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Understanding the formation mechanisms and alteration histories of diagenetic features in Gale crater, Mars, using Earth analogs

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Introduction: Data from NASA's Curiosity rover on Mars has shown that Gale crater held a long-lived lake containing organics and critical elements for life more than 3 billion years ago, however, the chemistry and persistence of this environment is poorly constrained. In particular, it is unclear which secondary minerals in the mudstone dominated Murray Formation formed in primary lake vs. later diagenetic events. Diagenesis is the alteration of rocks by fluids during and after their deposition. Understanding whether the alteration minerals were formed in the depositional environment or through diagenesis is crucial for studying habitability in Gale because these minerals provide key constraints on the timing and types of environments that existed and the preservation of signs of life and organics. The goal of this study is to better constrain the history of diagenetic processes in Gale using remote sensing rover observations and comparisons to Earth analogs.

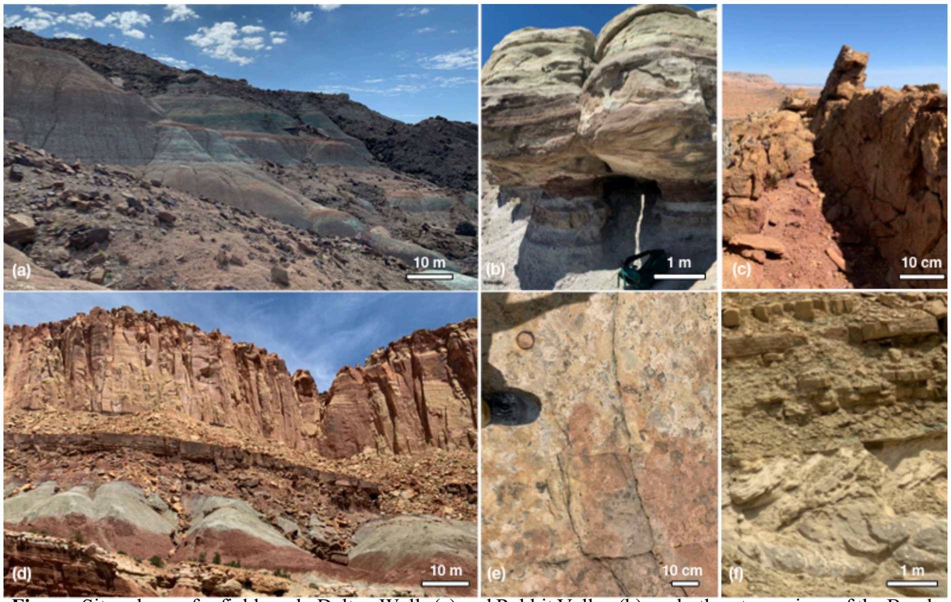

Figure: Sites chosen for field work; Dalton Wells (a) and Rabbit Valley (b) are both outcroppings of the Brushy Basin member deposited in a fluvio-lacustrine environment with early diagenetic oxidation/reduction. Zones of alteration can be seen around Robbers Roost Dike (c) as the igneous intrusion caused bleaching of nearby bedrock and iron mobilization. At Oiler Mine (d), uranium rich reducing fluids were trapped between impermeable mudstone layers. Sandstone at Spencer Flats (e) experienced multiple episodes of oxidation/reduction. Carmel Formation mudstone deposited in a shallow pond environment unconformably lies over the Navajo Sandstone at Justesen Flats (f).

Methodology: We visited sites where mudstones and sandstones are exposed in accessible outcrops (**Figure**). These rocks were deposited in lake environments with complex histories of alteration similar to paleo-lake Gale on Mars. In order to better understand the timing and controls of diagenetic fluids, we looked for outcrops with major unconformities, or a gap in the geologic record, and changes in grain size. The location color, tone, morphology, grain size, and sedimentology of each outcrop was recorded along with context images. Reflectance spectra were acquired using a portable spectrometer of diagenetic features and surrounding bedrock. Samples that appear visually and spectrally similar to those observed on Mars with the Mastcam multispectral imager onboard the Curiosity rover were taken back to the lab for further testing. In the lab, the bulk chemistry and mineralogy of selected rocks will be determined, and we will study individual grains under microscopes help determine whether diagenesis occurred early or late based on the size and position of mineral grains. By comparing what we have learned about how these analog rocks formed on Earth, we will be able to better constrain the aqueous events that formed the minerals we observed on Mars.

Preliminary Results:

- Many of the features observed in Gale are similar in appearance to rocks altered during diagenesis on Earth.
- Widespread oxidation and reduction that caused the color variation visible in the Brushy Basin member at Dalton Wells and Rabbit Valley (Fig. a/b) likely occurred during deposition.
- Iron oxide concretionary coatings observed in Spencer Flats and Robbers Roost Dike are likely formed during late diagenesis where an iron crust fills a fracture (Fig. c/e).
- Both unconformities and grain size differences (Fig. d/f) were observed to have limited the flow of diagenetic fluids as finer grained rocks served as a less permeable barrier

FOR FURTHER READING:

Grotzinger. J. P. et al., (2014) *Science*.
Potter-McIntyre. S., et al., (2014) *JSR*.
Sun. V. Z. et al., (2018) *Icarus*.