INTEGRATED MINERALOGICAL AND GEOCHEMICAL STUDIES OF AUTHIGENIC MAGNESIUM-PHYLLOSILICATES BY THE CURIOSITY ROVER AT GALE CRATER. Richard J. Léveillé, Canadian Space Agency (6767 route de l'Aéroport, St-Hubert, QC, Canada, J3Y 8Y9, richard.leveille@asc-csa.gc.ca).

Introduction: Knowledge of specific minerals present on Mars is critical to reconstructing past environments and geological processes, and is essential to accurately assessing habitability, the main objective of the Mars Science Laboratory mission. Phyllosilicates on Mars are particularly of interest as they indicate areas where liquid water was once present and where life could have existed. Specifically, Mg-phyllosilicates are proposed as priority targets for detailed geochemical and mineralogical investigation by the Curiosity rover at Gale Crater as these minerals may provide key information on habitability. In contrast to remote orbital observations, the proposed investigation will provide detailed geochemical information and definitive mineralogical identification at unprecedented spatial scales.

Clay Minerals as Paleoenvironmental Indicators: Clay minerals can form under a variety of conditions relating to pH, redox state, water to rock ratio, and water chemical composition [e.g., 1, 2, 3]. We propose here that magnesium-rich phyllosilicates (e.g., sepiolite, stevensite, kerolite/talc) are especially useful in identifying past geochemical conditions and assessing habitability on Mars. Because of the greater solubility and mobility of Mg, compared to Fe and Al, Mg-clay minerals preferentially indicate sustained aqueous conditions (either long-term presence of liquid water or high water-to-rock ratios). Mg-clay minerals form most commonly in circumneutral to alkaline conditions, either by direct precipitation (neoformation) or via transformation of precursor phases [e.g., 2, 4, 5]. In fact, pH is a major control on clay mineral precipitation and Mg-phyllosilicates will form mostly at a pH >8.0, with specific minerals often being indicative of narrow pH ranges [5, 6]. Hence, the presence of Mg-phyllosilicates on Mars may indicate areas of increased or extended liquid water activity, and/ (or) aqueous environments where circumneutral pH may have favored habitable conditions or the preservation of organics.

Clay-organic interactions: Clay minerals promote binding of organics, especially due to their high specific area, and may also store organics in interlayer space [e.g., 7]. Lake sediments rich in clay minerals are especially known to concentrate and preserve organic matter [e.g., 8]. Expandable clay minerals (e.g., smectites) are know to be particularly good a preserving organics. However, poorly-ordered phases, such as kerolite, may also contain abundant organics, as these organics may themselves have influenced mineral formation and poor crystal ordering [9]. We speculate that it may be easier to extract organics from poorly-ordered phases, such as kerolite, using the SAM instrument, compared to the organics in interlayer spaces in more ordered smectites.

Clays on Mars: Various clay minerals have been identified in ancient rocks on Mars, including rocks at Gale Crater, by orbiter-based spectroscopic analyses, as well as by in situ chemical and mineralogical analyses by the Mars Exploration Rovers. Their presence suggests an early active hydrologic system, and the formation of these minerals would have required the presence of persistent liquid water over extended periods of time. However, the timing of hydrologic activity and nature of mineral formation processes are poorly constrained [3]. While Al- and Fe-Mg-phyllosilicates seem to be most common on Mars, Mg-rich phyllosilicates (e.g., serpentine, talc, saponite, Mg-smectite) have also been identified [1, 10, 11]. However, the limited spatial resolution and non-definitiveness of remote spectroscopic observations made to date may overlook smaller-scale or dust-covered mineral deposits of interest. These limitations will likely be overcome by Curiosity and its suite of instruments.

Mission Investigations: Detailed in situ investigations, including using techniques that provide elemental and mineral composition, as well as textural data, are required to identify clay minerals and to fully distinguish between authigenic (neoformed) and detrital origins, and will also be required to accurately determine paleoenvironmental conditions and environmental change on ancient Mars [2, 12, 13]. We outline here an integrated geochemical and mineralogical targeting and sampling strategy for MSL (Table 1).

The first step will involve using MastCam images to identify first-order targets of interest. LIBS spectra and remote microscopic images will be taken of these targets using the the ChemCam instrument. In combination with these images, this compositional data will be used to systematically identify and map Mg-Si-rich targets. Targets with especially pure Mg-Si phases that would suggest little re-working will be prioritized. Based on mineral associations and geological features, specific targets will be selected for more detailed study. Following rover positioning, the MAHLI and APXS instruments will be deployed. MAHLI images will be used to further investigate geological context and possible biosignatures [e.g., 9]. APXS data will be used to confirm or refine chemical data obtained by ChemCam. If a target appears to contain Mg-clay minerals, a sample will be collected for delivery to CheMin. The XRD pattern obtained by CheMin will be analyzed and peak identification and matching to mineral phases will be done using standard JCPDS-based methods, in addition to assessing crystallinity. Sample material may also be provided to the SAM instrument if putative indicators of organic enrichment are found (e.g., carbon in LIBS spectra, crystal disorder), and possibly for isotopic analyses.

The unprecedented resolution, comprehensiveness and definitiveness of these instruments used in an integrated fashion will provide unique datasets that will enable more accurate elucidation of past environmental conditions and geological processes, as revealed by the geochemistry and mineralogy of near surface rocks and soils within Gale Crater. This investigation will therefore contribute directly to achieving the primary objective of the MSL mission, namely to characterize the habitability of a site on Mars through detailed, integrated analyses of the composition and geological context of surface materials.

Future Work: In order to prepare for MSL mission operations and the proposed investigation, a number of studies are underway:

- Characterization of natural and synthetic Mg-clay minerals using a Terra XRD instrument, laboratory and portable LIBS instruments; a prototype multi-spectral microscope; and regular laboratory analytical facilities.
- Chemical, microscopic, and isotopic studies of lacustrine and hydrothermal Mg-phyllosilicates.
- Field studies of playa pond sediments, Northern New Mexico.

In addition, synthetic and natural samples will be made available to the various instrument teams for further study. Particular areas of interest are the application of artificial neural networks to mineral identification/classification with LIBS spectra; novel analysis of X-Ray diffraction data; and extraction of organics from poorly-ordered phyllosilicates.

Table 1. Summary of instruments and their data analysis for the proposed investigation.

Instrument	Data Type	Analysis
MastCam	Color images	Geological context, distinct minerals, stratigraphic associations, sedimentary features
ChemCam - LIBS	Elemental abundances	Mg, Si, O, H; C (proxy for organics); and Mg/Si
ChemCam – RMI	Images	Geological context, distinct minerals, stratigraphic associations; imaging of LIBS targets
APXS	Elemental abundances	Bulk chemistry, Mg-Si-enrichements; refine LIBS data
MAHLI	Microscopic images	Microscale textures and variability, biosignatures
CheMin	X-Ray diffraction patterns	Identify and distinguish clay minerals (with chemical data) and accompanying phases
SAM	Organics and stable oxygen isotope ratios	Extract organics from poorly-ordered Mg-clay minerals; oxygen isotopic composition of clay minerals

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