A MARS-ANALOG SULFATE, MIRABILITE, TRAPS AND PRESERVES BIOLOGICAL MATERIALS FROM ITS ENVIRONMENT IN THE GREAT SALT LAKE, UTAH. K. K. Gill[1], E. A. Jagniecki[2], and K. C. Benison[1] [1] Department of Geology and Geography, West Virginia University, Morgantown, WV, USA 26506; karena.gill@mail.wvu.edu, [2] Utah Geological Survey, Salt Lake City, UT, USA, 84116

Introduction: Mirabilite ($Na_2SO_4 \cdot 10H_2O$) is a hydrous, sodium sulfate chemical sediment that forms as crystals when sulfate-saline spring waters interact with cold winter air temperatures. The Great Salt Lake (GSL) in Utah hosts several high salinity, Na_2SO_4-saturated spring seep pools and, during the winter months, hypersaline liquid cryobrines develop as air temperatures reach below 5 °C [1], [2]. Mirabilite precipitates as clear-bladed and tabular crystals (1-10 cm in length) at the air-water interface around the spring seep orifices. Continuous hydrologic discharge creates multiple generations of mirabilite as micro-terracettes from cascading flow, forming crystalline mounds. Mirabilite is stable in saturated solution but unstable in the ambient surface atmosphere where it dehydrates to the mineral thenardite (Na_2SO_4). This decomposition is very rapid and can occur within minutes, which makes studying mirabilite challenging. The objective of this abstract is to present evidence that mirabilite traps and preserves halophilic and halotolerant microbial life in primary fluid inclusion.

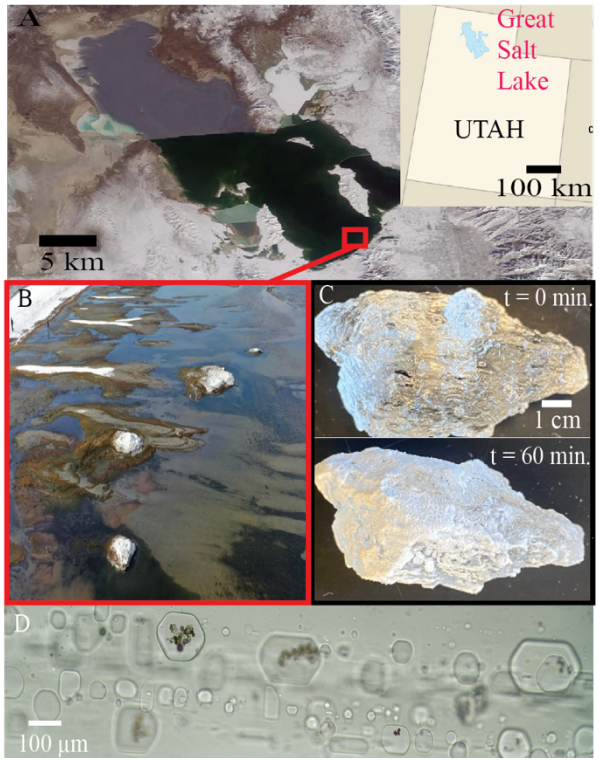

Fig. 1: Images of Great Salt Lake (A) and sample locations in the field (B). Mirabilite crystals (C) showing hydrated sample (t = 0 mins., upper) and cloudy, white dehydrated state after 1 hour of exposure to the open air in the lab (t = 60 min., lower). Growth band with abundant primary fluid inclusions and trapped organic material (D).

Sample Materials: Modern mirabilite crystals were sampled from surface deposits collected during the winter of 2020 from GSL. Samples were placed in a double-sealed ziplock bag with a cloth saturated with brine to keep the minerals hydrated and stored in a refrigerator. Small chips were cut with a razor blade and hand-grind/polished to appropriate thicknesses. To prevent rapid dehydration, samples were placed inside an O-ring glued to a large-format (oversize), 51 × 75 mm (2×3") glass slide and covered with another larger-format glass slide.

Organic Materials Trapped in Primary Fluid Inclusions: A diversity of organisms have been documented in and near GSL brines [1], [2]. Archaea, bacteria, algae, phytoplankton, and brine shrimp all live in GSL waters. The lake also supports halovirus, brine flies, and an avian population. The authors have also observed ostracods trapped within the mirabilite crystals.

Growth bands in mirabilite (Fig 1D) typically have abundant primary fluid inclusions. These inclusions are ~20 – 400 microns, large enough to observe trapped organic material. Our observations show that primary fluid inclusions in mirabilite traps and preserve micro-organisms, including suspect rod- and coccoid-shaped prokaryotes (Fig. 2E/F), halophilic green microalgae *Dunaliella* (Fig. 2A-D), and orange crystals of β-carotene (Fig. 2G/H). The organic materials trapped within the primary fluid inclusions exhibit bright blue and pink fluorescence, typically associated with organic material.

Organic signature by Raman in Mirabilite from Great Salt Lake: Raman spectroscopy has been used for decades to analyze fluid inclusions in situ [3]. Raman spectra of organic material in mirabilite crystals (Fig. 3A-D) have peaks consistent with β-carotene standards at 1010, 1158, and 1518 cm^{-1} [4]. Here, the petrography of fluid inclusions paired with the capability of Raman spectroscopy to detect both organic and mineral compounds, without the need for sample manipulation of both macro- and micro-samples, makes this combination of techniques one of the most non-destructive and promising analytical tools for the detection of organic signals.

Implications for the preservation of life in extreme environments: Besides preserving biosignatures, primary fluid inclusions in mirabilite crystals have the potential to yield high-resolution

measurements of environmental conditions, similar to other well-studied evaporite minerals [4]–[7]. This have the potential to yield high-resolution measurements of environmental conditions, similar to other well-studied evaporite minerals [4]–[6]. This study deepens the current knowledge on the potential of fluid inclusions to trap and preserve microbial communities in salt minerals from extreme environments on Earth.

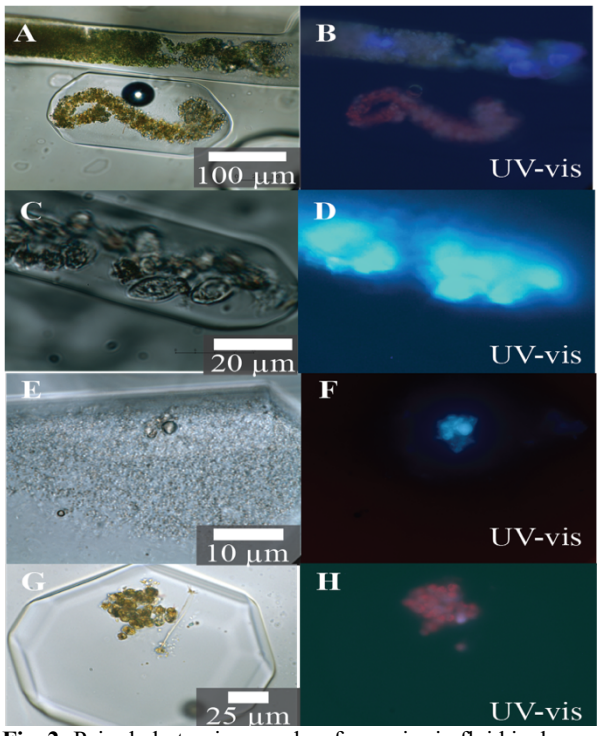

Fig. 2: Paired photomicrographs of organics in fluid inclusions in mirabilite. Light green and orange *Dunaliella* microalgae, suggest preservation of chlorophyll and β-carotene (A-B). Suspect diatoms (C-D), prokaryotes with brine shrimp (?) eggs (E/F). *Dunaliella* cells coated with orange β-carotene, with prokaryotes (G-H).

We show that cryogenic ecosystems could be an oasis of life, with halotolerant and halophilic genera preserved. The microorganisms present in the salts on Earth could be candidates for future studies on distant planets with comparable extreme conditions such as those found in the Great Salt Lake. This is especially applicable to the Mars sample return. Any salt minerals brought from Mars to Earth should be examined for these types of biosignatures [8].

While there is no definitive physical evidence of mirabilite on Mars, HiRISE Image data show white mounds that are hypothesized to be related to saline ground waters [9]. In addition, Martian soils have been shown to contain significant amounts of sulfates, most likely present as magnesium and sodium [10]. Microorganisms may resist extreme conditions such as those of the Martian atmosphere, especially if trapped in minerals. Great Salt Lake microbial organisms are excellent analogs for life that could have been hypersaline lakes on Mars and may remain preserved in the sulfate minerals there.

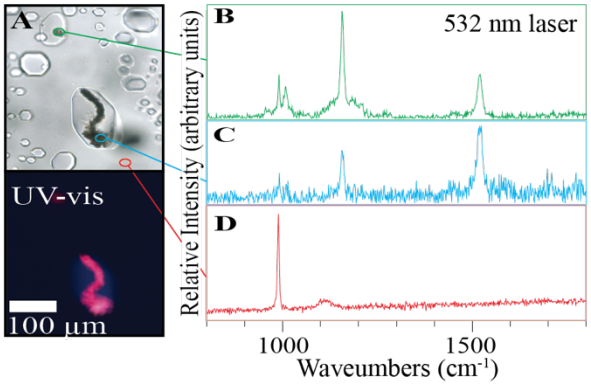

Fig. 3: Raman spectrum of mirabilite crystal in Na_2SO_4-saturated brine water. Paired photomicrographs of organics in fluid inclusions in mirabilite (A). Stacked Raman spectra of β-carotene (B and C) and mirabilite crystal (D).

Conclusions: The sulfate mineral mirabilite, traps and preserves microbial life and environmental conditions in primary fluid inclusions and is an important repository of organic materials that should be carefully examined in the search for ancient microorganisms on Earth, and possibly elsewhere in the Solar System. Mirabilite is capable of storing environmental data about the environment from which the mineral precipitated. Extremophile organisms including prokaryotes and algae, along with organic compounds such as β-carotene, are documented within individual primary fluid inclusions. The use of high-resolution petrographic images and Raman spectra is a very effective combination for the determination of the mineralogy and biosignatures of organic materials preserved within primary fluid inclusions in mirabilite. The confirmation of beta-carotene and its association with microorganisms in individual primary fluid inclusions suggests that mirabilite hosts and preserve microenvironments.

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