IN SITU ANALYSIS OF HYDROUS AND AQUEOUS MINERALS USING THE CHEMIN MINERALOGICAL INSTRUMENT ON MARS SCIENCE LABORATORY. D. F. Blake[1], D. L. Bish[2], S. J. Chipera[3], D. T. Vaniman[4], P. Sarrazin[5] and the CheMin Team. [1]MS 239-4, NASA Ames Research Center, Moffett Field, CA 94035 dblake@mail.arc.nasa.gov; [2]Dept. of Geological Sciences, Indiana University, 1001 East Tenth St., Bloomington, IN 47405; [3]Chesapeake Energy Corporation, 6100 N. Western Ave., Oklahoma City, OK 73118; [4]EES-6, MS D462, Los Alamos National Laboratory, Los Alamos, NM 86545; [5]inXitu, Inc., 2551 Casey Ave., Suite A, Mountain View, CA 94043.

Introduction: The CheMin mineralogical instrument on Mars Science Laboratory (MSL '09) [1] will return quantitative X-ray diffraction data (XRD) and qualitative X-ray fluorescence data (XRF; $14<Z<92$) from scooped soil samples and drilled rock powders collected from the Mars surface. Samples of 45-65 mm^3 from material sieved to <150 µm will be delivered through a funnel to one of 27 reuseable sample cells (five additional cells on the sample wheel contain diffraction or fluorescence standards). Sample cells are 8-mm diameter discs with 7-µm thick Mylar or Kapton windows spaced 170 µm apart. Within this volume, the sample is shaken by piezoelectric vibration at sonic frequencies, causing the powder to flow past a narrow, collimated X-ray beam in random orientations over the course of an analysis.

For typical well-ordered minerals, CheMin has a Minimum Detection Limit (MDL) of <3% by mass, an accuracy of better than 15% and a precision of better than 10% for phases present in concentrations >4X MDL (12%). CheMin utilizes a Co X-ray tube so that absorption in iron-rich samples is minimized. The resolution of the diffraction patterns is 0.30° 2θ, and the angular measurement range is 4-55° 2θ.

Terrestrial Versions of CheMin: Several terrestrial prototype CheMin instruments have been developed to evaluate the capability of the instrument for qualitative and quantitative analysis of single minerals and complex mixtures. Successful Rietveld analyses have been performed using data collected for only 5-10 minutes using the field-deployable Terra instrument, a commercial version of CheMin [2].

Analysis of hydrous and aqueous minerals with CheMin: To date, hundreds of analyses of a wide variety of rocks and minerals have been conducted using Terra and CheMin IV, a laboratory prototype of the MSL CheMin instrument. Some classes of minerals pertinent to the activity of water on the Mars surface are described below:

Analysis of Hydrous Phyllosilicates: OMEGA and CRISM have identified a diversity of hydrous phyllosilicate minerals [3-8]. CheMin can identify and readily distinguish between many of these. Discrimination between 1:1 phyllosilicates (such as the kaolin minerals), with repeat distances of ~7Å, and smectites (e.g., montmorillonite, nontronite, saponite), with repeat distances from 10-15Å, is straightforward. However, the variety of treatments used in terrestrial laboratories to aid in discrimination of clay minerals will not be accessible on Mars. Geologic context and elemental chemistry should help in this regard. In addition, it should be possible to identify the hydrated kaolin mineral, halloysite. The lowest-angle diffraction peak from 10.1Å hydrated halloysite occurs at ~10.2º 2θ with Co radiation and is easily detectable.

Analysis of Carbonates: Carbonates are readily identified by CheMin. The position of the principal peak of the calcite structure can be used to calculate mole % $MgCO_3$ along the Ca-Mg join. Hydrous phases (e.g., hydromagnesite), ordered phases (e.g., dolomite, ankerite) and orthorhombic phases (e.g., aragonite) can be readily discriminated.

Analysis of hydrous sulfates: Sulfate hydrates identified on Mars include hydrated and anhydrous forms of $CaSO_4$ (gypsum and anhydrite) as well as various hydration states of $MgSO_4$ (monohydrates and polyhydrates). Ferric sulfates may play a significant role in producing brines that remain fluid to very low temperatures and the ferric sulfate jarosite has been positively identified, providing evidence of acid-sulfate alteration. All of these phases are readily distinguished by XRD. The nature and hydration states of sulfates will provide important constrains on past and present water-rock interaction on Mars.

Analysis of amorphous silica: Geyserite, Opal A, Opal CT, etc. can be readily distinguished by diffraction. Silica resulting from acid weathering of volcanic materials may be identified by the presence of elements such as Ti in their XRF spectra. Likewise, volcanic glasses have distinct major and minor element signatures in their XRF spectra.

References: [1] http://msl-scicorner.jpl.nasa.gov/Instruments/CheMin/. [2] http://www.inxitu.com/index_analytical.html. [3] JP Bibring et al., (2004). Eur. Space Agency Spec. Pub. **1240**, 37. [4] A. Chicarro, et al., (2004). Eur. Space Agency Spec. Pub. **1240**, 3. [5] J-P Bibring et al., (2005). *Science* **307**, 1576-1581. [6] F. Poulet et al., (2005). *Nature* **431**, 623-627. [7] J.F. Mustard et al., (2008). *Nature* **454**, 305-309. [8] J.L. Bishop et al., (2008). *Science* 321, 830-833.