DEFINITIVE MINERALOGICAL ANALYSIS OF MARTIAN ROCKS AND SOIL USING THE CHEMIN XRD/XRF INSTRUMENT.

D.F. Blake[1], P. Sarrazin[1], S. J. Chipera[2], D. L. Bish[2], D. T. Vaniman[2], S. Sherrit[3], Y. Bar-Cohen[3], and S. Collins[4], [1]NASA Ames Research Center, MS 239-4, Moffett Field, CA 94035 (dblake@mail.arc.nasa.gov), [2]Hydrology, Geochemistry, and Geology, Los Alamos National Laboratory, MS D469, Los Alamos, NM 87545, USA, [3]Science and Technology Development Section, Jet Propulsion Laboratory, MS 82-105, Pasadena, CA 91109 and [4]CCD Imaging Group, Jet Propulsion Laboratory, MS 303-318, Pasadena, CA 91109

Mars Astrobiology Goals & Definitive Mineralogy

The search for evidence of life, prebiotic chemistry or volatiles on Mars will require the identification of rock types that could have preserved it. Anything older than a few tens of thousands of years will either *be* a rock, or will only be interpretable in the context of the rocks that contain it. In the case of Mars soil, identifying the type and quantity of both crystalline and amorphous components will be essential to understanding sources and processes involved in its generation.

The key role that definitive mineralogy plays is a consequence of the fact that minerals are thermodynamic phases, having known and specific ranges of Temperature, Pressure and Composition within which they are stable. More than simple compositional analysis, definitive mineralogical analysis can provide information about pressure/temperature conditions of formation, past climate, water activity, the fugacity (activity) of biologically significant gases and the like.

Definitive mineralogical analyses are necessary to establish the origin or provenance of a sample.

The search for evidence of extant or extinct life on Mars will initially be a search for evidence of present or past conditions supportive of life (e.g.,evidence of water) not for life itself. Definitive evidence of past or present water activity lies in the discovery of:

* *Hydrated minerals*. The "rock type" hosting the hydrated minerals could be igneous, metamorphic, or sedimentary, with only a minor hydrated mineral phase. Therefore, the identification of minor phases is important.

* *Aqueous sediments*. Sediments are commonly identified by the fact that they contain minerals of disparate origin that could only have come together as a mechanical mixture. Therefore, the identification of all minerals present in a mixture is important.

* *Hydrothermal precipitates*. Chemical precipitates such as silica or carbonate can be uniquely identified only by their structure. For example, Opal A, Opal CT, tridymite, crystobalite, high and low Quartz all have the same composition (SiO_2) but different crystal structures which are indicative of different environments - from high pressure shock metamorphism to low temperature, low pressure hydrothermal precipitation. Therefore, identification of crystal structures and structural polymorphs is important.

Crystal Structure Information is Required for Unequivocal Mineralogical Analysis

Mineralogical identification - the determination of *crystal structure* - is a critical component of Mars Astrobiological missions. Chemical data alone are not definitive because a single chemical composition or even a single bonding type can represent a range of substances or mineral assemblages. Definitive mineralogical instruments have never been deployed on Mars, and as a result, not a single rock type or mineral has been identified with certainty.

Minerals are defined as unique structural and compositional phases that occur naturally. There are only about 15,000 minerals that have been described on Earth. There are likely many minerals yet undiscovered on Earth, and likewise on Mars. If an unknown phase is identified on Mars, it can be fully characterized by structural and elemental analysis (XRD/XRF) without recourse to other data because XRD relies on first principles for its determinations. An unknown mineral discovered on Mars could be fully described (structure and composition), named and likened to terrestrial counterparts without recourse to other data. 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, and a radial distribution function can be calculated which will identify the principal atom-atom distances present in the material. When combined with XRF data, this will provide as complete a characterization as is possible, by any remote technique.

The CheMin XRD/XRF Instrument

The CheMin XRD/XRF instrument[2-5] is capable of quantitative mineralogical analysis. The original prototype has been modified (and made portable) by replacing the Philips-Norelco tube tower with an Oxford Instruments microfocus X-ray source (figure 1). In the current version, the microfocus source (70 μm diameter) and a 30 μm final aperture yield a beam diameter at the sample of ~100μm. A wide variety of minerals and rocks has been analyzed utilizing 40 KV accelerating voltage and 0.25 microamps beam current (10 watts). Interpretable patterns of single minerals can be obtained in a few minutes and quantifiable patterns of complex rocks can be obtained in a few hours.