

**LABORATORY SIMULATIONS OF MARS EVAPORITE GEOCHEMISTRY.** J. M. Moore<sup>1</sup>, M. A. Bullock<sup>2</sup>, H. E. Newsom<sup>3</sup>, and M. J. Nelson<sup>3</sup> <sup>1</sup>NASA Ames Research Center, MS 245-3, Moffett Field, CA, 94035, [jeff.moore@nasa.gov](mailto:jeff.moore@nasa.gov), <sup>2</sup>Southwest Research Institute, 1050 Walnut St., Suite 300, Boulder, CO 80302, <sup>3</sup>Institute of Meteoritics, University of New Mexico, Albuquerque 87131.

**Introduction:** This research is part of a multi-year experimental investigation to understand the nature and evolution of brines and evaporites on Mars [1][2]. The spectacular discoveries of the MER rovers and the infrared spectrometers aboard *Mars Express* and *Mars Reconnaissance Orbiter* both illustrate the relevance, as well as guide the future direction, of this work.

Evaporite-rich sedimentary deposits on Mars were formed under chemical conditions quite different from those on the Earth. Their unique chemistries record the chemical and aqueous conditions under which they were formed, and possibly subsequent conditions to which they were subjected. We have produced evaporite salt mineral suites in the laboratory under a variety of simulated Martian conditions. The compositions of these synthetic Mars evaporites depend on the atmosphere under which they were desiccated, as well as the chemistry of their precursor brines.

**Evaporite Experiments:** We synthesized two atmospheric compositions for these experiments: Present-day Martian conditions and a more acidic, 'paleo-Mars' gas mixture with trace amounts of SO<sub>2</sub>, N<sub>2</sub>O, and HCl to simulate an atmosphere influenced by volcanic emissions. Brines formed by the interaction of water with an SNC-derived synthetic Mars mineral mix, which were produced under the acidic Mars atmospheric gas mixture [2]. We then produced a synthetic brine (Table 1) that closely mimicked the brine we produced in our brine formation experiment [2]. The brines were then desiccated under simulated Mars conditions in the evaporite apparatus.

**Evaporites Experiment Apparatus:** Formation of the evaporites are carried out in thin, conical 50 cc teflon sample holders that sit inside and line cylindrical receivers. Precipitation occurs at the bottom of each sample holder on a gold-plated TEM sample grid with a holey-carbon thin film, which is removed at the conclusion of a run and placed directly into an XRD sample chamber. Each receiver contains a conical cavity for supporting the teflon sample holders, a helical path about the outside diameter, and two O-rings to contain coolant. The helical path provides efficient circulation of the coolant near each sample for temperature stability. The sample holders and receivers are mounted into a stainless steel cooling block that is itself fitted with coolant lines to further ensure an isothermal environment. The entire assembly (9 flasks within a block) resides within a vacuum desiccator chamber. The desiccator has been fitted with two gas valves; one for flushing its interior with a synthesized Mars gas, and

the other for pumping the desiccator down to pressures as low as 1 mbar when required. The gas input and output valves are teflon solenoids which can be actuated both manually and by the computer-controller. A pressure sensor feeds information back to the computer to ensure appropriate pressure in the chamber. Cambridge Sensotec Rapidox 200 O<sub>2</sub> sensors (capable of detection of O<sub>2</sub> down to 10<sup>-17</sup> ppm) have been fit into the vacuum lines. These are constantly monitored by the computer-controller in order to detect any oxygen contamination. An electrical feed-through allows signals from thermistors attached to the sample flasks to be passed to the computer controller. A laptop computer using Labview and a PCMCIA data acquisition card serves as the controller, measuring temperature and pressure in the chamber, logging data and controlling the vacuum pressure in the chamber

**Experimental Procedure:** The four-run experiment set we are reporting here involved the fast (days) and slow (weeks) evaporation of our brine once under the "modern Mars" head gas composition and again under the "paleo-Mars" composition. The rate of evaporation was controlled by the temperature and pressure of the samples. The slow evaporation temperature and pressure was held just above 0°C and 10 mbar, while the fast evaporation temperature and pressure was held at 25°C and 500 mbar. Also the gas flow rate was constant for all runs.

Brines were placed into 9 sample holders (in the amounts of 20 ml), and desiccated. The desiccation of liquid samples was followed by visual (video monitoring) inspection. The thoroughly dry precipitate samples were removed in an oxygen and moisture free glove box, sealed, and sent to analysis.

**Results:** Infrared reflectance spectroscopy (Fig. 1) and SEM microprobe analyses (Fig. 2) revealed that salts precipitated from the evaporating brine under simulated modern Mars conditions were chemically different from those formed under the acidic Mars atmosphere conditions.

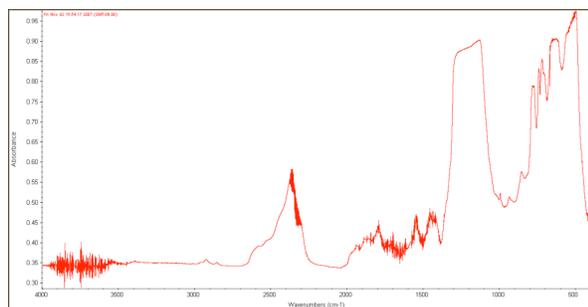
The primary salt precipitated from the brine evaporated under present-day conditions was a hydrated calcium sulfate, with lesser amounts of a magnesium sulfate. Small amounts of carbonate and an aluminum salt also precipitated. Salts precipitated from the brine evaporated under an acidic atmosphere were dominated by magnesium sulfates, with lesser amounts of calcium sulfates. Small amounts of carbonate and sodium and potassium salts also precipitated, but no detectable amounts of aluminum.

	Ion	K	Fe	Al	Mg	Ca	Na	Cl	NO3	SO4	CO3	Si
	Normality	1.79E-05	5.37E-07	3.45E-04	2.01E-03	1.42E-03	1.44E-04	5.36E-05	8.06E-06	3.75E-03	8.33E-07	7.80E-04
<b>Salt</b>												
KCl	1.79E-05	1.79E-05						1.79E-05				
FeCl2	5.37E-07		5.37E-07					1.07E-06				
Al2(SO4)3	1.72E-04			3.45E-04						5.17E-04		
MgNO3	8.06E-06								8.06E-06			
MgSO4	2.00E-03				2.00E-03					2.00E-03		
Na2SO4	7.18E-05						1.44E-04			7.18E-05		
CaSO4	1.16E-03					1.16E-03				1.16E-03		
CaCO3	2.63E-04					2.63E-04					2.63E-04	
HCl	3.46E-05							3.46E-05			1.73E-05	

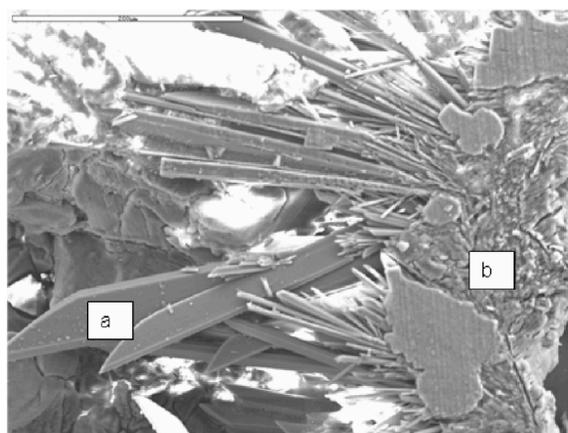
**Table 1.** Synthetic Mars-Analog Brines Recipe for an Acidic Mars Paleo-Atmosphere. The second row lists the ion concentrations of the experimental brine, while the second column shows the concentration of salt used in the synthetic brine. The last row shows the difference in concentration between the experimental and the synthetic brines.

These experiments suggest ways that relative cation abundances in Martian salt-bearing sediments can indicate the atmospheric and aqueous conditions under which they were formed. More experiments testing a wider range of chemistries and aqueous histories are necessary to illuminate the formation of salts on Mars. However, our preliminary conclusion is that the salts that make up the Meridiani sediments were probably formed by the interaction of igneous rocks at a high water-to-rock ratio under an atmosphere rich in acidic volcanic volatiles. This conclusion is consistent with our recent theoretical modeling of the paleo-Martian surface environment [3].

**References:** [1] Bullock M.A. et al. (2004) *Icarus*, 170, 404-423. [2] Bullock M.A. and Moore J.M. (2004) *GRL*, 31, L14701. [3] Bullock M.A. and Moore J.M. (2007) *GRL*, 34, L19201. This research was supported by NASA's Planetary Geology & Geophysics Program and Mars Fundamental Research Program.



**Fig. 1.** Annotated FTIR reflectance spectra of the Mars-analog evaporites. (b) Spectrum of evaporite formed by fast evaporation of Mars-analog brine under simulated acidic conditions on Mars. Peaks at 1250 and 1160  $\text{cm}^{-1}$  are diagnostic of sulfates, while peaks at 1525  $\text{cm}^{-1}$  shows the presence of calcite. Comparison with the ASU library shows the presence of Ca and Mg sulfates and Ca-carbonate.



**Fig. 2.** SEM micrographs (above) and microprobe elemental analysis (below) of the Mars-analog evaporites. Evaporites formed by rapid evaporation under simulated present-day Mars atmosphere. Analysis of the blade-like crystals, designated in box (a) shows that they are a calcium sulfate. The more blob like crystals are primarily magnesium sulfates. Small amounts of carbon and aluminum are seen; these are most likely carbonates and aluminum salts.

