Testing the Deltaic Origin of Fan Deposits at Bradbury Crater, Mars

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The five-second spiel:

The stratigraphic architecture of three fan-shaped deposits at Bradbury crater were investigated, and quantitative methods were applied to the north deposit displaying meter-thick layering. Fitted planes display a constant dip throughout the section at 7.4° to the northwest; therefore this landform lacks the stratigraphic architecture of a delatic system and presents no conclusive evidence for a sustained standing body of water at Bradbury crater.

Introduction:

Bradbury crater is located in Libya Montes, a region that experienced multiple extensive episodes of aqueous activity as evidenced by the valley networks carved through the Montes towards Isidis Planitia [1], and by the identification of various hydrous minerals [2]. Previous studies of Bradbury crater identified landforms that were interpreted as fluvial and lacustrine deposits resulting from the past presence of lakes, seas, and oceans [3]. *Erkeling et al.* [3] and more recent work [4–7] interpreted specific depositional environments for three deposits in particular, found to the north, east, and west (N, E, and W) of the crater center (*Figure 1*).

- **E deposit:** suggested to have formed in a standing body of water, as it is found in a 3 km depression termed an open paleolake by [3,5].
- **W deposit:** identified as an alluvial fan formed from Noachian fluvial activity [3].
- **N deposit:** identified as a delta by several contributions [3–7].

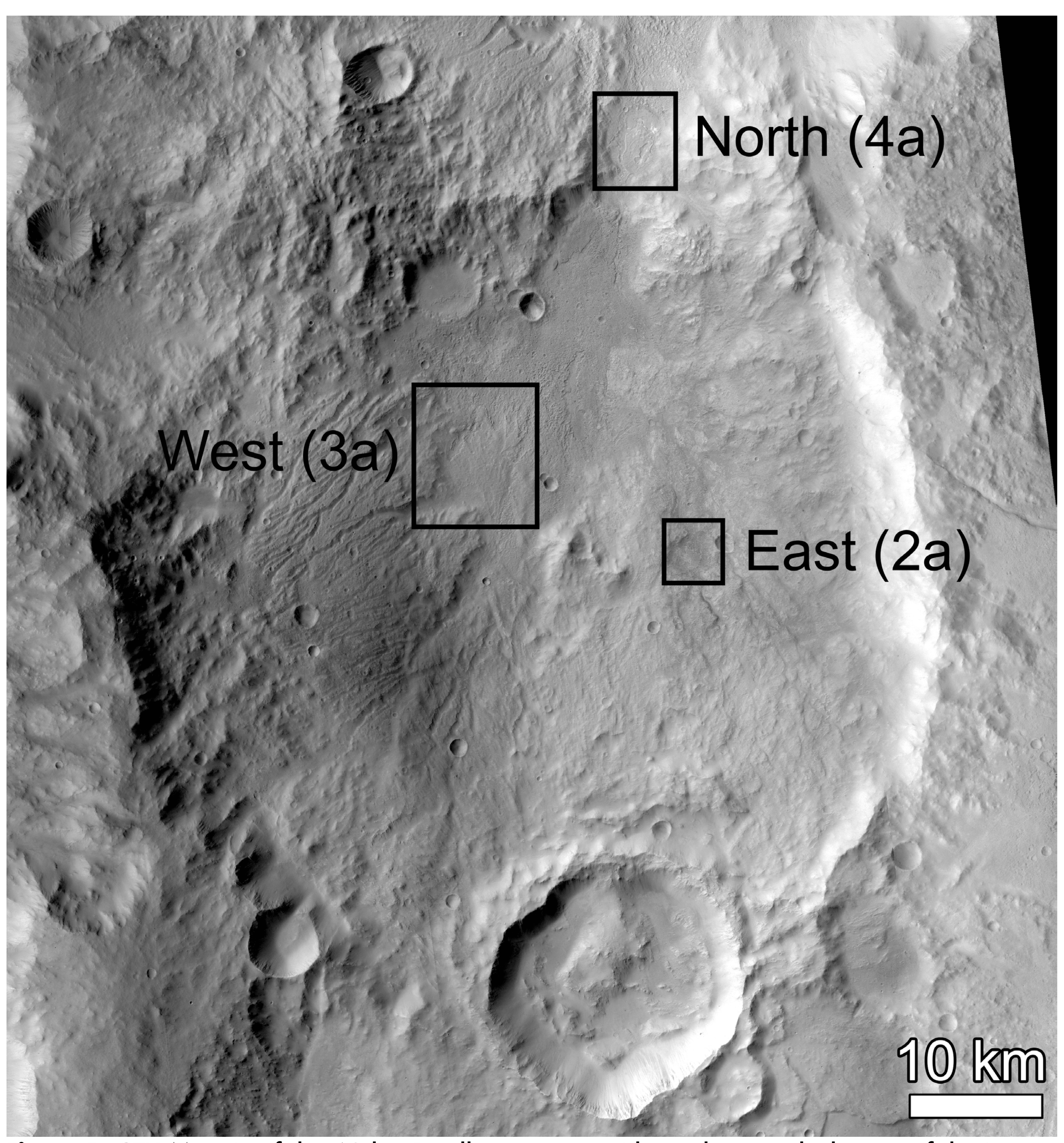

Figure 1: CTX Mosaic of the 60 km Bradbury crater with north towards the top of the image. The three landforms analyzed in this study are shown by their cardinal positions from the crater center. Mosaic of CTX images P04_002756_1826, P12_005802_1819, P16_007226_1809, P17_007727_1814, and P19_008518_1817.

Motivation:

- Previous morphologic mapping of these deposits using High Resolution Imaging Science Experiment (HiRISE) images was used to suggest the presence of topsets, foresets, and bottomsets of a deltaic system [4,5].
- In this study we investigate the stratal geometry and changes in bedding dip angles and orientations of these deposits using HiRISE data and apply quantitative stratigraphic methods, where possible, to test the purported deltaic origin of these deposits.

Methods:

- The progression of layer angles in a deltaic system provides a stratigraphic signature that can be investigated using high-resolution remote sensing data, as has been shown by several geometric analyses of martian fan-shaped deposit stratigraphy [8–11].
- All three deposits were qualitatively analyzed using orthorectified HiRISE images and digital elevation models (DEMs) produced using HiRISE stereo pairs and the NASA Ames Stereo Pipeline [12–14].
- We apply modified methods of [11] for quantitative analysis of the N deposit's stratigraphic architecture. A High Resolution Stereo Camera (HRSC) [15,16] DEM h2162_0002 was tied to MOLA [17] point shot data, and then the HiRISE DEM was tied to the corrected HRSC DEM [18].
- Discernable layers in the N deposit that were >50 m in length were mapped and location information of these layers was sampled at 2 m intervals in three dimensions.
- Planes were fit to the extracted layer position data using a linear least squares method [e.g., 8–10], and were recorded if the variance explained by the first principal component (PC) in a PC analysis was <99.5% and the ratio of the variance explained by the second and third PC was >15 [19].

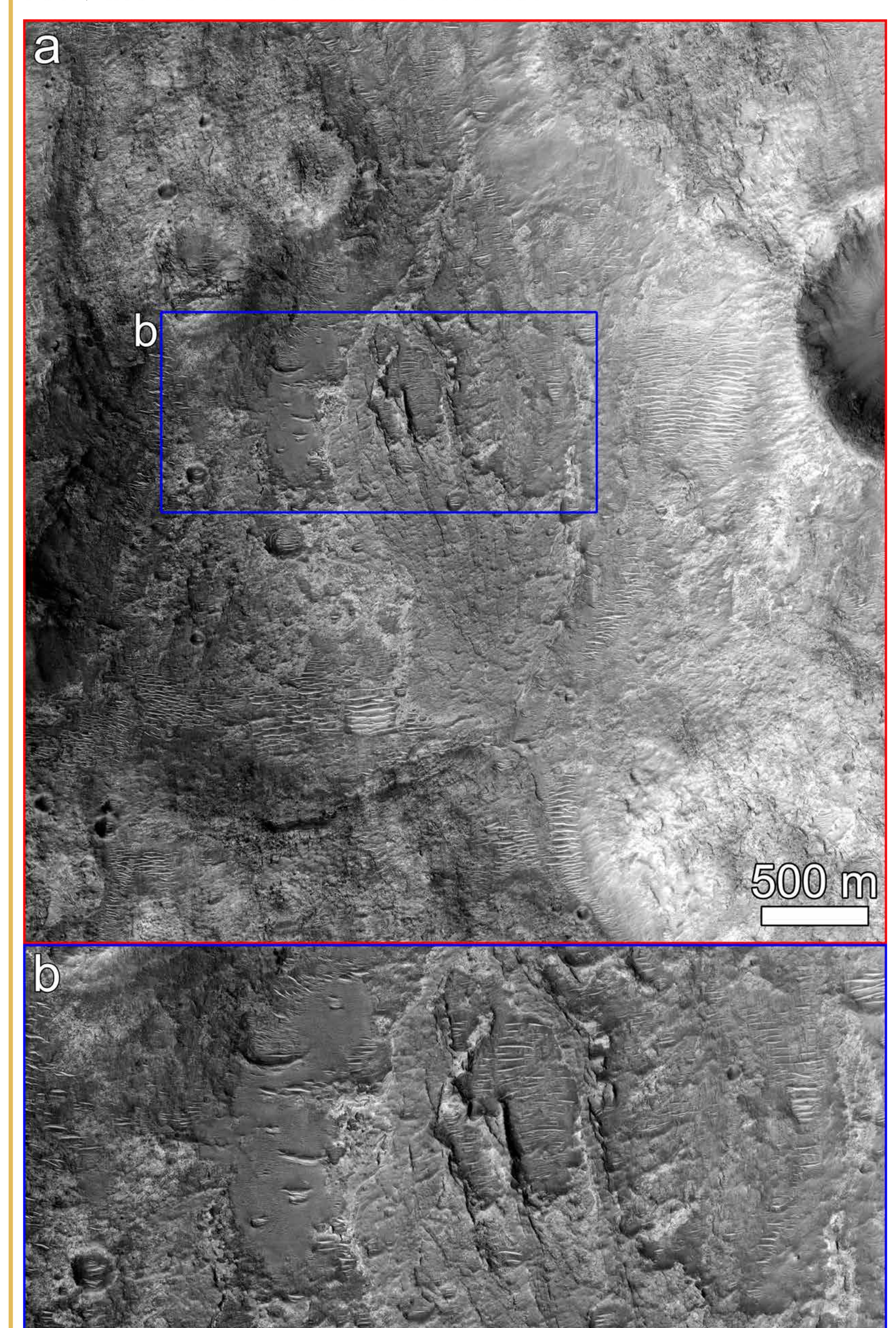

Figure 2: (a) Subframe of HiRISE image ESP_038530_1830 depicting the E deposit. (b) Subframe of (a) detailing the decameter-scale morphology of the E deposit. No meter-scale layering is observed. A decameter-scale stratigraphy is observed of light-toned material overlain by a dark-toned crater-preserving surface. Possible inverted channels are observed at the uppermost surface. North is up.

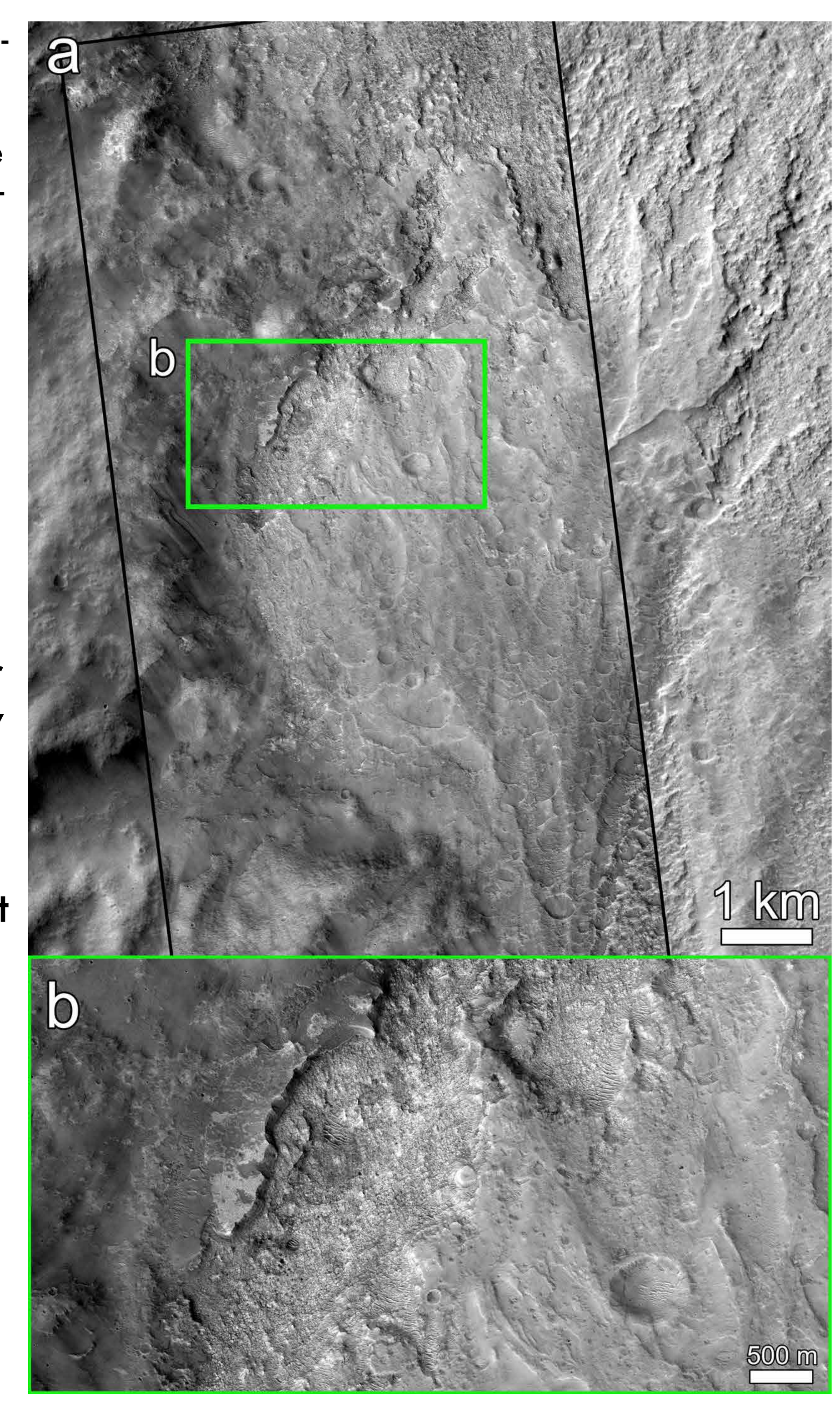

Figure 3: (a) Subframe of HiRISE image ESP_022337_1830 depicting the W deposit. (b) Subframe of (a) showing the similar decameter-scale morphology as seen at the E deposit. North is up in each frame.

Results:

- Though crudely stratified, the **E and W deposits** do not exhibit layering of sufficient resolution and continuity for quantitative analysis.
- Both deposits have similar decameter-scale stratigraphy that includes a meters-thick, light-toned, mottled unit containing dark-toned fractures overlain by a dark-toned unit with a corrugated surface texture (*Figures 2 and 3*).
- The **N deposit** is strikingly different and displays a fan shape with layering (*Figure 4*). Robust fits from six layers evenly spaced throughout the sequence (*Figure 4d*) show an approximately constant dip of 7.4 ± 1.4° and strike of 306.8 ± 2.1°, steeper than the ~2° regional slope through the breach in the crater wall (*Figure 1*).

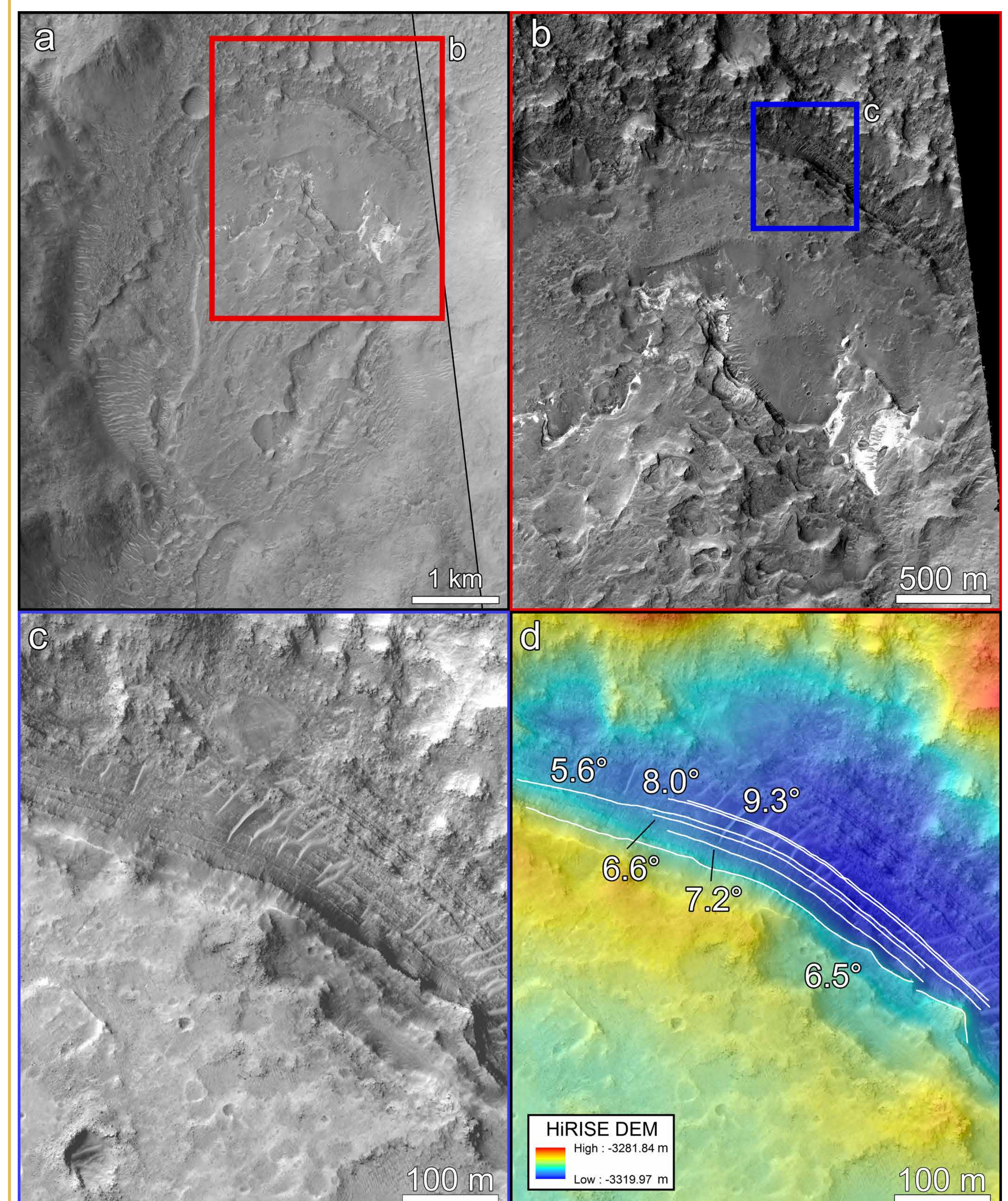

Figure 4: The N deposit of Bradbury crater. (a) Subframe of HiRISE image PSP_007727_1830 showing the N deposit. The lobate shape of the deposit is visible, as well as the large-scale stratigraphy observed at the other two deposits. (b) Subframe of (a) showing a segment of the layered sequence. (c) The layered sequence of the N deposit displaying approximately meter-thick layers. (d) HiRISE DEM made from the image in (a) and PSP_008808_1830 showing the region in (c). Colorized elevation of the deposit depicting the topography of the layered sequence. The white lines show fit layers and calculated dip angles are shown. North is up in each frame.

Implications:

- Our analysis of Bradbury crater's three fan-shaped deposits reveals no clear evidence for continuous bedding at the meter scale in the E and W deposits, and approximately constant layer dips throughout the layered section in the N deposit.
- The constant dip observed in the N deposit may be indicative of deposition in an alluvial, debris, or volcanic flow environment. The high layer dip angles could only be consistent with deltaic foresets and not topsets or bottomsets; however, the layered sequence is observed at the terminus of the N deposit in a region mapped as bottomsets by [3–5]. Instead, the ~7.4° slope is consistent with an alluvial/debris-flow fan origin. Importantly, we find no clear evidence for changes in bedding geometry that would imply emplacement in standing water or transitions in water depth.
- Quantitative stratigraphic analysis of the N deposit at Bradbury crater conclusively shows this deposit is not consistent with a deltaic origin, therefore the evidence is lacking to support a sustained standing body of water having been present in Bradbury crater during the fan deposit formation.
- The amount of water that may have been present in Bradbury crater is thus more poorly constrained compared with deposits elsewhere on Mars that exhibit orbital-scale stratigraphic architecture consistent with a deltaic environment.

References: [1] Jaumann R. et al. (2010) EPSL, 294, 272–290. [2] Bishop J. L. et al. (2013) JGR, 118, 487–513. [3] Erkeling G. et al. (2012) Icarus, 219, 393–413. [4] Erkeling G. et al. (2015) LPS XLVI, Abstract #1779. [5] Erkeling G. et al. (2016) LPS XLVII, Abstract #1451. [6] Tirsch D. et al. (2015) LPS XLVI, Abstract #1738. [7] Tirsch D. et al. (2016) LPS XLVII, Abstract #1444. [8] Lewis K. W. and Aharonson O. (2006) JGR, 111, E06001. [9] Ansan V. et al. (2011) Icarus, 211, 273–304. [10] DiBiase R. A. et al. (2013) JGR, 118, 1285–1302. [11] Goudge T. A. et al. (2017) EPSL, 458, 357–365. [12] Broxton M. J. and Edwards L. J. (2008) LPS XXXIX, Abstract #2419. [13] Moratto Z. M. et al. (2010) LPS XLI, Abstract #2364. [14] Shean, D. E. et al. (2016) ISPRS J. Photogramm. Remote Sens., 116, 101–117. [15] Neukum G. et al. (2004) Eur. Space Agency Spec. Publ., 1240, 17–35. [16] Gwinner K. F. et al. (2010) EPSL, 294, 506–519. [17] Smith D. E. et al. (2001) JGR, 106, 23689–23722. [18] Beyer R. A. et al. (2014) LPS XLV, Abstract #2902. [19] Lewis K. W. et al. (2008) JGR, 113, E12S36.