Structure and Geometry of the Interior Layered Deposits within Hebes Chasma, Valles Marineris, Mars.

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Introduction: The formation of Valles Marineris (VM) is known to involve tectonic extension and subsequent erosion. Isolated ancestral basins [1] were later linked by further extension faulting [2]. Hebes Chasma (Fig. 1A), an isolated depression north of central VM, is thought to be one such ancestral basin. As in many of VM's chasmata, large free-standing interior layered deposits (ILDs) are located within Hebes' interior. Hebes' enclosed form is unique in that its present structure cannot be explained by erosion of the ILD through outwash channels, a feature commonly observed in other VM's chasmata. Ground water circulation [3] and salt diapirism [4] have been proposed as mechanisms for producing Hebes' present structure.

This study examined small-scale fractures as well as topographic features, including landslide scars, to gain a better understanding of the structure and deformation of the main Hebes ILD mound, Hebes Mensa.

Hebes Chasma ILD: The main ILD mound is 120 km across and 43 km wide, and lies within the approximate centre of the chasma. Its elevation ranges from approximately -2,000 m to 3,800 m, measured from the northern floor. Four large erosional features, or landslide scars (Green in Fig. 1B), occur on three sides of the mound.

Methodology: A CTX mosaic registered to a HRSC composite DTM (orbits 0360, 2116, 2138, 2149, 5142, 5160, 5178) forms the base data for the study. Small-scale fractures were examined within HiRISE images. Attitudes of planar features were obtained using Orion software (Pangaea Scientific).

Results: Fractures were examined within five HiRISE images located on the ILD. Fractures were not common; most were isolated, such as those depicted on the north slope of the ILD mound (Fig. 1C and 1D). No orthogonal fracture sets were found, as those documented in the ILDs of western Candor Chasma [7]. In some cases layers have an apparent offset by several meters along fractures (Fig. 1E).

The top surface of the ILD mound has a shallow dip of 3˚ to the north (Fig. 1H). The mound's northern and southern slopes have an average inclination of 17˚ and 27˚, respectively.

Several major landslide scars (Fig. 1B, P1-P4) are located along the mound's edge. Each landslide scar follows the distinct geometry of a steep slope grading to an almost horizontal shelf which extends several kilometers before the slope steepens again (Fig. 1G, red dotted lines). Slumped material appears to have been deposited off the mound as units can be traced across the scar boundary immediately below the shelf (Fig 1D arrows). The elevation of the shelf (Fig. 1G) varies around the mound, but tends to be higher on the southern side.

To determine if these shelves are an exhumed stratigraphic level, points were placed along the upper boundary of each nearly horizontal section of the landslide scars. This placement of points covers an elevation range of 1960 m for all the shelf surfaces. The best-fit plane through these points has a maximum deviation of only 264.62 m, and an attitude with strike 278.9°±8.5°, dip 4°±2° (Fig. 1H).

Discussion: While some fractures were observed, Hebes' ILD mound displays relatively little deformation and lacks the complexity and abundance of fracturing documented within Candor Chasma [7]. This may be due to the isolated nature of Hebes Chasma, which would not have experienced any later deformation related to the linking of isolated chasmata elsewhere in Valles Marineris.

While the mound is centered within the chasma, its topography is asymmetrical. The top surface dips gently towards the north and the northern erosional slope is 10˚ shallower than the southern side.

That a plane with a relatively low maximum deviation can be fit through P1-P4 suggests that the near horizontal portions of the landslide scars may correlate to a significant stratigraphic level. The dip of both this plane and the mound's top surface are strikingly similar, suggesting that the entire mound has either been deposited non-horizontally or has been tilted by a few degrees towards the north following formation. The 10˚ difference of the northern and southern slopes may indicate the mound has not eroded uniformly and could be an expression of erosion related to a possible tilting episode of the mound.

References: [1] Lucchitta, et al. (1994), J. *Geophy. Res.*, 99, 3783-3798. [2] Schultz, R. A. (1998), *Planet. Space Sci.*, 46, 827–829, doi: 10.1016/S00320633-(98)00030-0. [3] M.A. De Pablo (2003), LPS XXXIV, Abstract #1072. [4] M.P.A. Jackson, et al. (2011), GSA Bulletin, 123, 1596-1627. [5] Moratto, Z.M., et al. (2010), LPS XLI, Abstract # 2364. [6] Broxton, M.J. and Edwards, L.J. (2008). LPS XXXIX, Abstract #2419. [7] Birnie, C., et al. (2012), J. Geophys. Res., 117, E11001, doi:10.1029/2012JE004144.

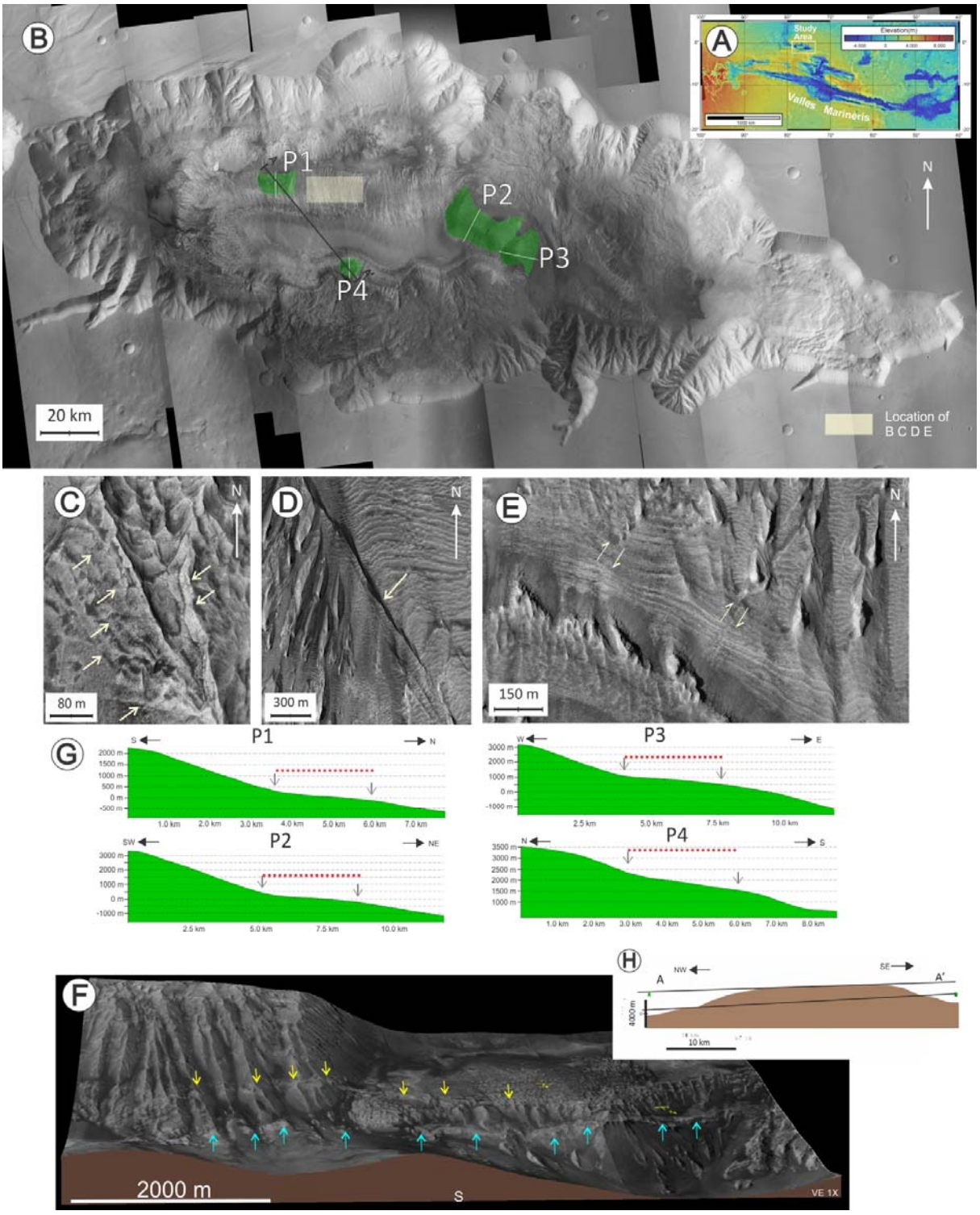

Figure 1: A) Study location; B) Hebes Chasma with location of landslide scars P1, P2, P3, P4; B, C, D) HiRISE image PSP_006520_1790; C) View of parallel fractures; D) View of large scale fracture; E) View of parallel faults; F) CTX 3D view of P4; arrow indicate units that can be traced across traced below the shelf surface; G) Cross sections of landslide scars P1, P2, P3, P4 with shelf indicated by dotted red line; H) Cross section of ILD mound from P1 to P2 (A to A') showing best fit plane of landslide scars P1, P2, P3, and P4's surface and best fit plane of the ILD mound's surface.