MINERAL ABUNDANCES OF THE FINAL FOUR MSL LANDING SITES AND IMPLICATIONS FOR THEIR FORMATION. F. Poulet[1] and J. Carter[1,2], [1]Institut d'Astrophysique Spatiale, CNRS/Univ. Paris Sud, 91405 Orsay Cedex (francois.poulet@ias.u-psud.fr), [2]European Sourthern Observatory, Santiago 19, Chile.

Introduction and objectives: The Gale crater landing site was selected for Mars Science Laboratory by NASA Headquarters in July 2011 after a selection process of several years. This site was chosen among 4 down selected landing sites (Gale, Eberswalde and Holden craters, Mawrth Vallis) that clearly addressed the primary scientific goal of assessing the past habitability of Mars with the phyllosilicate-bearing deposits as the main astrobiological targets. A key constraint on the formation process of these phyllosilicate-bearing deposits is in the precise mineralogical composition. We present the modal mineralogy of the major phyllosilicate-bearing deposits of the four MSL landing sites derived from the modeling of CRISM spectra using a radiative transfer model, and then discuss the differences between the four candidate sites and the implications for their formation processes.

Methodology: Mineral abundances is derived using a nonlinear unmixing modeling based on the radiative transfer model of Skkuratov [1]. This model simulates the reflectance of a particulate surface (also referred to as an intimate mixture) from the complex indices of refraction of each component. The scattering theory of Shkuratov is also used to iteratively determine the imaginary index of refraction of various hydrated materials from the laboratory reflectance spectra [2,3]. An optical constant library of ~15 hydrated minerals is used. For each CRISM spectrum extracted from the phyllosilicate-bearing deposits, the model must reproduce the shape and depth of each absorption band, the shape of the continuum, as well as the absolute value of the Lambertian albedo reflectance. The spectra are fitted in the 1.35-2.51 µm wavelength range using a simplex minimization algorithm. The quality of the fit is evaluated by a visual, qualitative comparison of the model and data, and quantified by the value of the residual mean squared (RMS). The absorption features of CRISM spectra of phyllosilicate-bearing terrains are much shallower than those of spectra of pure phyllosilicates. In addition to the hydrated mineral phases, admixture of non-phyllosilicate anhydrous components is therefore required to account for it. Primary minerals such as plagioclase, pyroxenes, and olivines are thus considered as potential end-members.

An example of the fit procedure of a spectrum extracted from the iron-rich phyllosilicate unit of Mawrth Vallis is shown in Figure 1. A mixture of five minerals with a large abundance of phyllosilicates (~70%) is required to reproduce the spectral characteristics of this unit. These results are consistent with previous estimates obtained from the modeling of OMEGA data [4].

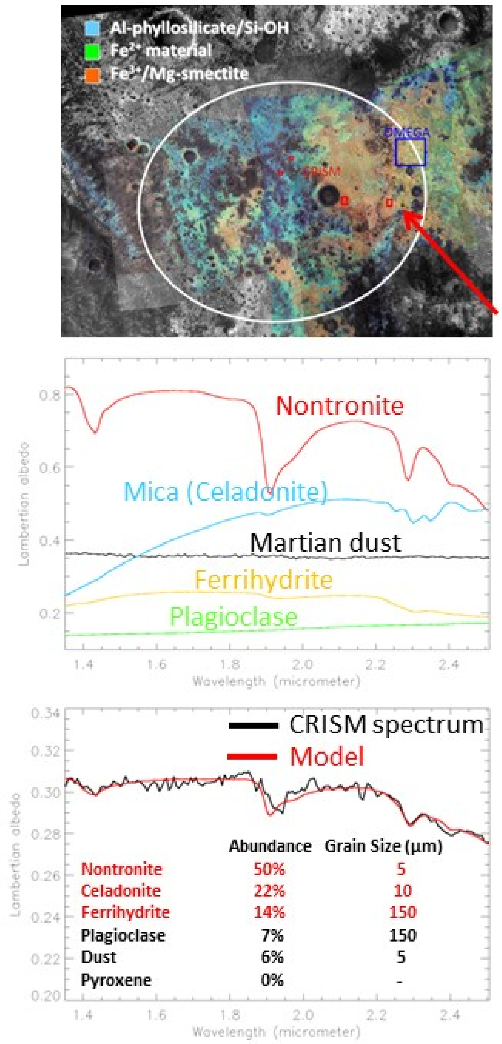

Figure 1. (Top) Landing site ellipse of one of the final four landing sites (here Mawrth Vallis). The red arrow indicates the location of the CRISM spectrum that is modeled. (Middle) Spectra of the mineral endmembers used for the modeling. (Bottom) Data spectrum (black line) compared to its best-fit (red line). The abundance (Vol %) and grain size (µm) of each endmember are indicated. The RMS is equal to 0.21%.

Results: Table 1 shows a comparison of the mineralogy derived for the four landing sites. The largest abundance of phyllosilicates (30-70%) is found in Mawrth Vallis (MV hereafter), the lowest one in Eberswalde (<20%). Except for MV, the anhydrous primary phases are the dominant phases and the presence of pyroxenes is required, suggesting formation conditions with a lower alteration grade and/or a post-formation mixing with anhydrous phases. Below the modal mineralogy is detailed for each site.

Holden crater: The best fit of the spectra extracted from clay-bearing material found in light-toned layered deposits is obtained using the minerals saponite and celadonite (total abundance between 25-45%) mixed with anhydrous primary phases (plagioclase and pyroxene). The association of saponite with celadonite is usually the result of hydrothermal alteration of basalts at temperature ranged between 20 and 60°C [5]. Since such conditions are not expected in a fluvial-lacustrine system, the composition of Holden layered deposits thus suggests a transport and a deposition of altered basalts of the Noachian crust without chemical transformation.

Eberswalde: The clay signatures of the deltaic deposits of Eberswalde crater are subtle. 10-20% at most of hectorire mixed with a large amount of primary basaltic minerals provides the best fit. The presence of hectorite, usually the product of altered volcanic tuff ash, could suggest alteration of volcaniclastic debris. Another piece of the puzzle is provided by the presence of opaline in the deltaic deposits [6]. Opaline that is not found in the Noachian crust, implies little to no aqueous activity following its formation. Therefore, the presence of hectorite and opaline could indicate an authigenic formation during the deposition and/or transport of the volcaniclastic sediments by the fluvial/deltaic system.

Mawrth Vallis: MV exhibits the most diverse and complex composition of the four landing sites. The iron-rich phyllosilicate unit shows a large abundance of nontronite (30-70%). The addition of the mica celadonite significantly improves the fit. On Earth, glauconite is usually found with nontronite but glauconite does not provide a good fit. Celadonite is a product of the submarine weathering of volcanics or hydrothermal fluid (T° between 20°C and 60°C). This clay assemblage is very different from those formed in hydrothermal systems or low-grade metamorphic conditions which are characterized by the sequence: saponite → randomly ordered chlorite-smectite mixed-layered minerals → corrensite → chlorite, and which are found in many locations in the martian crust [7,8]. Among the main formation processes of this unit previously discussed in numerous papers (Surface weathering in wet, neutral conditions; Submarine hydrothermal; Subsurface hydrothermal), the submarine hydrothermal formation process is thus the favored one with regard to our derived composition. The modal mineralogy of the Al-rich phyllosilicate unit of MV is dominated by a complex mixture of Al/Si-bearing hydrated phases (kaolinite, poorly crystalline hydrous Al/Si-OH material, opal). Since localized sulfate signatures have been also identified in this unit, the composition supports active hydrolysis and ion leaching due to acidic conditions rather than hot and humid climates.

Gale: Gale crater exposes a thick sequence of finely bedded deposits with nontronite signatures. The best fit of an average spectrum of 917 CRISM pixels of these hydrated deposits is given by a mixture of nontronite (<30%), anhydrous primary basaltic materials (45-70%) and martian dust (5-20%). HCPyroxene (10-20%) is required, which indicates a low alteration grade. Nontronite can precipitate for relatively low pH (~4) in the case of high silica activity [9], so that localized (in space and time) environments could produce both nontronites and sulfates. Such a formation process may have occurred in Gale.

References: [1] Shkuratov Y. et al. (1999) *Icarus, 137,* 235. [2] Poulet F., Erard S. (2004) *JGR, 109,* 2003JE002179. [3] Roush T. et al. (2007) *JGR, 112,* 2007JE002920. [4] Poulet F. et al. (2008) *A&A, 487,* L41. [5] Duplay J. et al. (1989) *CRAS, 309,*53. [6] Carter J, Poulet F. (2012), *this meeting*. [7] Carter J. (2011) PhD Thesis. [8] Ehlmann B. et al. (2011) *Science, 479,* 53. [9] Chevrier V. et al. (2011) *Nature, 448*, 60.

*Table 1. Modal mineralogy of the phyllosilicate-bearing deposits (*HCP= High-Calcium Pyroxene, LCP= Low-Calcium Pyroxene)

Abundances (% Vol)	Gale crater	Holden Crater	Eberswalde crater	Mawrth vallis (Fe-rich unit)	Mawrth vallis (Al-rich unit)
Phyllosilicates	Nontronite: 50+/-20 Celadonite: 10+/-10	25-45 (Mg-smectite saponite + Mg-mica celadonite)	<20 (Mg-smectite hectorite)	Nontronite: 50+/-20 Celadonite: 10+/-10	Kaolinite: 10-30 Al/Si-OH phase: 10-30 Opal: 5-15
Primary anhydrous minerals	15+/-15	>50 (HCP required)	>70 (HCP and LCP required)	15+/-15 (no pyroxene)	5-15 (no pyroxene)