NEW CONSTRAINTS ON THE ORIGIN AND EVOLUTION OF THE LAYERED DEPOSITS IN GALE CRATER, MARS. B. J. Thomson[1], N. T. Bridges[1], R. Milliken[1], J. F. Bell III[2], W. C. Calvin[3] and C. M. Weitz[4]; [1]Jet Propulsion Lab, Caltech, Pasadena CA (bradley.j.thomson@jpl.nasa.gov), [2]Dept. of Astronomy, Cornell Univ., Ithaca, NY, [3]Dept. of Geological Sciences & Engineering, Univ. of Nevada, Reno, NV, [4]Planetary Science Inst.

Summary: Gale Crater contains an unusual central mound of layered deposits and has been considered as a potential landing site for both the MER (Mars Exploration Rover) and MSL (Mars Science Laboratory) missions. We have analyzed newly returned Mars Reconnaisance Orbiter data to help unravel the complex geologic history evidenced by these layered deposits and other landforms in the crater. Results from imaging data confirm geomorphic evidence for fluvial activity and may indicate an early lacustrine phase. Analysis of spectral data have revealed the presence of alteration minerals in some of the lower mound layers, again suggestive of some aqueous activity.

Background and regional context: Gale Crater is a large (152 km diameter) crater located in Aeolis Mensae centered at 5.5°S lat, 222.3°W lon. It straddles the planetary dichotomy boundary, and the northern rim of the crater appears to have been degraded by the same processes that have affected the dichotomy boundary and created the fretted terrain. One of the crater's most notable features is a large central mound of layered material. This interior mound is approximately 45 km by 90 km in plan view, and has a maximum relief of 5 km (meaning the difference between the highest point on the mound and the lowest point of the crater floor) and average relief ~2 km. The nature, origin, and even age of this layered mound are not agreed upon [*e.g.,* 1-4]. Other recent work on Gale includes investigations into the thermophysical properties of the uppermost surface [5], analyses of Gale as a potential landing site for the MER [6] and MSL missions [7, 8], and a preliminary stratigraphic analysis of layer geometry using HRSC stereo-derived DEM data [9].

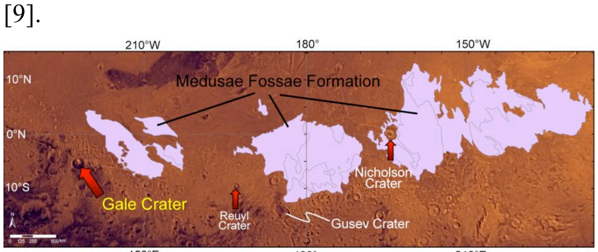

Figure 1. Viking color composite map with Medusae Fossae Formation outlined in purple [from 1, 10]. Nearby large craters with layered interior mounds, including Gale Crater, are indicated by red arrows.

As is evident in the regional context map given in Figure 1, Gale Crater does not contain an isolated occurrence of layered material. Unconformable layered deposits comprising the Medusae Fossae Formation (MFF) occur nearby [1, 10], and numerous other outliers of layered material have been identified [*e.g.,* 11].

Nature of layered material: Images from the MRO HiRISE and CTX instruments have revealed new details about the layers. The layered mound consists of two distinct members: a Lower and an Upper Member. The Lower Member is finely layered and exhibits conformal contact relationships. As observed in HiRiSE images, individual layers are between 1 to 10 m thick. The Upper Member has an erosional contact with the lower member, a fact noted previously [4, 12]. Both massive and layered units are present in the Upper Member.

Spectral signature: Near-infrared spectral data from the CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) instrument have revealed the presence of phyllosilicates in at least one lower layer of the Gale Crater mound (Figs. 2-3). This phyllosilicate-bearing layer is located just below the inverted fan-shaped deposit highlighted in Figure 2.

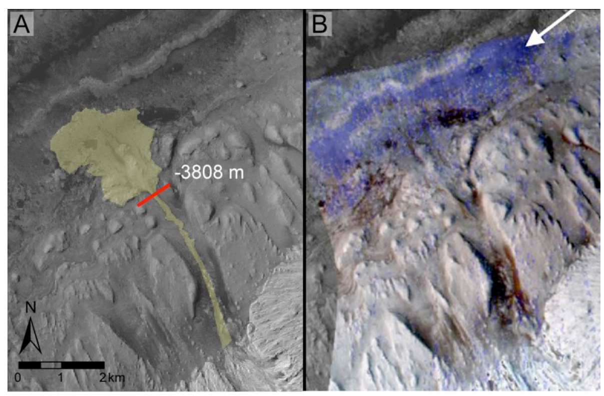

Figure 2. **(A)** CTX image P02_001752_1753_XI_04S222W _061210 showing inverted channel deposit (highlighted in yellow) identified by [4]. **(B)** CRISM color image FRT000058A3 (RGB=2.5, 2.0, 1.1 μm) with 2.3 μm band strength overlain in blue. White arrow points to a coherent layer with strong 2.3 μm signature, which is consistent with the presence of phyllosilicates.

A ratioed spectrum of this phyllosilicate-bearing layer is given in Figure 3. This spectrum exhibits distinct spectral features at 1.91, 2.28, 2.39 and 2.5 μm, which are consistent with a Fe/Mg-bearing smectite. For comparison, a spectrum of nontronite ($Na_{0.3}Fe^{3+}{}_2Si_3AlO_{10}(OH)_2 \cdot nH_2O$) measured in the lab is also given.

Fluvial features: Several characteristics of the inverted channel deposit (Fig. 2) are unusual. First, the transition from channel to depositional fan appears to occur in the middle of a topographic slope. Typically, fans form either at abrupt changes in slope or when a fast-moving stream enters a slower-moving body of water. Second, above the contact between the Upper and Lower Members, the channel changes expression from an inverted channel to a normally incised channel. The Upper Member of layered material appears to be the source region drained by the channel. Finally, this channel is somewhat unique on Mars in that both its source and sink are contained within the basin (and have been preserved). Therefore, in terms of this channel deposit, Gale Crater can be considered a closed hydrologic system. This stands in contrast to the open-flow nature of most other Martian fluvial features [*e.g.,* 13].

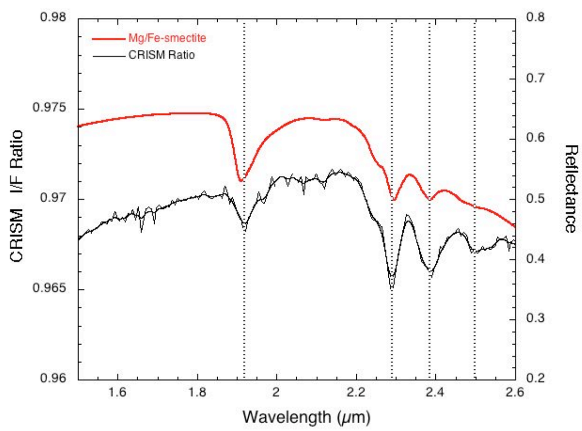

Figure 3. Black line is a ratio of a CRISM spectrum of region of enhanced 2.3 μm signature (marked by white arrow in Fig. 2b) to a nearby layer that lacks such a signature. A lab-measured spectrum of nontronite is given in red for comparison.

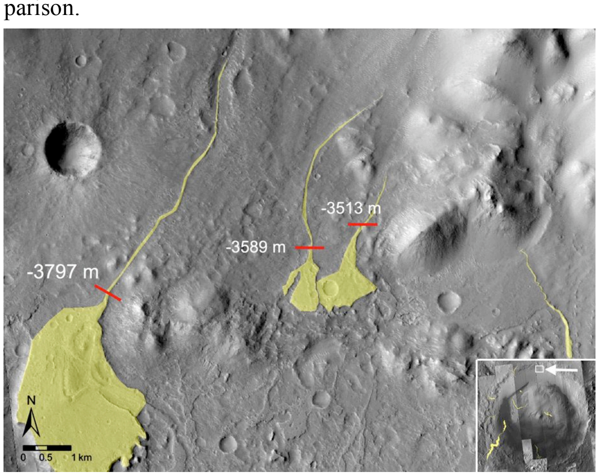

Figure 4. CTX image mosaic showing inverted channels with depositional fans on Gale Crater's northern rim. Red bars denotes transitions from channel to fan; elevation is given in meters. Inset at lower right shows mosaic location marked with white arrow.

Several other inverted channels with associated fan deposits are present along the northern rim of the basin (Fig. 4). Unlike the inverted channel on the layered interior mound (Fig. 2), these channels do not appear to emanate from a distinct layer boundary. But similar to the interior channel, the transition from channel to fan does not appear to be slope-controlled. Indeed, the elevation of these transitions is between about -3800 to -3500 m.

Constraints on geologic history: Some have hypothesized that layered deposits found within Gale Crater and in the MFF are accumulations of volcanic airfall ash [*e.g.,* 14-16]. Yet the observation of fluvial channels, now inverted, that are sourced by the layered material in Gale Crater suggests that a volatile component was also present. The presence of phyllosilicates in at least one of the lower layers of the interior mound also points to the former presence of volatiles, particularly water. It is tempting to infer that the transition from channel to fan on a uniform topographic slope requires the presence of a standing body of water within Gale Crater, but since this transition may have been influced by topography that has since been eroded, such an inference is speculative.

Future exploration: Recent radar sounding measurements of the MFF indicate that they are composed of an extremely low density or ice-rich material [17]. The layered deposits in Gale Crater may provide an easy way to access and explore these enigmatic materials during a moderate rover traverse. We hope to provide further constraints upon the timing of various phases of activity within the crater to help unravel it's complex history.

References: **[1]** Greeley R. & Guest J.E. (1987), *USGS Misc. Map I-1802-B*. **[2]** Scott D.H. et al. (1995), *USGS Misc. Map I-2461*. **[3]** Cabrol N.A. et al. (1999) *Icarus*, *139*, 235-245. **[4]** Malin M.C. & Edgett K.S. (2000) *Science*, *290*, 1927-1937. **[5]** Pelkey S.M. et al. (2004) *Icarus*, *167*, 244-270. **[6]** Bridges N.T. (2001) *1st MER Landing Works.*, abstract #9033. **[7]** Bridges N.T. (2006) *1st MSL Landing Works*. **[8]** Bell J.F., III et al. (2006) *1st MSL Landing Works*. **[9]** Rossi A.P. et al. (2007) *LPSC XXXVIII*, abstract #1553. **[10]** Scott D.H. & Tanaka K.L. (1987), *USGS Misc. Map I-1802-A*. **[11]** Schultz P.H. & Lutz A.B. (1988) *Icarus*, *73*, 91-141. **[12]** Edgett K.S. & Malin M.C. (2001) *LPSC XXXII*, abstract #1005. **[13]** Carr M.H. (1996), *Water on Mars*, 229. **[14]** Scott D.H. & Tanaka K.L. (1982) *JGR*, *87*, 1179-1190. **[15]** Tanaka K.L. (2000) *Icarus*, *144*, 254-266. **[16]** Hynek B.M. et al. (2003) *JGR*, *108*, doi:10.1029/2003JE002062. **[17]** Watters T.R. et al. (2007) *Science*, *318*, 1125-1128.