

MICROSCALE CHEMICAL AND SPECTRAL CHARACTERIZATION OF CLAY-BEARING EVAPORITES AND IMPLICATIONS FOR THE MARS 2020 ROVER. M. J. Meyer¹, R. E. Milliken¹, K. M. Robertson¹, and J. A. Hurowitz². ¹Dept. Earth, Env., and Planetary Sciences, Brown University, Providence, RI 02912, ²Dept. Geosciences, Stony Brook University, Stony Brook, NY 11794. melissa_meyer@brown.edu.

Introduction: Searching for biosignatures as evidence of past life is an important goal of current and upcoming rover missions to Mars. Sedimentary deposits containing hydrated minerals such as sulfates and clays have been detected by both orbiters and rovers and may indicate past potential surface habitability [1-3]. Sulfate-rich strata, in particular, have been identified in many locations on Mars [4-6] and may have formed through evaporation of surface water [7-9] or diagenetic precipitation via groundwater circulation [4].

On Earth, occurrences of sulfate and clay in stratigraphic successions can have specific implications for surficial paleoclimate conditions and biosignature preservation potential. Clay minerals have a strong absorptive affinity for organic compounds, can catalyze organic reactions, and have even been proposed to play a role in the origin of life on Earth [10]. Terrestrial sulfates commonly indicate the evaporation of surface or near-surface brine bodies in arid climates [11]. The sulfate-rich evaporites that precipitate in shallow shelf basins behind carbonate reef margins—which are investigated here—commonly host and preserve chemical and morphological evidence of past life [12]. Thus, studying the preservation of biosignatures in these sulfate and clay-enriched environments on Earth, and examining how they may (or may not) be properly identified using rover-based payloads, can provide insight about mineralogically-similar sedimentary environments on Mars. Specifically, it is important to

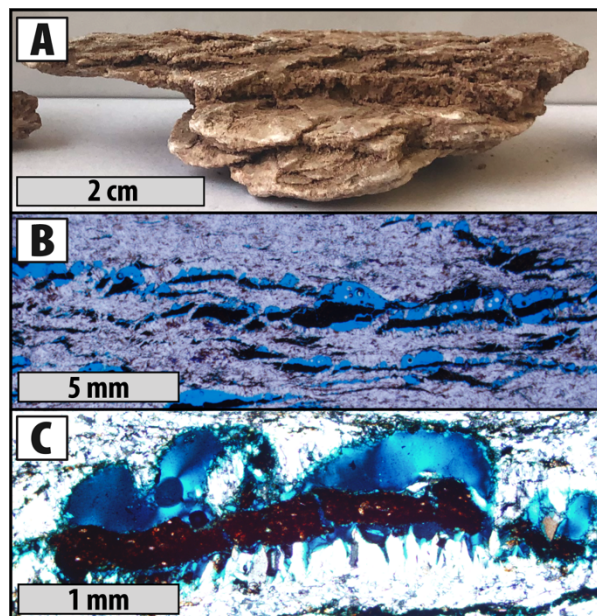


Fig. 1: (A) hand samples and (B & C) thin section images of Seven Rivers Formation evaporite samples. Blue tones are epoxy. Dark 'dust' regions are clay-rich.

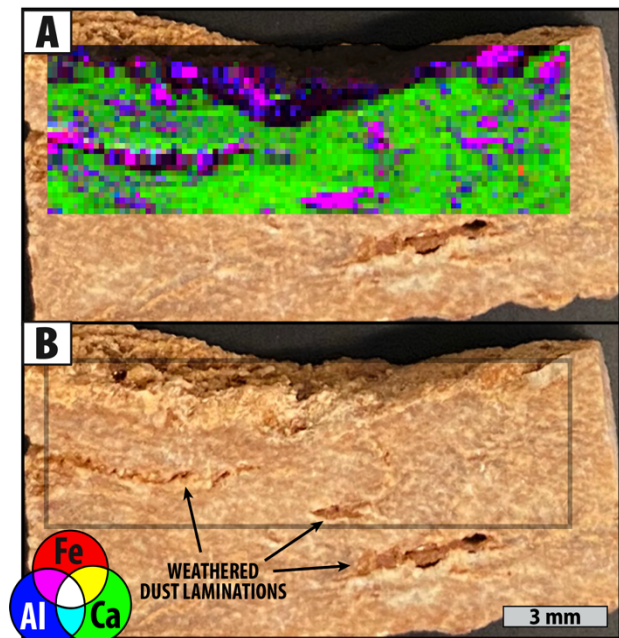


Fig. 2: (A) PIXL RGB elemental map and (B) corresponding true color image of sample. 'Dust' regions are enriched in clay and organics relative to surrounding sulfate.

understand how measurements at rover (micrometer to meter), airborne (decimeter to meter), and orbital (meter to kilometer) scales can be integrated to better assess the composition, likely depositional environments, and biosignature preservation potential of ancient sedimentary environments.

As part of this process, this study examines the Seven Rivers Formation near Carlsbad, NM, which preserves the shallow, restricted marine backreef facies of the Permian Capitan Reef (Guadalupe Mountains, NM). Strata of this field site preserve several distinct biosignatures, are enriched in a variety of Mars-relevant minerals (sulfate, clay, carbonate, Fe-oxides), and were the location for the 2007 MSL rover slow motion field test [13]. Our preliminary investigation includes rover-scale analyses of patterns in texture, mineralogy, near-IR point and imaging spectroscopy, and chemistry of select samples. We include measurements made with a laboratory version of the Mars 2020 rover Planetary Instrument for X-ray Lithochemistry (PIXL) instrument to provide elemental and textural information. Here we focus on the characterization of organic enrichment that is associated with eolian dust preserved in between laminations of precipitated and recrystallized gypsum in samples from the backreef environment (Fig. 1 and 2).

Methods: For powdered analyses, bulk rock samples were ground and sieved to < 45 μm particle size. 'Dust-rich' areas were separated from the laminated gypsum

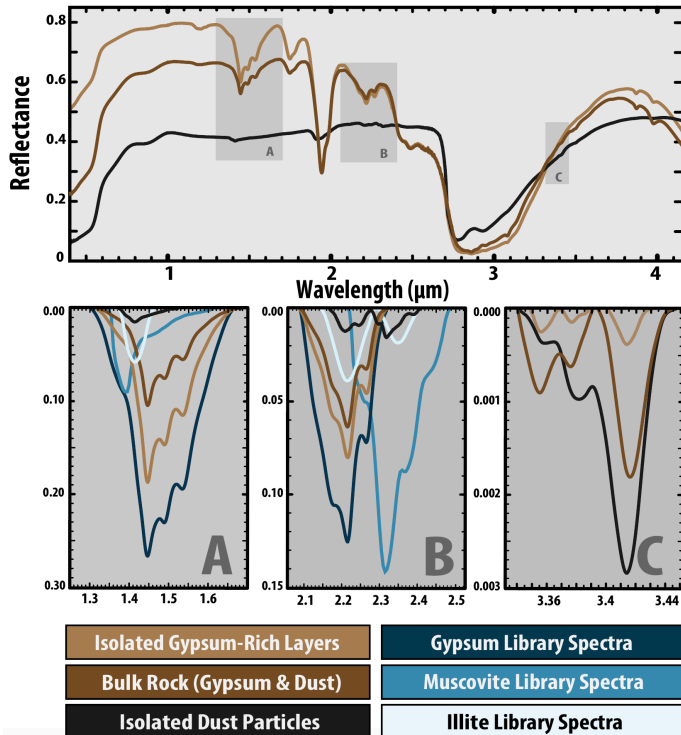


Fig. 3: Reflectance spectra for the bulk rock sample and isolated constituents. Insets show continuum-removed key absorption features for each measurement and relevant library spectra.

matrix, ground, and sieved to $<45\ \mu\text{m}$ particle size. Powdered x-ray diffraction patterns were measured from $2 - 90^\circ\ 2\theta$ using a Bruker D2 Phaser with a Copper-K α x-ray source. Reflectance spectra acquired with an ASD FieldSpec3 ($0.35 - 2.5\ \mu\text{m}$) and Thermo iS50 FTIR spectrometer ($1.5 - 25\ \mu\text{m}$) were spliced at $2.1\ \mu\text{m}$ to provide continuous reflectance values from $0.35 - 25\ \mu\text{m}$. Reflectance measurements were also taken using a Bruker LUMOS FTIR microscope ($1.5 - 16\ \mu\text{m}$) in order to constrain the spectral characteristics of microscopic textures. Elemental maps were collected across samples using the breadboard PIXL instrument at Stony Brook University with a $150\ \mu\text{m}$ step size.

Results: Thin section observations (Fig. 1B) confirm previous interpretations that the Seven Rivers Formation evaporites were deposited in a salina (i.e., subaqueously in a shallow shelf basin under a density-stratified water column) [14, 15]. Fine-grained, wavy-discontinuous gypsum laminations are dominant and interbedded with secondary amounts of wavy-discontinuous dark-red silt laminations. These silt particles are interpreted as wind-blown dust particles deposited via suspension settling (Fig. 1A). This interpretation is consistent with the broader geologic interpretation that the Seven Rivers Formation records deposition in an arid climate where eolian processes delivered sand to the inner shelf where they were

reworked subaqueously [14,15]. Mosaic textures replace much of the primary gypsum laminations observed petrographically and indicate early diagenesis [14]. Gypsum preferentially dissolves around dust particles (Fig. 1C) and reprecipitates as meniscus cements, which enhances the physical weathering of dust laminations.

The matrix of these samples is dominated ($>90\ \text{wt}\%$) by gypsum with secondary amounts of apatite and dolomite. In contrast, dust particles contain a wide variety of major and trace phases including most notably quartz, albite, muscovite, smectite, and hematite. Spectroscopic (microscope FTIR) measurements of isolated dust laminations, isolated gypsum cement, and bulk rock powdered samples suggest that gypsum-rich layers are spectroscopically distinct from dust particles (Fig. 3). When isolated, dust particle spectra exhibit band positions consistent with montmorillonite and illite/muscovite. However, point spectral measurements of the bulk rock powders lack clear evidence of clays and are instead dominated by gypsum. Characteristic C-H vibration organic bands are also clearly observed in dust particle spectra (Fig. 3C) and their strength correlates with clay bands. However, the C-H bands overlap with carbonate bands, making them difficult to delineate in bulk rock and isolated gypsum-rich samples (Fig 3C).

PIXL elemental maps (Fig. 2) capture the above-described petrographic textures and chemical variations. Dust-enriched laminations correspond with increased abundances of Si, Al, Fe, Ti, Mg, and K. Gypsum-rich laminations correspond with higher abundances of Ca, S, and Sr.

Relevance to Mars: Although a carbonate reef is not an ideal environmental analog, many mineralogical, textural, and paleoclimatic aspects preserved in the Seven Rivers sediments are relevant to Mars. Reflectance spectra of the dust particles indicate a clay fraction that is associated with the presence of organic compounds. These subtle but important components are apparent in spectra when the clay-bearing dust is isolated and powdered, but they are overpowered by the dominant presence of gypsum in bulk rock samples. These textural and chemical features are, however, captured by the PIXL instrument, which is promising should the Mars 2020 rover encounter similar deposits in Jezero Crater.

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