**INTRODUCTION:** Gypsum (CaSO₄·2H₂O) can be a powerful indicator of environment, climate, and life. On Mars, hydrated and anhydrous sulfate minerals are abundant and have recently been associated with the discovery of possible organic compounds [1 - 3]. Although the potential for terrestrial sulfates to contain biosignatures and environmental indicators (such as water chemistry) has been documented, these studies have been limited to depositional sulfates [4 - 6].

Diagenetic gypsum, such as cement crystals in gypsum veins, have yet to be evaluated for preservation of microbes, organic compounds, and parent waters and gases. Rocks containing diagenetic sulfates have been sampled by the Perseverance rover for return to Earth [7]. This calls for the investigation of terrestrial gypsum veins and their capacity to yield biosignatures and environmental indicators.

This project describes Mars-analog gypsum veins from the Permian Cloud Chief Formation of Texas and the Triassic Red Peak Formation of Wyoming and evaluates their capacity to preserve evidence of groundwater chemistry and microbial life.

Assessing the biosignature preservation potential and interpreting parent groundwater chemistry of ancient gypsum veins from Earth has relevance to two Mars Sample Return objectives [8]:

- **Objective 1:** Interpret the primary geologic processes and history that formed the Martian geologic record, with an emphasis on the role of water.
- **Objective 2:** Assess and interpret the potential biological history of Mars, including assaying returned samples for the evidence of life.

The same methods used to reconstruct groundwater chemistry and identify trapped microbes and organic compounds from ancient terrestrial gypsum veins may also be used on Mars return samples.

**BACKGROUND:** Gypsum can form in multiple ways at and near the Earth surface; each style of formation is marked by a different texture. Most depositional gypsum, otherwise known as bedded gypsum, precipitates at the Earth’s surface in saline lakes or seawater. Some gypsum crystals that originated as surface water precipitates are physically reworked and deposited as clastic bedded gypsum. In contrast, diagenetic gypsum forms when saline groundwaters precipitate in pore spaces in a pre-existing sediment or rock, or when saline groundwaters promote gypsum replacement of a pre-existing mineral. One common occurrence of diagenetic gypsum is in the form of veins (Fig. 1A-C). Gypsum veins form when a saline groundwater precipitates gypsum cement crystals in a fracture in rock. Veins composed of gypsum and other sulfate minerals are common on Earth and Mars, but their history of alteration and biosignature preservation potential is unknown [9 - 13].

**PETROGRAPHY:** Petrography was conducted using transmitted, reflected, polarized, and UV-vis light at 20-2000x magnification. Vein cement crystals were visually evaluated for: (1) types of fluid inclusion assemblages, (2) phases present in primary fluid inclusions, and (3) the presence of any suspect microbes or organic compounds, either as solid inclusions or within fluid inclusions (Fig. 1D). Fluorescent response to UV-vis light was used to recognize carbon-carbon and carbon-hydrogen bonds, providing a preliminary indicator of the presence and type of organic material [14]. For example, bacteria and archaea fluoresce pale green, algae fluoresces blue, and beta carotene fluoresces orange-pink [15].

**LASER RAMAN SPECTROSCOPY:** Laser Raman spectroscopy was used to identify the mineral composition of the vein cement crystals and suspect microbes and organic compounds targeted during petrography. We used a Renishaw InVia Raman microprobe with a 532 nm laser. Micron-scale targets in crystal interiors were targeted with long-working distance microscope objectives. Spectral peaks were matched with SpectraGlyph 1.1 software, the RUFF database, and literature of known Raman peaks. Because gypsum has its own Raman spectra, deciphering the spectral peaks of potential biosignatures from the peaks of the host gypsum is challenging. When analyzing Raman spectra of suspect microbes or organic compounds, we stacked the host gypsum spectrum with the spectrum of suspect biosignatures, and used non-gypsum peaks to confirm the presence of organic compounds.

**RESULTS:** Preliminary results suggest that most fluid inclusions in gypsum vein cements are smaller than 5 µm. Many are less than 1 micron in size, which is too small to investigate with many Raman and petrographic technologies. Solid inclusions of suspect microbes were identified in gypsum vein cements (Fig. 1D). These suspect organics are 20-40 µm, which is big enough to easily inspect with both petrography and Raman...
spectroscopy. Therefore, diagenetic sulfate minerals have the potential to preserve biosignatures as solid inclusions.

Laser Raman spectroscopy indicates that the vein cements are composed of gypsum, rather than its dehydrated form, anhydrite. This may suggest that these terrestrial gypsum veins have not experienced neomorphic alteration since their cement growth. Textural evidence, including the absence of interlocking crystal mosaic, supports this interpretation.

**Conclusions:** Ancient diagenetic sulfates from Earth may preserve suspect biosignatures. Gypsum vein cements contain unaltered proxies of past groundwater. This study demonstrates the previously unexplored capacity of Martian diagenetic sulfates to contain biosignatures and indicate original groundwater composition. Non-destructive techniques of petrography and laser Raman spectroscopy should be conducted on sulfate vein cements from Mars.

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**References:**


Figure 1: Gypsum veins in Triassic red siliciclastic mudstone from Wyoming. A, in outcrop, white gypsum veins crosscut red mudstone. B, in outcrop, the gypsum vein cement crystals have a vertical, fibrous texture. C, in thin section, the veins crosscut red mudstone and have a vertical texture; XPL. D, within the crystal interiors of the gypsum vein cements, suspect microbes and organic compounds (orange) and tiny fluid inclusions are visually identified; transmitted light.