

REMOTE MINERALOGICAL ANALYSIS AS A WINDOW INTO THE ORIGIN AND PROCESSING OF SOLAR SYSTEM OBJECTS D.F. Blake¹, P. Sarrazin², D. L. Bish³, S. J. Chipera⁴, D. T. Vaniman⁴, D. Ming⁵, D. Morris⁵ and Albert Yen⁶. ¹NASA ARC, MS 239-4, Moffett Field, CA 94035 ([dblake@mail.arc.nasa.gov](mailto:dBlake@mail.arc.nasa.gov)), ²In-Xitu, Inc., 2551 Casey Ave. Ste A, Mountain View, CA 94042, ³Dept. Geological Sciences, Indiana University, Bloomington, IN 47405, ⁴Hydrology, Geochemistry, and Geology, Los Alamos National Laboratory, MS D469, Los Alamos, NM 87545, ⁵NASA Johnson Space Center, Houston, TX 77058, MS 300-315L, Pasadena, CA 91109, ⁶MS 183-501, Jet Propulsion Laboratory, Pasadena, CA 91109

Introduction: The surface mineralogy of the rocky satellites of the inner solar system contains a record of their origin and post-formational processing. Impact metamorphism, impact gardening, accretion / ablation, weathering, hydrothermal processing and the like can all be elucidated through mineralogical analysis. The key role that mineralogy plays is a consequence of the fact that minerals are thermodynamic phases, having known and specific ranges of Temperature, Pressure and Composition (T, P, X) within which they are stable. More than simple compositional analysis, mineralogical analysis can provide information about pressure/temperature conditions of formation, water activity, the fugacity (activity) of volatile materials and the like.

Mineralogical analysis by X-ray Diffraction

(XRD): Minerals are defined as unique structural and compositional phases that occur naturally. There are only about 15,000 known minerals, all characterized using X-ray diffraction and cataloged in databases such as the ICDD powder diffraction file. X-ray diffraction is the principal means of identification and characterization of minerals on Earth.

Modern X-ray diffraction methods are able to identify all minerals in a complex mixture using full-pattern fitting methods such as Rietveld refinement.¹ When X-ray amorphous material is present, Rietveld refinement can determine the relative amount of amorphous material. When combined with XRF data, this will provide as complete a mineralogical characterization as is possible, by any remote technique.

The CheMin XRD/XRF instrument: CheMin is a compact XRD/XRF instrument that has been under development at NASA Ames Research Center since 1991.²⁻⁴ NASA was awarded a patent for the concept in 1996⁵ and an R&D 100 award in 1999. CheMin was selected for flight as an analytical laboratory instrument on the Mars Science Laboratory (MSL '09) mission in 2004. The instrument consists of 3 components (see figure 1); an X-ray source, a transmission sample holder and an energy-discriminating CCD which records both XRD and XRF data simultaneously. The CCD is operated in single photon counting mode such that both the x,y position and the energy of each detected photon can be recorded. Characteristic

X-rays from the source are summed into a 2-D diffraction pattern (used for determining the amount and identity of each mineral). All detected X-rays are summed into an energy histogram from which the elemental composition of the sample is determined.

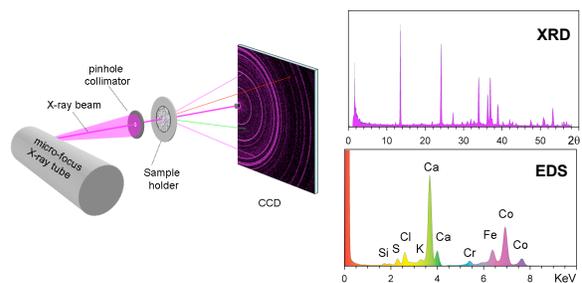


Figure 1. Geometry of the CheMin instrument. A collimated beam of X-rays passes through a powdered sample held between two X-ray transparent windows. Diffracted and fluoresced X-rays are detected by an energy-discriminating CCD and are used to create an X-ray diffraction pattern (upper right) and an energy-dispersive X-ray fluorescence spectrum (lower right).

Phobos and Deimos: The satellites of Mars are thought to be captured objects which originated at greater radial distances from the sun. Landed robotic missions to these moons could provide mineralogical ground truth for a whole class of asteroids that may have been the source of carbonaceous chondrites – primitive meteorites which contain a few % carbon including abiotic organic compounds that could have played a role in the origin of life on Earth.

References: [1] Bish, D.L., and J.E. Post (1993) *Amer. Min.* **78**, 932–942. [2] Blake, D.F., et al., (1992), *LPSC XXIII*, 117–118. [3] Vaniman, D. et al., (1998). *J. Geophys. Res.* **103**, 31,477-31,489. [4] Sarrazin et al., (2005) *Powder Diffraction* 20(2), 128-133. [5] Blake, D.F., et al., (1996) US Patent No. 5,491,738.