CLAY AND SULFATE-BEARING ROCKS IN A STRATIGRAPHIC SEQUENCE IN GALE CRATER.

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Introduction: Gale Crater is a ~150 km diameter impact crater located at 5.3°S, 137.7°E that contains a thick (>5 km) sequence of strata interpreted as sedimentary rocks [1]. Gale is one of four final candidate landing sites for the 2011 Mars Science Laboratory (MSL) rover. Recent data acquired by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument show evidence for clay-bearing rocks overlain by and potentially interbedded with sulfate-bearing units in this stratigraphic sequence.

Data and Methods: We examined all existing CRISM 'targeted' images (ranging from ~18 – 36 m/pixel) covering Gale's central mound and surrounding portions of the crater (Fig. 1). CRISM radiance spectra were divided by the solar flux, cosine of the incidence angle, and a scaled atmospheric transmission spectrum to produce I/F spectra. Pixels (spectra) were then averaged for different units of interest and then divided by the spectral average of a dusty or otherwise spectrally 'neutral' area. Spectral ratios act to accentuate weak absorption features that might otherwise not be observed in the unratioed I/F spectra and have been used successfully in previous studes [e.g., 2, 3]. High Resolution Imaging Science Experiment (HiRISE) and Context Camera (CTX) images were used to guide the pixel selection process to ensure that averaged pixels corresponded to distinct stratigraphic or geologic units.

Band parameters (e.g., band depth of the 1.9 µm H_2O feature) described by [4] were also examined to search for mineralogically interesting areas and to help select pixels for averaging. Maps of these band parameters were overlain on CTX and HiRISE images to determine the stratigraphic relationship of different mineral signatures (Fig. 2).

Results: CRISM spectra of the bottom ~2 km of stratigraphy in the mound exhibit absorptions consistent with the presence of Fe-rich smectites (i.e., nontronite, Fig. 3), mono- and polyhydrated sulfates (likely Mg sulfates, Fig. 4), hematite, pyroxene, and olivine. The uppermost portion of the mound is spectrally similar to dusty regions, consistent with the lower thermal inertia values [5] that also suggest dust mantles the upper rock units. The dark dunes on the crater floor commonly exhibit pyroxene and/or olivine signatures. Similarly, what appears to be the youngest stratigraphic unit also exhibits pyroxene signatures. This unit is found in the northern part of the crater (including areas adjacent to the proposed MSL landing ellipse) and onlaps the lowermost strata of the mound with a dip to the north-northeast. In some locations, small (~100s meters) erosional windows through this unit exhibit hematite signatures, though more data are needed to determine the exact stratigraphic position and extent of these oxides.

The majority of beds exposed in the lower ~2 km of the mound exhibit sulfate signatures, primarily polyhdyrated sulfates. These signatures are weak along the northern portion of the mound owing to moderate dust cover, but they become progressively stronger along the western edge of the mound where the dust cover is minimal. In Fig. 2, the reddish-orange units indicative of sulfates can be traced along the mound and are clearly exposed in a large canyon on the west side of the mound. The sulfate spectra are most consistent with polyhydrated suflates, although spectra of the cyan-colored regions in Fig. 2 exhibit features at ~2.1 and ~2.4 µm consistent with a monohydrated sulfate such as kieserite (Fig. 4).

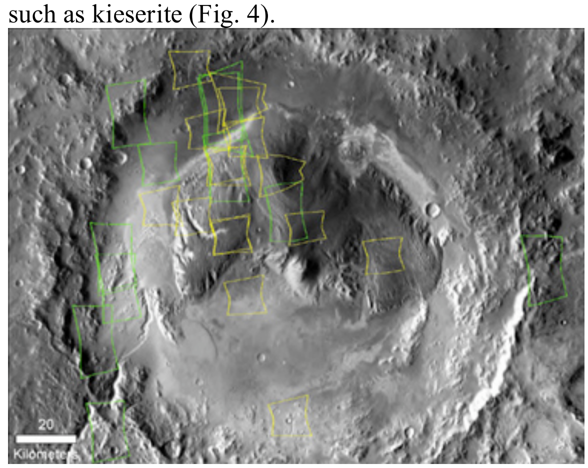

Fig. 1. CRISM coverage in Gale Crater. Yellow boxes were acquired at ~18 m/pixel, green boxes at ~36 m/pixel.

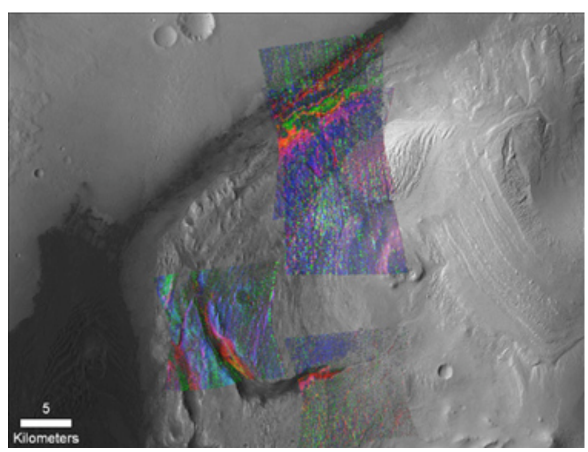

Fig. 2. CRISM band parameter maps overlain on CTX mosaic. Red indicates Fe-bearing materials, green clays, blue sulfates, and reddish-orange indicates sulfates mixed with mafic minerals.

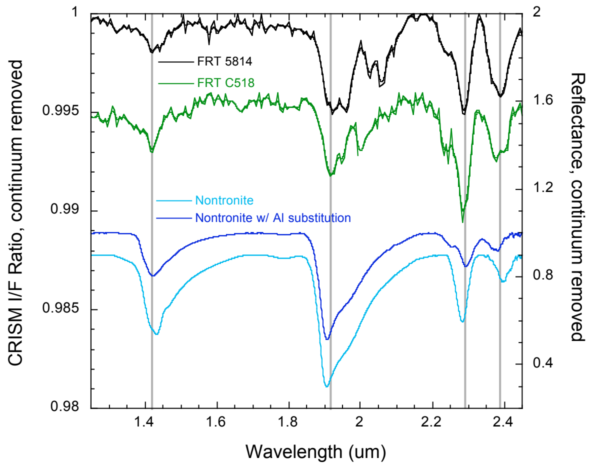

Fig. 3. Continuum-removed spectral ratios of clay-bearing units in CRISM show that the position of the metal-OH band is at ~2.29 µm, consistent with Fe as the dominant cation. The shoulder at ~2.25 indicates some Al is present. CRISM spectra are from the green unit in the upper half of Fig. 2.

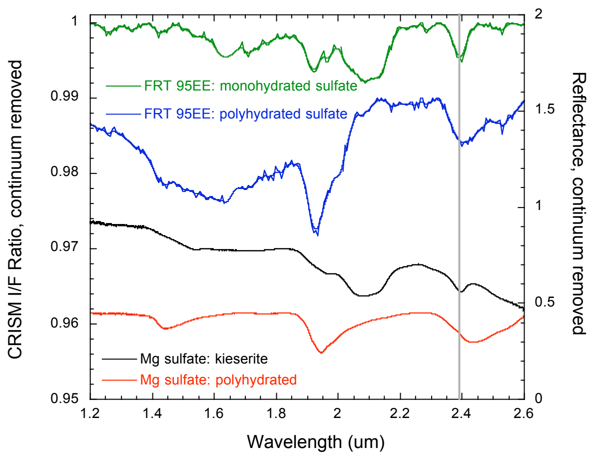

Fig. 4. Continuum-removed spectral ratios of sulfate-bearing units show evidence for mono- and polyhydrated sulfates. The lack of clear Fe bands suggests they are Mg-bearing sulfates. CRISM spectra are from the orange and bluish units in the bottom left image in Fig. 2.

The canyon on the west side of the mound provides an excellent cross-section of this portion of the sedimentary sequence. In addition to exposures of the sulfate-bearing strata, CRISM data indicate the presence of several contiguous clay-bearing beds located within the thicker sulfate sequence (Fig. 5). The spectral signatures of these clays are similar to those exposed at the base of the northern portion of the mound (green area in top half of Fig. 2), although some spectral ratios in the canyon suggest the clays are mixed with sulfates in these rocks. Additional data and analysis of the strike and dip of these clay beds are needed to determine if the clay beds exposed in the canyon are the same units exposed along the northern edge of the mound. Regardless, it is clear the sulfate-bearing rocks overlie the clay-bearing rocks within the mound and, in the case of the canyon, sulfates appear to underlie the clay-bearing unit as well.

Conclusions: Although previous studies of spectral data for Gale Crater were not able to identify the presence of specific hydrated phases, the high spatial and spectral resolution of CRISM has resulted in the detection of both clay minerals (nontronite) and sulfates. These phases are present in the lower several kilometers of the mound, but their presence in the upper portions cannot yet be determined due to dust cover and incomplete CRISM coverage. The majority of the mound appears to be sulfate-bearing, whereas clay-bearing rocks are restricted to several distinct stratigraphic units. CRISM mapping data (100-200 m/pixel) also show clays along the base of the northern crater rim and at the base of the southern edge of the mound, but higher resolution CRISM data are needed to explore these outcrops in detail.

The changes in mineralogy with stratigraphic position in Gale Crater indicate changes in environmental conditions, source area, water level, depositional mechanisms, diagenetic conditions, or a combination of these factors. Although there is no direct evidence that Gale contained a persistent body of water, the role of groundwater is currently unknown and the presence of nontronite indicates moderate pH and reducing conditions [6] in the clay source area, which are favorable for the preservation of organic material. Such a thick sedimentary sequence with diverse mineralogy likely preserves an equally diverse record of depositional and environmental conditions, thus making Gale Crater an excellent target for the MSL mission.

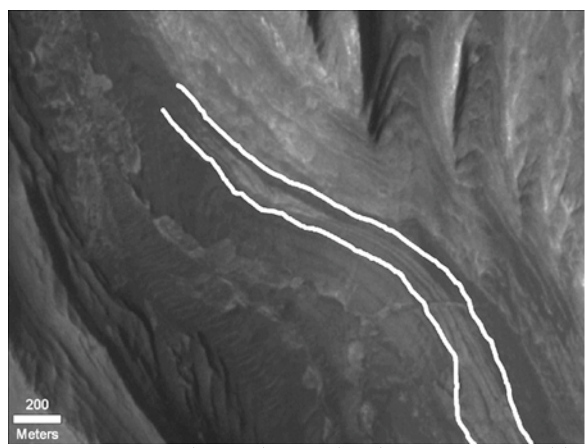

Fig. 5. Annotated CTX image showing strata exposed in a large canyon on the west side of the central mound in Gale. CRISM indicates that beds between the white lines contain clays, whereas those above and below contain sulfates.

References: [1] Malin and Edgett (2000) Science 290, 1927–193; [2] Mustard et al. (2008), Nature, 454, 305-309; [3] Milliken et al. (2008) Geology, 36, 847-850; [4] Pelkey et al. (2007), JGR, 112, E08S14; [5] Pelkey et al. (2004) Icarus, 167, 244-270; [6] Harder (1978) Clays & Clay Min., 26, 65-72.