CHEMIN: A DEFINITIVE MINERALOGY INSTRUMENT IN THE ANALYTICAL LABORATORY OF THE MARS SCIENCE LABORATORY (MSL '09). D.F. Blake[1], P. Sarrazin[2], D. L. Bish[3], S. J. Chipera[4], D. T. Vaniman[4], S. Feldman[1], and S. Collins[5] [1]NASA Ames Research Center, MS 239-4, Moffett Field, CA 94035 (dblake@mail.arc.nasa.gov), [2] In-Xitu, PO Box 730, Mountain View, CA 94042, [3]Dept. Geological Sciences, Indiana University, Bloomington, IN 47405, [4]Hydrology, Geochemistry, and Geology, Los Alamos National Laboratory, MS D469, Los Alamos, NM 87545, [5]CCD Imaging Group, Jet Propulsion Laboratory, MS 300-315L, Pasadena, CA 91109

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 diagrammatic view of the instrument is shown in Figure 1a.

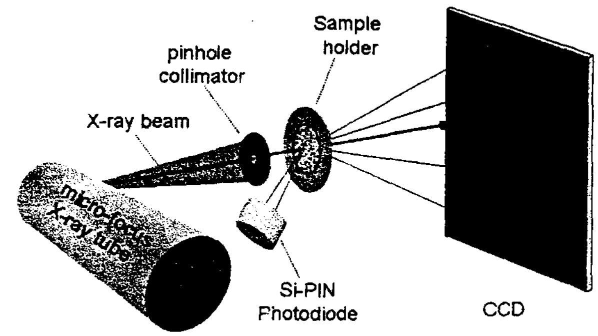

Figure 1a. Schematic diagram of CheMin diffraction and fluorescence geometry. Diffracted primary beam characteristic X-rays (magenta) are identified by their energy. A 2-D image of these constitutes the diffraction pattern.

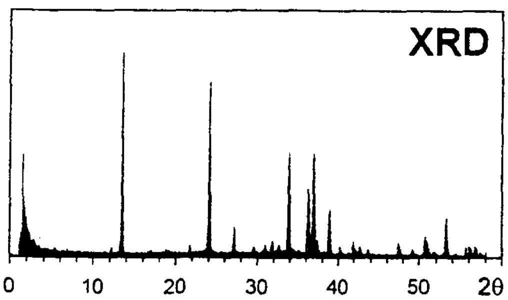

Figure 1b. The 2-D pattern (magenta in Fig. 1a) is summed circumferentially about the central beam to yield a 1-D diffractogram.

A 2-D diffraction pattern (magenta in Fig. 1a) results from the diffraction of characteristic Co X-rays by the sample. These X-rays are summed circumferentially into a 1-D diffractogram (Fig. 1b). Fluorescence X-rays from the sample (multicolored in Fig. 1a) are summed into a histogram of photon energy vs. number of counts, representing the X-ray fluorescence spectrum (Fig. 1c).

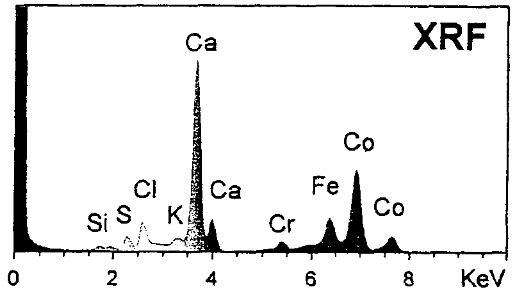

Figure 1c. Fluorescence X-rays from the sample (multicolored in Fig. 1a) are summed into a histogram of photon energy vs. number of counts.

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?

The diffraction and fluorescence data shown in Figures 1b-c were obtained from soil samples analyzed *in situ* in Badwater Basin, Death Valley, CA using the CheMin III field-portable instrument. Rietveld refinement of the diffraction data yielded the quantitative mineralogical results shown in Table 1. XRF data shown in Figure 1c 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 [4].

Table 1. *Rietveld refinement of Badwater Basin sediment sample data shown in Fig. 1b.*

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

Figure 2 shows a CheMin XRD pattern of jarosite mixed with two hydrated Mg-sulfate salts – kieserite and hexahydrite. Using quantitative methods such as Rietveld refinement [5], the relative abundances of these salts can be determined (Figure 2 inset).

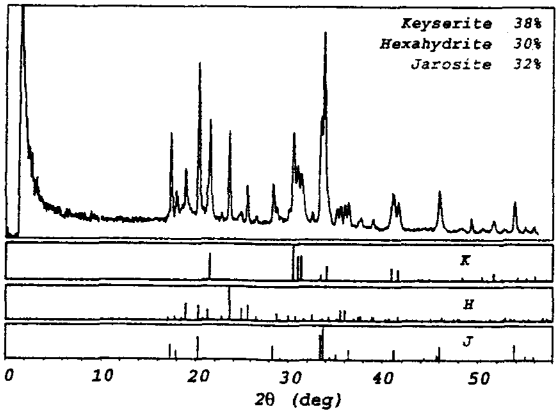

Figure 2 *CheMin diffractogram of a mixture of equal parts of jarosite, kieserite and hexahydrite. Colored bars show the position and relative intensity of diffraction maxima from each mineral. Inset: quantitative analysis by Rietveld refinement (nominally 33% of each phase present).*

CheMin Spacecraft Instrument: The data shown in Figs. 1-2 were collected using the CheMin III prototype XRD/XRF instrument. A conceptual diagram of the CheMin flight instrument is shown in Figure 3, and the relevant performance requirements are shown in Table 2 below.

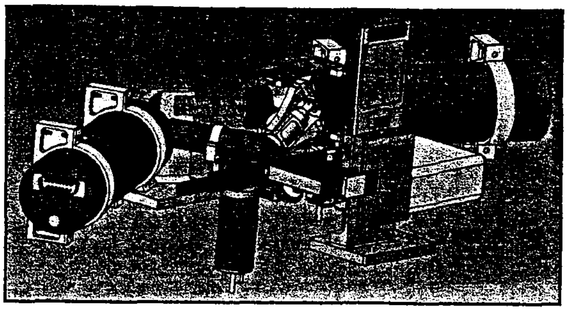

Figure 3. *The CheMin flight instrument. CheMin will sieve and analyze the fine-grained component of crushed rock samples delivered to it from the MSL rock crusher. As many as 148 individual samples can be analyzed during the 2-year duration of the MSL mission.*

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

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 quantitation of amorphous components. Taken together, these data should generally allow unambiguous mineral identification of virtually any combination of minerals.

References: [1] MER Rover web site (http://www.jpl.nasa.gov/mer2004/rover-images/mar-02-2004/images-3-2-04.html [2] Kerr R. A. (2004) *Science* **303**, 1450. [3] Feldman W. C. et al. (2003) *6th Int. Conf. on Mars*, abstract #3218. [4] Sherman, J. (1955) Spectrochim. Acta 7, 744-749. [5] Bish, D.L., and J.E. Post (1993) *Amer. Min.* **78**, 932–942.

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