FRACTURE FORMATION BY COMPACTION-RELATED BURIAL IN GALE CRATER, MARS: IMPLICATIONS FOR THE ORIGIN OF AEOLIS MONS.
J. A. Watkins[1], J. P. Grotzinger[1], and J-P. Avouac[1], [1]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA, jwatkins@caltech.edu.

Introduction: Gale crater's 5-km-high central mound, Aeolis Mons (Mt. Sharp), has two leading hypotheses for its formation: buildup of windblown sediments [1], and exhumation of deeply buried strata [2]. The deep burial hypothesis implies deformation by gravitational body forces and we evaluate that idea here. Ubiquitous fracture-related features have been regionally mapped from orbit and observed by the Curiosity rover in sedimentary strata including the Murray formation (dominantly mudstone) and the unconformably overlying Stimson formation (sandstone) [3,4]. Large fractures which exhibit complex banding structures (Fig. 1) with distinct chemical trends (e.g., halos) [5] are primarily found in the Stimson formation, but do extend into the Murray formation in one location [6]. Smaller, sulfate-filled fractures are most prevalent in the Murray but are also associated with haloed fractures in the Stimson. We test a compaction-related burial origin for these features based on a mechanical model for mode I fracture formation in order to constrain the regional stress history.

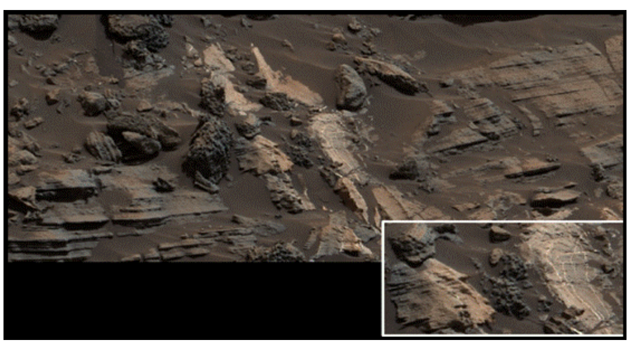

Figure 1. Sulfate-filled fractures associated with fracture-related halo in the Stimson (NASA/JPL-Caltech/MSSS).

Data and Methods: Fractures were first surveyed in High Resolution Science Imaging Experiment (HiRISE, [7]) image data. Criteria for mapping fracture-related features from orbit included ridge expression (raised topography on both sides, i.e., not just a scarp), approximately linear morphology, dark in color as compared to nearby sand dunes, and along the MSL traverse route. Mapped features were classified by confidence level based on how closely they match these criteria (Fig. 2).

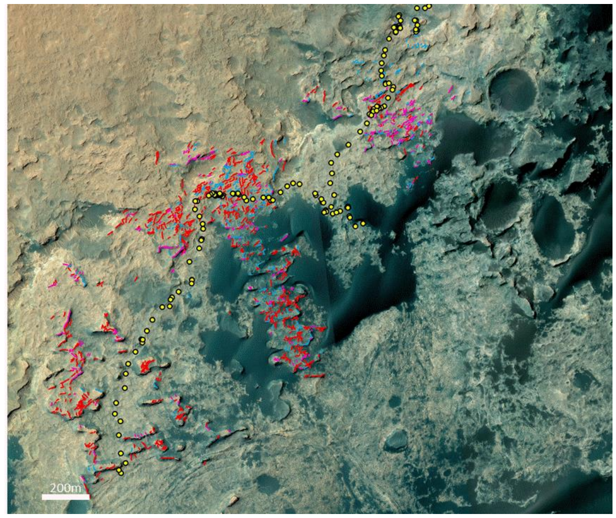

Figure 2. Fracture-related feature locations mapped from orbital data (red= high confidence; magenta= medium; blue= low).

Mastcam image data between sols (4094) and (6249), including mosaics, were also analyzed for the study. We mapped positive-relief fractures, fracture-related halos, and Ca-sulfate-filled fractures using rover data based on defining physical characteristics for each fracture type, including topographic relief, complex compositional banding, and smaller-scale veining, respectively. Fracture orientations in rover images were calculated using Navcam and rover localization data, and their locations were plotted onto the HiRISE image and a high resolution DTM created from the HiRISE stereo pair and MOLA elevation data.

Results: According to the Mohr-Coulomb failure criterion, extension fracturing requires that the minimum principal stress (σ_3) exceed the elastic tensile strength in the plane perpendicular to the opening. Given that tectonic driving processes are inoperative within Gale crater, non-tectonic mechanisms including overburden removal (maximum compressive stress; $\sigma_1 = \rho g D$) and pore fluid pressure release ($p_f \; \alpha \; D$) during exhumation must account for this tensile stress. Significant compaction as a result of increased depth of burial is required for p_f to exceed minimum compressive stress and cause fracturing. When applied to Gale, we find that horizontal stress (σ_3), as induced by crater topography and thermal expansion, is negligible, requiring a substantial burial depth to produce sufficient p_f to cause hydrofracture.

Discussion: Rheology contrasts likely caused fractures to develop and propagate more easily in the Stimson sandstone, which can support a smaller σ_3, than in the Murray mudstone. In these permeable rocks, the sudden local decrease of p_f at fractures likely caused flow of pore water into the fracture, creating the observed alteration of fracture-related halos. Positive-relief fractures, on the other hand, may instead represent preserved bounding surfaces within the cross-bedded eolian Stimson strata [8]. These results imply that formation of these fractures requires at least one significant burial event in the evolution of Mt. Sharp (Fig. 3), providing key insight into the geologic history of Gale crater.

References: [1] Kite E. S. et al. (2013) *Geology, 41*, 543-546. [2] Grotzinger J. P. et al. (2015) *Science, 350*, 6257. [3] Watkins, J. A. et al. (2016) *LPS XLVI*, Abstract #2939. [4] Watkins, J. A. et al. *Geology*, submitted. [5] Yen, A. (2016) *LPS XLVI*, Abstract #1649. [6] Gasda, P. et al. (2016) *LPS XLVI*, Abstract #1675. [7] McEwen A.S. (2007) *JGR*, *112*, E5. [8] Banham S. et al. (2016) *LPS XLVI*, Abstract #2346.

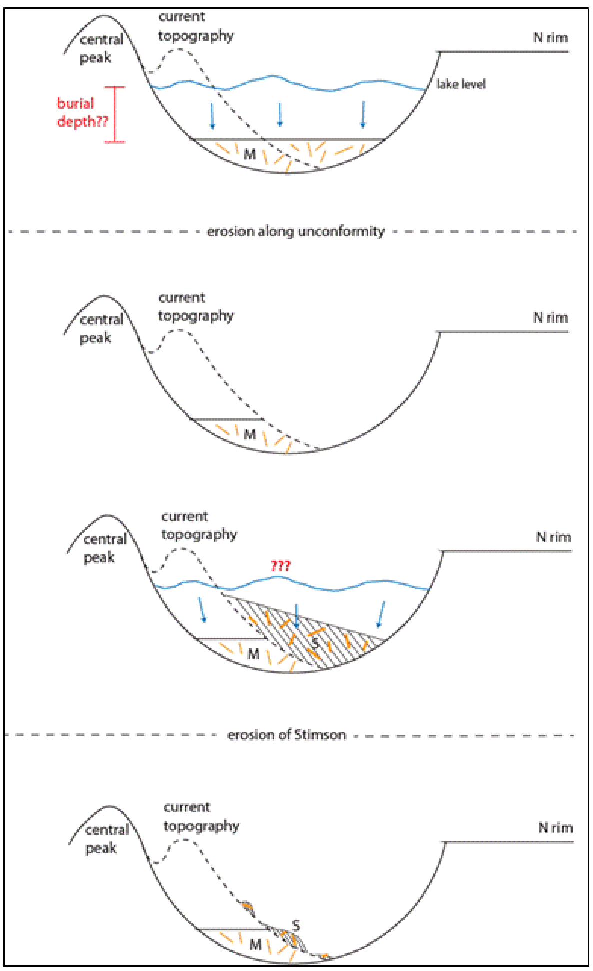

Figure 3. Schematic model for formation of observed fracture-related features within stratigraphic context of Gale crater.