A MINIATURE MINERALOGICAL INSTRUMENT FOR *IN-SITU* CHARACTERIZATION OF ICES AND HYDROUS MINERALS AT THE LUNAR POLES.

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Robotic investigation of lunar polar regolith: Lunar missions over the past few years have provided new evidence that water may be present at the lunar poles in the form of cold-trapped ice deposits [1, 2], thereby rekindling interest in sampling the polar regions. Robotic landers fitted with mineralogical instrumentation for *in-situ* analyses could provide unequivocal answers on the presence of crystalline water ice and/or hydrous minerals at the lunar poles.

Data from *Lunar Prospector* suggest that any surface exploration of the lunar poles should include the capability to drill to depths of >40 cm. Limited data on the lunar geotherm indicate temperatures of ~245-255 K at regolith depths of 40 cm, within a range where water may exist in the liquid state as brine. A relevant terrestrial analog occurs in Antarctica, where the zeolite mineral chabazite has been found at the boundary between ice-free and ice-cemented regolith horizons, and precipitation from a regolith brine is indicated [3]. Soluble halogens and sulfur in the lunar regolith could provide comparable brine chemistry in an analogous setting.

Regolith samples collected by a drilling device could be readily analyzed by CheMin, a mineralogical instrument that combines X-ray diffraction (XRD) and X-ray fluorescence (XRF) techniques to simultaneously characterize the chemical and mineralogical compositions of granular or powdered samples [4, 5]. CheMin can unambiguously determine not only the presence of hydrous alteration phases such as clays or zeolites, but it can also identify the structural variants or types of clay or zeolite present (e.g., well-ordered versus poorly ordered smectite; chabazite versus phillipsite). In addition, CheMin can readily measure the abundances of key elements that may occur in lunar minerals (Na, Mg, Al, Si, K, Ca, Fe) as well as the likely constituents of lunar brines (F, Cl, S). Finally, if coring and analysis are done during the lunar night or in permanent shadow, CheMin can provide information on the chemistry and structure of any crystalline ices that might occur in the regolith samples.

The CheMin XRD/XRF instrument: The central element of CheMin is a CCD detector capable of both spatial and energy resolution of X-ray photons. Energy discrimination is applied for XRF measurements whereas spatial discrimination is used for XRD analyses.

A proof-of-concept prototype has demonstrated capabilities for mineralogical characterization never achieved with any previous spacecraft instrument. Examples of data obtained with the prototype are shown in Figure 1. When appropriate, XRD data can be analyzed by Rietveld refinement to quantitatively determine the composition of complex mixtures.

The simple geometry and limited number of moving parts make CheMin suitable for deployment in a lightweight lander or rover, making it particularly appropriate in the context of lunar pole exploration. The flight instrument will offer simultaneous XRF and XRD in a package expected to weigh under 1 kg with a volume smaller than 1 dm^3 (Figure 2).

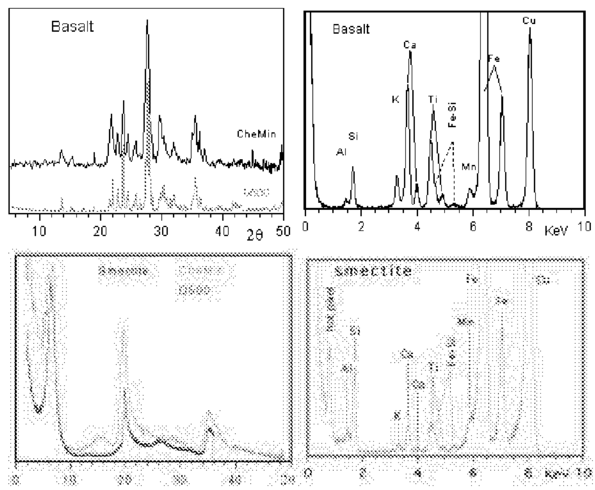

Figure 1: Example of data provided by CheMin, left: CheMin diffractogram compared with diffractogram from laboratory diffractometer (Siemens™ D500); right: CheMin XRF spectrum; top: basalt; bottom: smectite

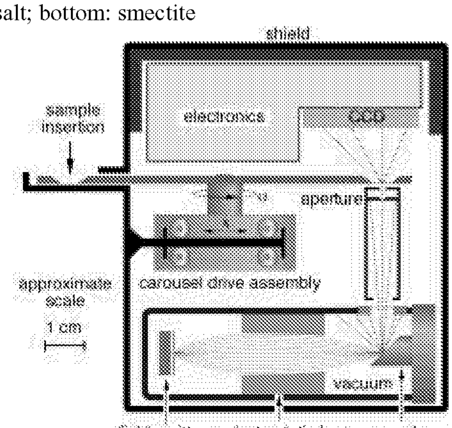

Figure 2: Schematic drawing of the spacecraft instrument fitted with low-power X-ray source and rotating carousel for sample loading.

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