National Aeronautics and Space Administration

# Experimental Constraints on Groundwater-Driver Redox Gradients on Mars


## Science Principal Investigator: Rachel Sheppard (322)
## Principal Investigator: Abigail Fraeman (322); Co-Investigators: Rachel Sheppard (322), Laura Barge (322)


**Program: FY21 R&TD** **Strategic Focus Area: Enabling Mars Sample Return Science at JPL**

**Objectives:** Although we have observed evidence of groundwater environments across the surface of Mars, the connectivity of these environments to the surface is poorly understood. Assessing habitability of the subsurface requires an improved understanding of how subsurface water produces solute concentration gradients, and how redox gradients depend on environment type. In this initiative, we simulate the martian subsurface in a biology-free laboratory environment.

Our experiments apply state-of-the-art terrestrial soil/subsurface characterization techniques to the Mars subsurface environments for the first time to study the conditions under which abiotic nitrate cycling may have occurred in the martian subsurface **(Figs. 1-2)**.

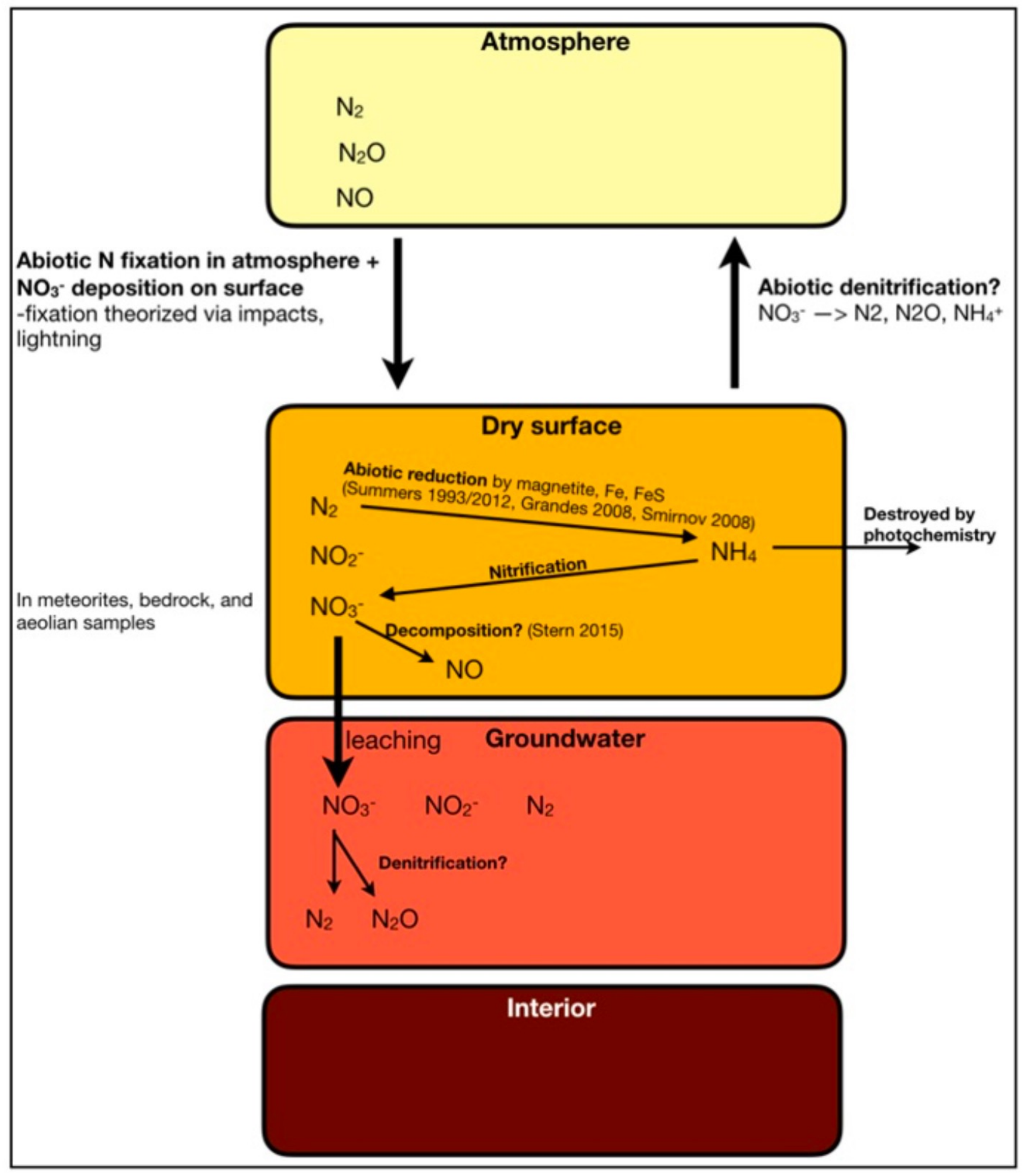
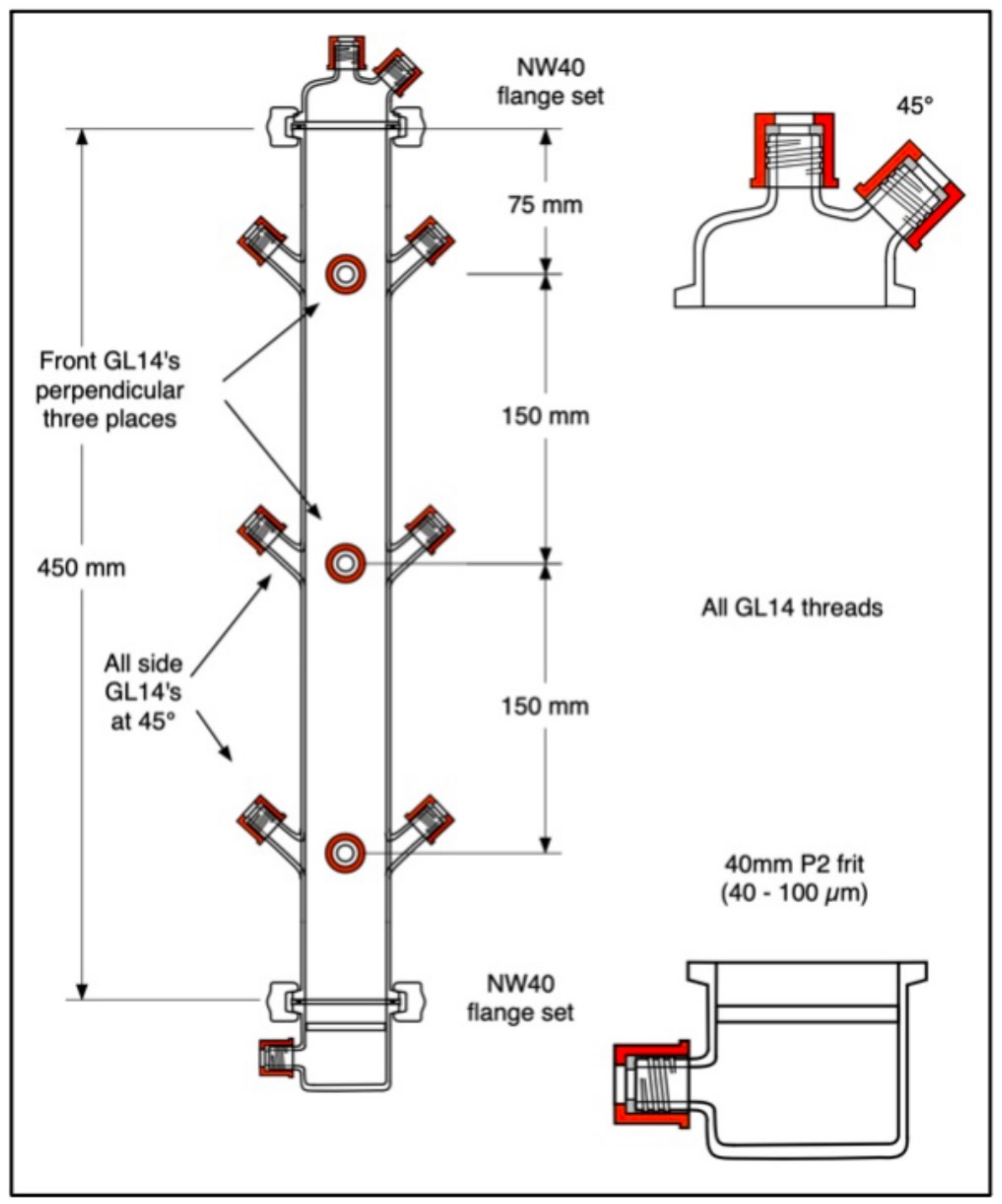



**Fig. 1:** Possible steps occurring in a martian nitrogen cycle.

**Background:** The martian subsurface has moved to the forefront in the search for martian habitable environments because a subsurface environment could harbor all the ingredients necessary for a microbial biosphere: groundwater rich in cations, an energy source (redox and/or geothermal), and protection from radiation. Oxidation and reduction are common energy sources for microbial communities on Earth. The martian interior hosts unmixed reservoirs of differing redox states and lacustrine sediments at Gale crater host plausible redox couples. The spatial coexistence of redox pairs could provide energy-yielding processes that life could harness. Furthermore, any upwelling of the groundwater could have moved biosignatures or environmental indicators of habitability to the surface where they could be observed and explored today.



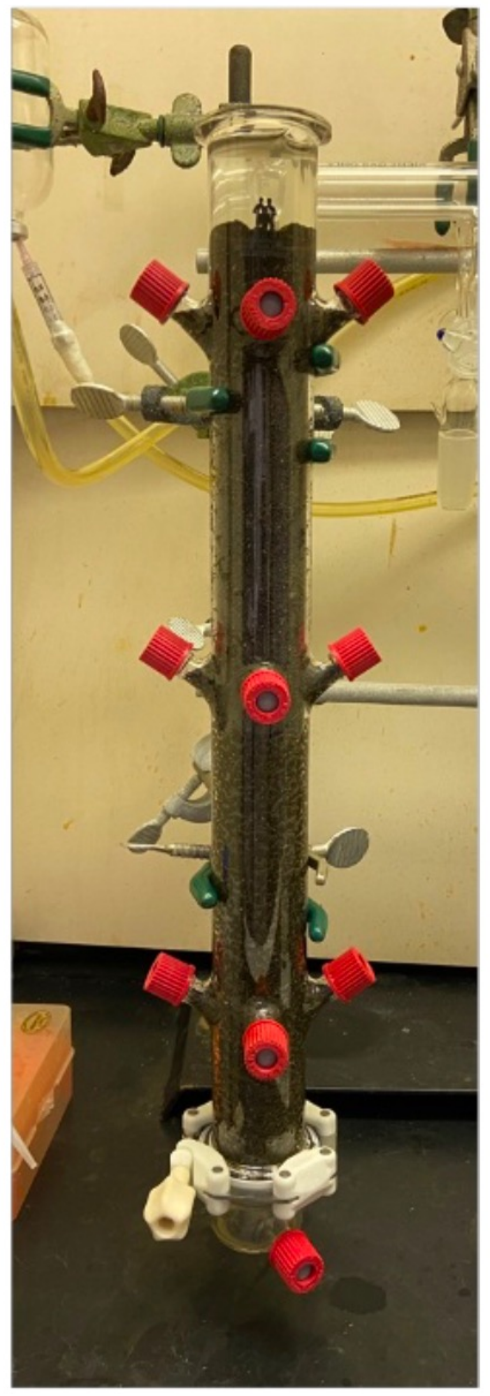
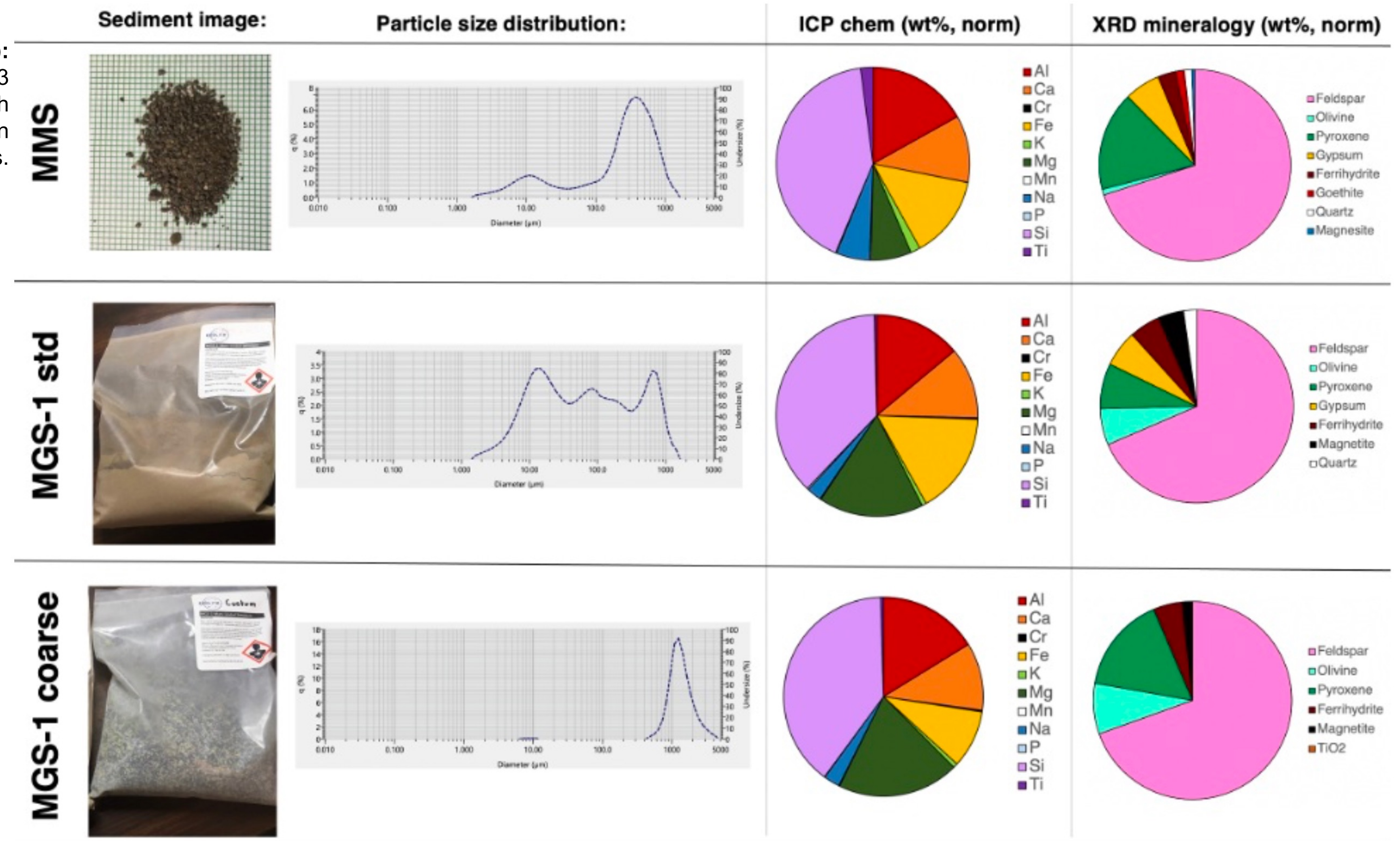



**Fig. 2:** Schematic design of the custom glassware column (left) and image of the custom glassware column filled with MMS simulant (right).

**Approach:** We designed custom sediment columns to simulate the martian subsurface environment. The column can be filled with one of three compositional analog of martian regolith: Mars Mojave Simulant (MMS), Mars Global Simulant-1 (MGS-1), and a version of MGS-1 with only the crystalline component (MGS-1 coarse) **(Fig. 3)**. A tank of groundwater simulant is attached to the bottom of the column, allowing for groundwater to be pumped into the base of the column. Valves on the side and top of the column will allow for sampling of the groundwater at multiple locations and thus measurement of vertical chemical gradients **(Fig. 2)**. This high-resolution sampling will be able to capture the spatial and temporal development of the environment. We vary the volume, refresh rate, pH, and solute concentration of the groundwater in a series of experiments to test the link between environmental conditions, chemical gradients, and changes in nitrate reservoir sizes through time.

**Results and Next Steps:** To prepare for resource-intensive column runs, we first conducted a series of batch experiments exposing the three martian regolith simulants to water of different pH for 28 days **(Fig. 3)**. We found that for all three simulants, groundwater was rapidly buffered to a pH of 9 even in an open system where the water was cycled through. Spectral, chemical, and mineralogical characterization before and after exposure to the fluid is helping guide protocol creation for the longer column experiments. During full columns runs, which will begin next FY, temperature, pH, and redox potential probe will be used to monitor conditions within the sediment as simulated groundwater is cycled through. Liquid and solid samples will also be taken for chemical analysis, with ~5 mL of fluid will be extracted through each of the column ports throughout the experiment, and the same volume of fresh groundwater then added back in. The concentration gradients of nitrate species and other ions will be monitored through time by analyzing each fluid sample separately.

**Fig. 3 (right):** Characterization of 3 Mars regolith simulants used in experiments.




**Significance/Benefits to JPL and NASA:** This is a timely endeavor as the field turns more attention toward subsurface environments. This work explores the source and fate of nitrogen reservoirs in Mars-relevant conditions, addressing whether nitrogen cycling can occur in the groundwater-saturated analogue martian subsurface **(Fig. 1)**. These questions are tied to the goals of ongoing and future missions oriented toward identifying and characterizing water and habitable environments. Understanding the specifics of the martian near-surface groundwater environment will help constrain what water chemistries could have acted as cementing agents for the diagenetic features observed across Mars, with implications for Mars Sample Return, active exploration of the Mars surface, and future exploration of icy worlds including Europa, where understanding surface-subsurface connectivity is critical.

**National Aeronautics and Space Administration**

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California



**Poster No.**
**Clearance No.**
**JPLTask#R20049**