EVIDENCE FOR PAST KILOMETER-SCALE OVERTURN(S) IN DEFORMED, LAYERED TERRAIN NEAR THE DEEPEST POINT ON MARS. E. S. Kite[1], M. Manga[1] and J.T. Perron[2], [1]University of California, Berkeley (kite@berkeley.edu), [2]Massachusetts Institute of Technology (perron@mit.edu).

Summary: Deep in the Hellas basin on Mars, wind has exhumed layered terrain showing ductile deformation. A kilometer-scale cellular pattern is identified, consistent with thermal and/or compositional (diapiric) convection. 'Frozen-in' convection within an impact melt sheet is consistent with observations, but overturn(s) within an evaporitic layer cannot be excluded. Spectrometer follow-up will be complicated by dust.

Background: Kilometer-scale cellular and 'honeycomb' terrain in the NW Hellas basin has been interpreted as formed by ice blocks sinking into soft sediment [1], or as the result of salt diapirism [2]. Previous study [3] relied largely on Viking images. CTX and HiRISE permit a closer look, and confirm pervasive hectometer-scale deformation, most intense in shear zones at cell boundaries (Figure 1). The deformed, layered terrain is basal to the stratigraphy and is overlain unconformably by an erosionally resistant, relatively dark-toned, ridge-forming unit.

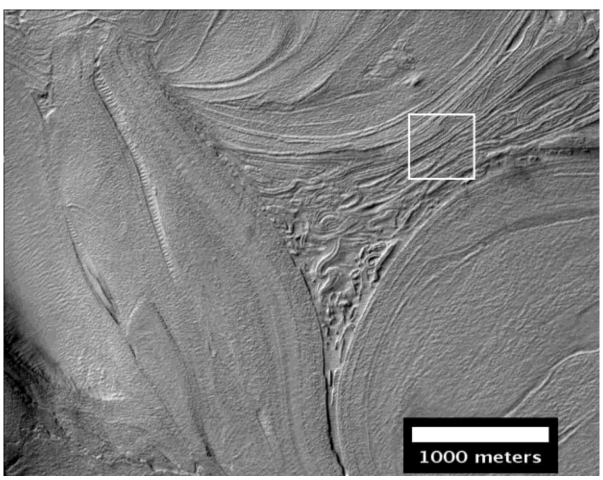

Figure 1. Shear zone within deformed, layered terrain. Subset of HiRISE frame PSP_007715_1420. Shear zone within white box shown in more detail in Figure 2.

Deformation appears three-dimensional: We are re-examining NW Hellas. Our most important inference so far is that the deformation in the deformed, layered terrain has a vertical scale that is not much smaller than its (~4km) horizontal scale - it is three-dimensional. Present-day topography is rugged, reflecting non-uniform aeolian erosion, in places showing hundreds of meters of relief at length scales of kilometres. These steep slopes are most useful for deciphering 3D structure: cell-cell boundaries in these relatively steep slopes are not common. Three-dimensional deformation is consistent with previously-suggested salt diapirism [2].

Processes: No combination of angular unconformities, folding, and movement along planar or listric faults can account for the Hellas shear zones. Syndepositional (gravity current) or postdepositional (compositional or thermal overturn) mixing is required. Turbulence within gravity currents has a self-similar (Kolmogorov) scaling. This is inconsistent with the regular decameter-scale band thickness(es) apparent within shear zones (Figure 2), the regular kilometre-scale wavelength we have identified in the outer part of deepest Hellas, and the clear division between shear zones and cell interiors. If the layered terrain was deposited by gravity currents, it was deformed after deposition.

Kilometer-scale compositional overturn has been studied in the context of salt diapirism on Earth, well-expressed in Iran's Kavir desert [4] and, offshore, in the Gulf of Mexico [5]. However, the cellular pattern in deepest Hellas is less organized, and undistorted inter-diapir areas are absent. These differences may suggest that deformation in deepest Hellas involved multiple overturns (for example, thermal convection), producing a more contorted pattern than the single, diapiric overturn observed in the Great Kavir.

In a flat-bottomed circular pan where the ratio of radius to depth is large, concentric circles of upwelling and downwelling develop if the system is marginally unstable to convection [6]. As thickness (or heat flow) is increased, this pattern is replaced by equant, polygonal cells with upwelling in their centers and downwelling at their margins. The thickness of a basin-filling, flat-topped unit would increase toward the center and decrease toward the margins of the Hellas basin, and this scenario is consistent with with the distribution and orientation of cells in deepest Hellas.

Materials: Axisymmetric impact simulations [7] suggest a Hellas-scale impact produces ~2 km thickness of impact melt. Compositional homogeneity of terrestrial impact melt sheets [8], and low viscosity of superheated magmas, imply that impact melt sheets cool convectively at least during early stages of solidification. By analogy to features preserved in frozen lava lakes [9], a variety of features and processes produce layering in the upper parts of melt sheets: variations in vesicularity and phenocryst content, and melt segregations produced by filter pressing. Top-down solidification would ‘freeze in’ structures produced in boundary layers, or generated by late-stage overturn and crustal foundering. Shear zones also contain features that suggest brittle deformation and boudinage, consistent with the expected rheological behaviour of crystal-rich melts at high strain-rates.

Ice and salt are alternatives to magma. On Earth, ice sheets do not convect because they are not confined: pressure differences due to ice surface slope are much greater than stresses due to thermal expansion of ice, so lateral advection of ice overwhelms the vertical convective instability. The deformed, layered terrain, if basinwide, would have been confined by Hellas' bowl shape. Using best-estimate Early Mars heat flow (~50 mW/m^2) [10], convection within thick ice is predicted. However, no subsurface dielectric contrasts indicative of ice have been reported in deepest Hellas, despite ongoing radar surveys at two wavelengths.

With best-estimate early Martian heat flows, tectonic stability, a depth-to-wavelength ratio of ~1, and a wet rock salt viscosity, it can be shown that an evaporate layer in Hellas would be unstable to thermal convection. However, if evaporites were present throughout the Hellas basin, a very large volume of salt-saturated water (hundreds of meters Global Equivalent Layer) would be required to account for the volume of deformed terrain.

Together with the apparently basaltic composition of the surface (from Gamma-Ray Spectrometer elemental maps [11]), these considerations support past convection within an impact melt sheet as most consistent with data.

References: [1] Moore J.M., & D.E. Wilhelms (2001) *Icarus*, *154*, 258-276. [2] Mangold, N., & P. Allemand (2003), *Sixth Mars Conf.*, Abstract #3047. [3] Moore J.M., & D.E. Wilhelms (2007), USGS Scientific Investigations Map 2953, v1.0. [4] Jackson, M.P.A., et al. (1990), Geol. Soc. Am. Memoir 177. [5] Warren, J.K. (2006), Evaporites, Springer. [6] Koschmeider, E.L. (1993), Bénard Cells and Taylor Vortices, Cambridge. [7] Nimmo, F., et al. (2008) *Nature*, *453*, 1220-1223. [8] Zieg, M.J., & B.D. Marsh (2005), *Geol. Soc. Am. Bull.*, *117*, 1427-1450. [9] Helz, R.T. (1980) *Bull Volc.*, *43*, 675-701. [10] Solomon, S.C., et al. (2005), *Science*, *307*, 1214-1220. [11] Boynton, W.V., et al. (2008), pp. 105-125 in Bell, J.F., ed. (2008), The Martian Surface, Cambridge.

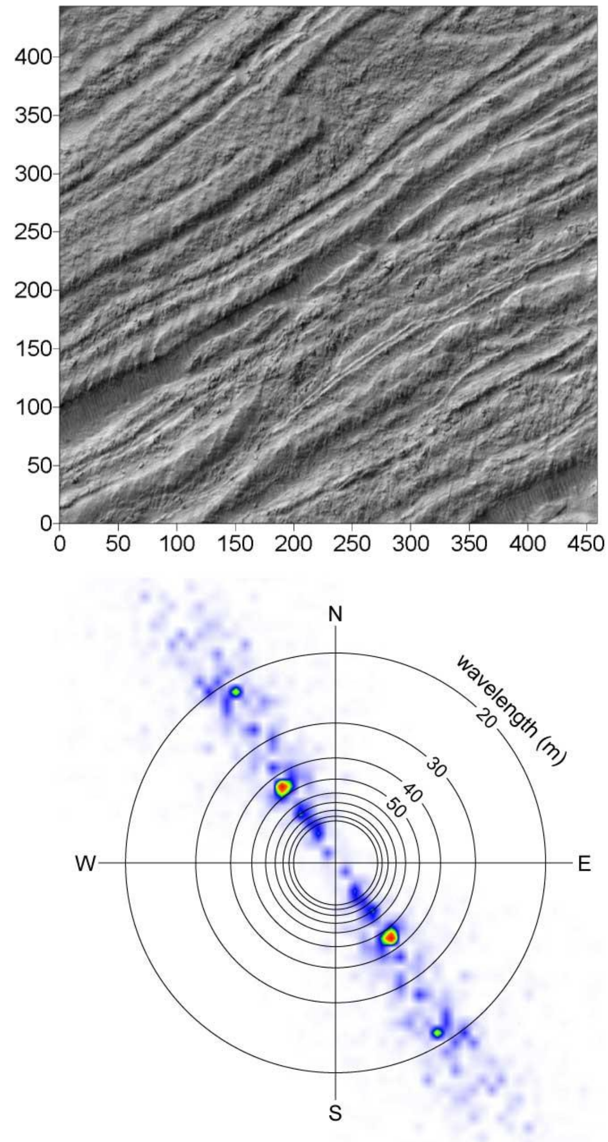

Figure 2. Upper panel: Close-up of shear zone (scale in meters). Lower panel: 2D power spectrum. Colors correspond to spectral power, with warm colors indicating high spectral power. Circles indicate wavelength, with zero frequency at the center. Two peaks are apparent: one at a wavelength of 45m, and a smaller one at 21m. These are visually consistent with the scale and orientation of the banding in the image. Spectral power declines outside of this wavelength band, implying that band thickness (as recorded by erosional resistance and image brightness) is not self-similar. We reason that the best place to try to measure shear band thickness is between two cells of comparable size, where we are most likely to find near-vertical dips. This needs to be confirmed with HiRISE and/or CTX stereo.