA SPACECRAFT MAY HAVE LANDED ON AN EARLY MARS MEGA-TSUNAMI DEPOSIT IN 1976. J.A.P. Rodriguez[1], Jeffrey S. Kargel[1], Victor R. Baker[2], Darrel K. Robertson[3], Goro Komatsu[4], Daniel C. Berman[1], Gregory J. Leonard[2]. [1]Planetary Science Institute (1700 East Ft. Lowell Rd., Suite 106, Tucson, AZ 85719-2395 – alexis@psi.edu), [2]LPL, University of Arizona, Tucson, AZ 85721, [3]Science & Technology Corp., NASA Ames Research Center, Moffett Field, CA 94035. [4]Università d'Annunzio, Pescara, Italy.

Introduction: Nearly half a century ago NASA's Mariner 9 discovered on Mars the first extraterrestrial landscapes of likely fluvial origin [1]. These landscapes include possible catastrophic flood channels of enormous proportions (outflow channels) [1-4]. The landing site of the 1976 Viking 1 Lander (V1L) was on the northern plains in what could have been the outflow zone of Maja Vallis [5, 6] (Fig. 1A).

An unexpected result of the V1L mission was the finding that the landing site lacks distinct fluvial features [7, 8]. Instead, the lander returned images of boulder-rich terrains forming the top of a matrix-supported breccia deposit several meters in thickness [9]. Initial investigations suggested that an impact [10], or a volcanic eruption [7], could have produced a debris flow that emplaced the breccia [7, 9, 10]. In a subsequent geologic map of the Chryse Planitia region, Craddock et al. [11] produced an investigation correlating the lander and orbiter data. Their work indicated that the breccia materials forming the landing site are part of a broad sedimentary unit extending significantly beyond the spacecraft's visual range, which accumulated at the bottom of a standing body of water that existed during outflow channel formation. Based on measurements of buried craters they indicated that the unit might be ~50 m thick. A recent analysis of Arecibo radar imagery also reveals that the deposit forms part of an extensive radar-bright (i.e., rocky) unit covering most of the highland-lowland boundary plains between Maumee and Kasei Valles [12]. However, Harmon and Nolan [12] suggested that outwash materials from Bahram Vallis likely form the breccia deposits.

Methods: We have mapped and examined the deposit's boundaries and geomorphology using a combination of (1) thermal infrared image data (Mars Odyssey Thermal Emission Imaging System (THEMIS) night-time and day-time infrared image mosaics (100 m/pixel)), (2) visible image data (Mars Reconnaissance Orbiter Context Camera (CTX, (5.15–5.91 m/pixel)) images, and (3) Mars Global Surveyor Mars Orbital Laser Altimeter (MOLA, ~460 m/pixel horizontal, ~1 m vertical resolution) digital elevation models.

Results: Our mapping shows that the deposit consists of two large sedimentary units; a lower unit that covers the lower reaches of Maumee Valles, and a significantly more extensive upper unit that comprises most of the highland surfaces adjoining Kasei Valles, Maumee Valles, and Xanthe Montes (Fig. 1A). The V1L site occurs within the lower reaches of the latter (Fig. 1A). Both units have upper boundaries that exhibit a broad landward lobate morphology and include scoured surfaces with streamline patterns (Fig. 1B) indicative of run-up flow erosion. The scour marks' orientations and distributions, as well as the lobes' lengths, are consistent with the run-up flows sourcing from within the northern plains and dominantly propagating towards the west-northwest. The upper unit's uppermost boundary includes sedimentary ramps that partly cover the lower margins of Xanthe Montes and intrusive lobes into Vedra and Bahram Valles (Figs. 1C). These observations indicate that the flows reached the Montes at high speed and ceased to propagate due to deceleration over the steeper gradient topography of the mountain range's flanks. We propose that the deposits' emplacement was due to rapid run-up flows that extended from the northern plains, which we interpret as due to a mega-tsunami that propagated from within a northern plains ocean. Kasei and Simud Valles truncate the deposits' lower-most extents (Fig. 1A). In contrast, the deposits' areas, which intrude Maumee Vallis, show no distinct evidence of flood modifications. These stratigraphic relationships indicate that the mega-tsunami occurred during the Late Hesperian, a period when these outflow channels are thought to have mostly formed [13] and when an ocean likely existed in the northern plains [14, 15]. However, we note that the proposed mega-tsunami deposits documented in Rodriguez et al. [16] and Costard et al. [17] overlap both the lower reaches of Kasei and Simud Valles and that consequently, they formed due to mega-tsunami that occurred later in the Late Hesperian. Based on the state of preservation of impact craters at the V1L landing site, Arvidson et al. [18] inferred that the breccia deposit's present thickness experienced less than 10 m of erosion since the time of emplacement. At a broader scale the presence of widespread low relief surface grooves, scour marks, and lobate fronts, as well as of numerous embayed mesas that lack scour marks above their embayment level, are consistent with the overall retention of the deposit's primordial thickness. These results, along with the elevation of the outflow channel erosion of the deposit's basal areas (Fig. 1A), indicate that the mega-tsunami ascended into the highlands at least ~1.2 km in elevation over a distance of ~350 km.

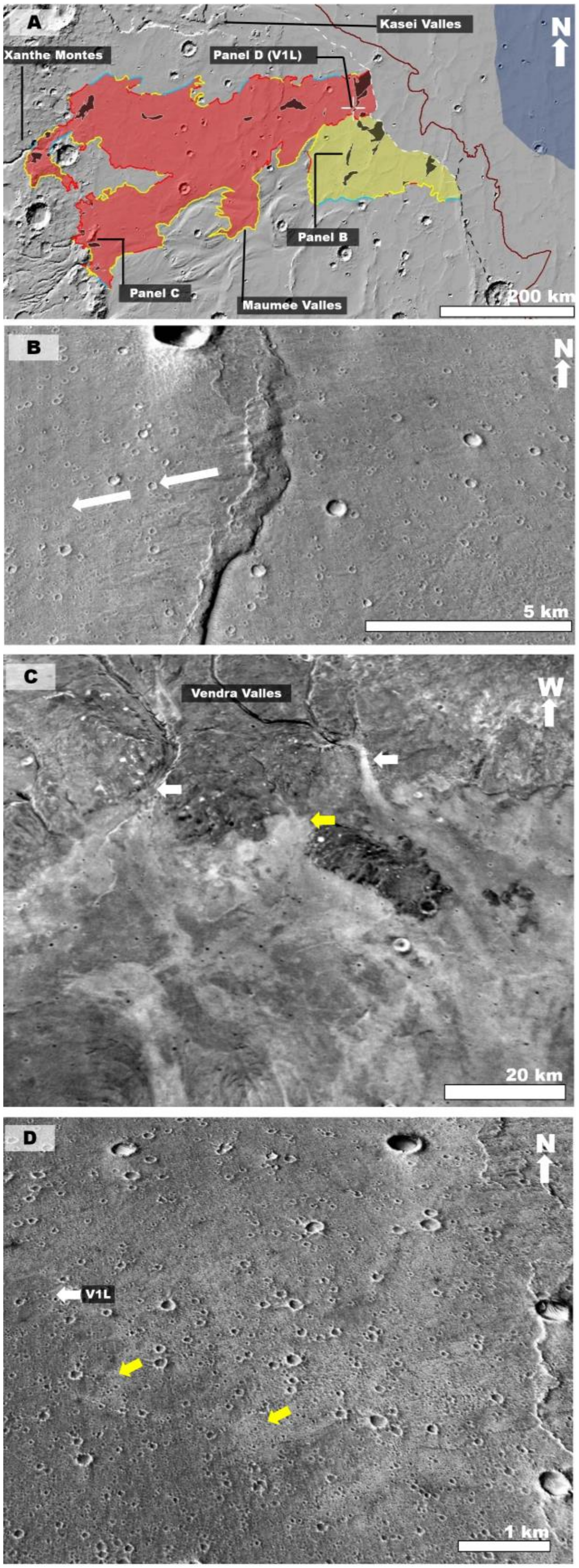

Fig. 1 (A) Map of highland-facing lobate deposits over the boundary plains bounded by Maumee Valles, Kasei Valles, Xanthe Montes, and the northern plains. The blue shading shows the ocean reconstruction presented in Rodriguez et al. [16], with a shoreline elevation at -3,800 m. The brown line traces the upper boundary of the older mega-tsunami deposit they proposed. The dashed white and black lines are erosional contacts of lower Simud and Kasei Valles, respectively. The areas shaded in yellow and red, respectively, identify the older (lower) and younger (upper) deposit units. The mapping of the deposits include abrupt (red lines), diffused (yellow lines), and reconstructed (blue lines) outer boundaries. The interior zones marked in black are scoured surfaces, with orientations and bedforms that indicate upslope flow. The image base is a MOLA-derived shaded relief. The locations and contexts of panels B-D are identified. Note that we rotated the image in panel C, so that west (and the direction of propagation) are up. **(B)** CTX view of wrinkle ridge that shows bedforms indicating upslope flow (white arrows) towards the west. **(C)** THEMIS nighttime IR view of the upper unit's upper boundary (bright). The unit's upper reaches include run-up intrusions into Vendra Vallis (white arrows) and run-up ramps onto sections of Xanthe Montes (yellow arrow). **(D)** CTX view of the Viking Lander 1 landing site. The white arrows show the frontal margins of lobes that were emplaced due to run-up slurry flows.

The V1L site occurs at the terminus of a west-trending lobe within the upper unit (Fig. 1D). Consequently, we can infer that mega-tsunami deposits likely dominate the landing site's geology. Our initial numerical assessment indicates that an impact ~150 km in diameter could have produced the wave, perhaps aided by the hydraulic funneling effect of the presence of an ice cover over shoaling water.

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