Geochemical variability seen by the Mars Exploration Rovers and acid-fog alteration modelling

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Since 2004, the twin rovers Spirit and Opportunity of the Mars Exploration Rover (MER) mission have been investigating their respective landing sites at Gusev Crater and Meridiani Planum, making use of the Athena Science Payload [1]. This scientific payload includes the Alpha Particle X-Ray Spectrometer (APXS) [2] whose role is to determine the elemental composition of the material found at the Martian surface. After more than 5 (terrestrial) years and several km driven by both rovers, the complementary suite of instruments has characterized diverse geological sites, and the APXS instruments have analyzed ˜340 samples of rocks and soils, providing abundances for at least 16 chemical elements.

The adequacy of mathematical tools such as Principal Component Analysis (PCA) to highlight and interpret compositional variations provided by the APXS multidimensional dataset has been recently demonstrated. Taking into account the available chemical information simultaneously, PCA was used as an unsupervised tool to identify and characterize the different families of samples encountered by the rovers [3]. Along with hierarchical clustering a robust classification of samples can be performed, shedding light on the petrogenetic relationships between them, and this classification can be related to their stratigraphic and spatial organization [3, 4], a prerequisite if one wants to compare this in-situ chemical information with orbital data. This analysis was found to be particularly useful in the case of samples from Gusev where a high diversity of rock types has been observed in the Columbia Hills, this variability being attributed to a combination of geological processes including aqueous alteration, igneous fractionation, impact and volcanic processes [3, 5].

We extended this rock classification work by taking into account the recent APXS measurements from both rovers, which include silica-rich samples encountered by Spirit around the Home Plate feature at Gusev [6], and outcrops analyzed during Opportunity's descent into the 700 m wide Victoria crater at Meridiani. Using a similar approach, we also performed a classification of soil samples from both sites. Although most of the soils are relatively homogeneous in composition, it was possible to identify some outliers and to assess the contribution of the local rocks to the soil composition (relatively to the other soil components) and its impact on the spatial distribution of soil classes.

The interpretation of the PCA results, highlighting that the compositional variability of Meridiani rocks is dominated by variations in sulphur content, also led us to explore a simple geochemical model of acid fog alteration of Martian basalts, assuming either equivalent alteration of all phases or preferential alteration of certain phases. The secondary mineralogies predicted by the model were broadly coherent with compositions measured by the MER rovers [3]. Following these encouraging results, we have now performed more detailed modelling, refining the hypotheses and taking into account reaction kinetics, the mineralogies being calculated as a function of time. Considering the role of brine circulation and evaporation, the results of this model appear to account for chemical and mineralogical observations made by Opportunity at Meridiani, suggesting an alteration occurring in highly acidic brines and involving small amounts of water.

References: [1] Squyres et al. (2003), JGR, 108 (E12), 8062. [2] Rieder et al. (2003), JGR, 108 (E12), 8066. [3] Truier et al. (2008), JGR, 113 (E12), S34. [4] McCoy et al. (2008), JGR, 113 (E6), E06S03. [5] Ming et al. (2008), JGR, 113 (E12), E12S39. [6] Squyres et al. (2008), Science, 320, 5879.

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