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CheMin: A definitive mineralogy instrument in the Analytical Laboratory of the Mars Science Laboratory (MSL '09).

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Introduction: An important goal of the Mars Science Laboratory (MSL '09) mission is the determination of definitive mineralogy and chemical composition. CheMin is a miniature X-ray diffraction/X-ray fluorescence (XRD/XRF) instrument that has been chosen for the analytical laboratory of MSL. CheMin utilizes a miniature microfocus source cobalt X-ray tube, a transmission sample cell and an energy-discriminating X-ray sensitive CCD to produce simultaneous 2-D X-ray diffraction patterns and X-ray fluorescence spectra from powdered or crushed samples. A 2-D diffraction pattern results from the diffraction of characteristic Co X-rays by the sample. These X-rays are summed circumferentially into a 1-D diffractogram. Fluorescence X-rays from the sample are summed into a histogram of photon energy vs. number of counts, representing the X-ray fluorescence spectrum.

Analysis of Mars analog evaporite assemblages: The discovery of up to 30-40 wt% sulfate salts in sediments at Meridiani Planum [1,2] indicates that evaporite sediments have played an important role in the hydrogeologic history of Mars. Data available to date support the presence of the mineral jarosite (an OH-bearing Fe-sulfate), hydrous Mg-sulfate, and lesser amounts of salts containing Cl and Br. These data imply that several sulfates, mixed with halogen salts, combine to form a complex salt assemblage. One of the most exciting features of the Meridiani sediments is the possibility that the salts may be hydrated. Water abundances in hydrated salts can be considerably greater than water abundances in hydrous silicates such as clays and zeolites. Water storage in minerals may be a significant source of the elevated hydrogen abundances seen in some equatorial regions by the Odyssey spacecraft, with abundances up to 8-9 wt% water-equivalent H present in areas where water ice should not be stable [3]. Salt hydrates in evaporite sediments might account for some equatorial water. Could such a water-rich system harbor life at depth, or at least preserve evidence of brine-dwelling organisms?

XRD is a particularly valuable technique for the identification of evaporites and the various hydration states of minerals that are key indicators of present or past water activity. More than 100 fully quantitative analyses of a variety of mineralogies and lithologies have been conducted using the CheMin III field-portable prototype instrument, including a variety of hydrated mineral assemblages. The introduction of a piezoelectric vibration system [4] has allowed the analysis of crushed and sieved samples from the JPL rock crusher [5], proposed as a sample preparation tool on MSL '09. We collected diffraction and fluorescence data from soil samples analyzed *in situ* in Badwater Basin, Death Valley, CA using the CheMin III field-portable instrument. Rietveld refinement [6] of the diffraction data yielded the quantitative mineralogical results shown in Table 1. XRF data (not shown) include internal self-fluorescence of the CCD camera components (Fe, Cr). Once internal self-fluorescence is removed, these data are fully quantifiable utilizing fundamental parameters methods [7].

Table 1. *Rietveld refinement of sediment sample from*

Badwater Basin, Death Valley, CA USA.

Mineral	**Amount (σ)**
Gypsum ($CaSO_4 \cdot 2H_2O$)	75 (1)%
Halite (NaCl)	22(1)%
Quartz (SiO_2)	tr.
Anhydrite ($CaSO_4$)	tr.

CheMin Spacecraft Instrument: the relevant performance requirements of the proposed CheMin spacecraft instrument are shown in Table 2 below. The flight instrument will be capable of measuring XRD data comparable in resolution to many standard laboratory XRD instruments, and the use of Co radiation will facilitate improved analysis of Fe-bearing minerals. The CheMin XRF capability will assist in the quantification of amorphous components. Taken together, these data should generally allow unambiguous mineral identification of virtually any combination of minerals.

Table 2. *CheMin performance requirements*

Parameter	**Expected**
2θ range, deg	2 - 55
2θ resolution, deg	0.24
Range of sensitivity, keV	0.15 - 12
	(5<Z<92)
Energy resol. eV	
@ 1.0 keV	70
@ 5.9keV	150
Mass (incl. reserve), kg	6.8
Volume, liters	10.6
Power (incl. Reserve), W	18.8

References: [1] MER Rover web site (http://www.jpl.nasa.gov/mer2004/rover-images/mar-02-2004/ima
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