FIELD STUDIES OF MARS ANALOG MATERIALS USING A PORTABLE XRD/XRF INSTRUMENT.

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Introduction: CheMin is the X-ray diffraction (XRD) instrument onboard the NASA Mars Science Laboratory (MSL) rover [1]. A portable field XRD/XRF instrument called Terra was developed based on the CheMin technology to provide a field-deployable instrument for terrestrial applications. The CheMin Science Team uses a number of Terra instruments to practice field mineralogy in Mars analog terrains.

XRD/XRF instruments: The architecture of CheMin is shown in Figure 1. A fine X-ray beam is generated by a microfocus X-ray tube combined with a 60µm diameter pinhole collimator. The material to be analyzed is loaded in a vertical cell composed of two thin polymer windows separated by 175µm. The cell is placed in the X-ray beam and vibrated to generate granular motion for improved statistics [2]. A CCD detector collects the X-ray signal scattered by the sample in transmission mode. The CCD is operated in direct detection (i.e., no phosphor is used for conversion of the X-ray signal to visible light) to allow measurement of the energy of incoming photons as well as their location on the detector. The CCD of the MSL instrument is cooled to -100°C with a cryocooler to limit dark current.

A number of prototypes based on this architecture have been developed over the last decade to demonstrate the concept and refine the design of the MSL instrument. The CheMin-4 prototype was implemented for field operation and deployed in Death Valley (California), Spitsbergen (Norway) and Rio Tinto (Spain) [3]. The system showed good performance but its deployment potential was limited by the weight (30kg) and size of the unit, the labor intensive data processing required to extract XRD and XRF data, and the requirement for periodic vacuum pumping of the CCD chamber. As a result of its fidelity to the MSL instrument, a number of CheMin-4 instruments are used today in laboratories to study Mars analog materials, as well as to evaluate the performance and test the calibration of the Mars instrument.

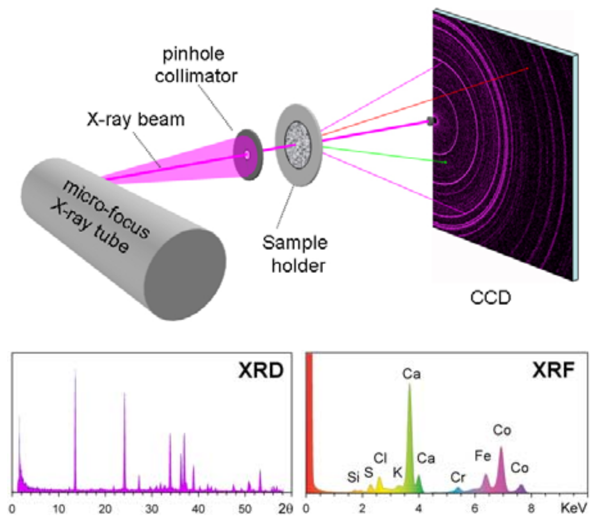

Figure 1: Schematic layout of the CheMin instrument and typical data output.

A new field-deployable XRD/XRF: A new instrument called "Terra" (Figure 2) was developed in 2007 for improved performance under extreme conditions in the field. The Terra architecture is based on the same general layout as CheMin but was redesigned around a smaller CCD to save cost, mass and power. The CCD is cooled to -45°C using a Peltier cooler. The collimation was redesigned with miniature slits in place of the pinhole to maximize throughput. The system includes an embedded computer to control the instrument, acquire and process data in real time, and offer a graphical user interface through a wireless link. Li-ion batteries provide about 4 hrs of autonomous operation. The complete instrument weights less than 15kg, including batteries and a field-ruggedized case.

The diffraction resolution of Terra is slightly better than that of previous systems (0.25-0.30° 2θ FWHM). XRD data of quality sufficient for mineral identification of major phases can be obtained in as little as a few minutes. XRF data, though limited in energy range (3-8 keV), are useful to restrict the search space for mineral identification with complex samples.

Figure 2. The Terra instrument in Spitsbergen (Norway) during the AMASE 2007 expedition.

Field deployment: Terra instruments have been deployed in Spitsbergen (Norway), in the Dry Valleys of Antartica, and in British Columbia (Canada).

During the 2007 Arctic Mars Analog Svalbard Expedition (AMASE) expedition, the instrument was used for a variety of field tests, including two rover operation simulations. In one of the deployment sites (Figure 3), a sample collected from a carbonate-depositing cold spring was analyzed in the field and found to be composed of calcite with a minor amount of monohydrocalcite (Figure 4). Samples collected from this site and later analyzed onboard the expedition ship did not show any monohydrocalcite, the phase having been dehydrated to calcite by conventional laboratory sample preparation methods. This illustrates the benefit of *in-situ* field mineralogical analysis for the identification of sparingly stable or ephemeral phases .

Conclusions: Field-deployable XRD/XRF instruments offer new capabilities for the study of Mars analog and other geological materials. Conventional geological field work involves the collection and storage of samples for later analyses with laboratory XRD instruments. Routine field collection of mineralogical data with Terra allows geologists to develop and confirm working hypotheses in the field and to collect data otherwise unobtainable by conventional techniques. Although not common practice for terrestrial field work, this method is similar to that used on Mars with remote instruments. Furthermore, temperature or humidity sensitive minerals can experience phase transitions during transport to the laboratory. The capability to analyze these materials *in-situ* allows determination of native mineralogical compositions.

The Terra instruments are used by the CheMin Science Team to learn the potential of the MSL mineralogical instrument and to practice robotic science in concert with other geological and astrobiological instruments.

Figure 3. Carbonate deposits of Jotun Spring analyzed in the field (Bockfjord, Spitsbergen).

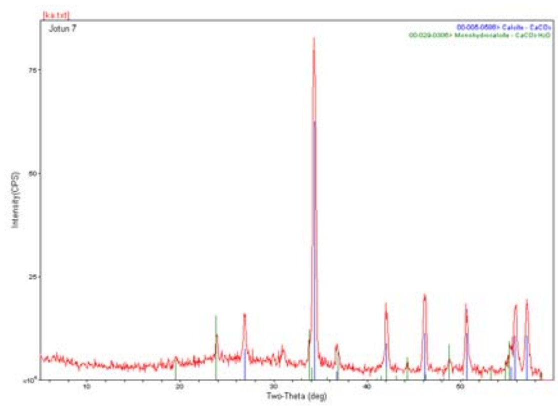

Figure 4. XRD pattern (collected in the field) of Jotun Spring carbonate showing calcite and monohydrocalcite.

References: [1] Blake, D. et al (2007) *LPS XXXVIII,abstract #1257* [2] Sarrazin, P. et al, (2004) *LPS XXXV,abstract #1794.* [3] Sarrazin, P. et al, (2007) *LPS XXXVIII,abstract #1163*