Simulating the Martian Chemical Enivronment

Conference or Workshop Item

How to cite:

Ramkissoon, N. K.; Schwenzer, S. P.; Pearson, V. K. and Olsson-Francis, K. (2018). Simulating the Martian Chemical Enivronment. In: 49th Lunar and Planetary Science Conference, 19-23 Mar 2018, The Woodlands, Houston, Texas, USA.

SIMULATING THE MARTIAN CHEMICAL ENVIRONMENT.

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Introduction: The detection of Recurring Slope Lineae (RSL) on the martian surface suggests the presence of contemporary fluids on Mars [1-3]. The chemistries of these fluids are likely to be controlled by the lithology of their source region [4,5] and, given the varied lithologies identified on Mars, are likely to have variable chemistries. In addition to this, fluid chemistries would, in turn, influence the local chemical environment, through the dissolution of primary minerals and the precipitation of secondary minerals. An understanding of the formation of these fluids, and their precipitating minerals, will help to identify where on Mars such chemical environments may have developed and, by utilizing these fluids in simulation experiments, will help identify which environments on Mars may be or have been potentially habitable.

We will present new martian regolith simulants and the fluid chemistries resulting from their interaction with water.

Modelling the chemical environment:

Regolith simulants: To experimentally determine fluid chemistries and support out astrobiological experiements [6], we have developed new martian regolith simulants to represent four specific chemical environments: 1) a basaltic shergottite [7], representative of magmatic, unaltered martian bedrock; 2) Rocknest at Gale crater [8], representing a globally average martian soil composition; 3) Paso Robles at Columbia Hills ([9] a sulfur rich soil), and 4) Haematite Slope at Meridiani Planum ([10] an iron rich regolith). Using geochemical data of these four compositions, regolith simulants were developed using various proportions of gabbro, dunite, anothosite, quartz, gypsum, magnetite, pyrite, haematite, apatite and an Fe^{2+}-silicate glass [11]. X-ray fluorescence (XRF) and sulfur gas analysis of the simulants indicated that their chemistries are within 5 wt% of their martian counterparts (Fig. 1).

Thermochemical Modelling: CHIM-XPT ([12] previously known as CHILLER) has been used to model the water-rock interactions between these simulants and pure water, at 1 bar and 25 °C; this mimics the physical condition for initial simulation experiments. The model assumes the complete dissolution of reactants in a fixed amount of solvent, and determines the mineral precipitates and remaining fluid chemistries using a series of mass balance and mass action equations [13]. The model is run in small increments, which enables us to identify the chemistries of different aqueous environments depending on the water/rock ratio, i.e., rivers and lakes (high W/R ratios) and in pore spaces or diagenetic settings (low W/R ratios).

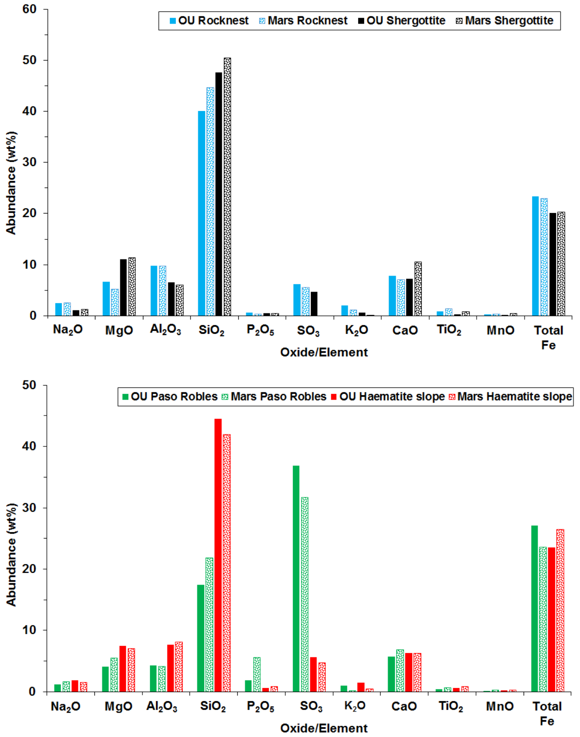

Fig. 1. *Comparison of the composition of regolith simulants (solid) with their martian counterparts (patterned). Compositions determined by XRF and sulfur gas analysis.*

Results: Thermochemical modelling of these new simulants shows variations in the minerals precipitated (Fig. 2). At high W/R ratios (100000), chlorites are the dominant minerals precipitated, with the second most abundant mineral being Fe-oxide (for shergottite and Haematite slope simulants), and pyrite (for Paso Robles simulant). At lower W/R ratios (1000), smectite clay minerals are the dominant mineral phase precipitated for shergottite and Haematite slope and the second dominant type of mineral formed for Rocknest. Consistent with high W/R ratios, chlorites and pyrite are the two most dominant minerals precipitated for Pasa Robles. Interestingly, Paso Robles also has a high proportion of apatite (10 wt%) precipitating, which reflects the high P of the simulants.

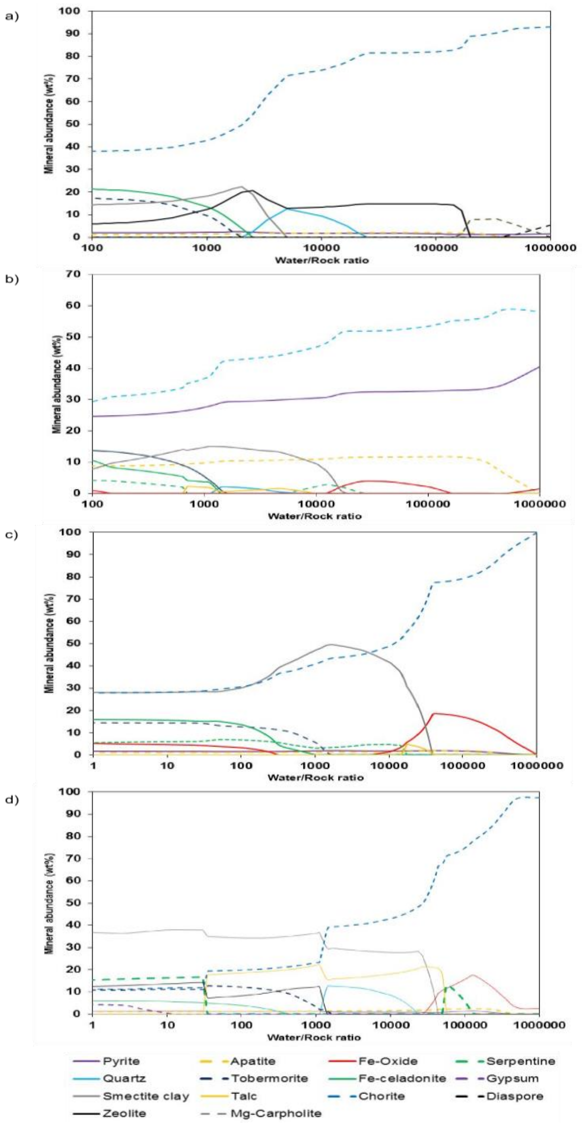

Fig 2. *Secondary mineral assemblages determined by the thermochemical modelling of the the new simulants ((a) Rocknest, (b) Paso Robles, (c) Haematite slope and (d) and shergottite.*

Derived fluid chemistries (Fig. 3) determined after mineral precipation have the same dominant species ($SiO_{2(aq)}$, K^+, SO_4^{2+}, Na^+ and Ca^{2+}) for all four simulants at both W/R ratios. However, Mg^{2+} becomes a more dominant species at a W/R ratio of 100000 and Cl^- becomes more prevailing at a W/R ratio of 1000. There are lower abundances (approximately five orders of magnitude) of Mg^{2+} and Fe^{2+} when compared to Na^+ and Ca^{2+} concentrations, which is similar to what was seen by [4]. However, these results differ from fluid chemistries identified by [14], where only a single order of magnitude in difference occurs, but the initial starting fluids used in [14] were enriched with Mg and Fe.

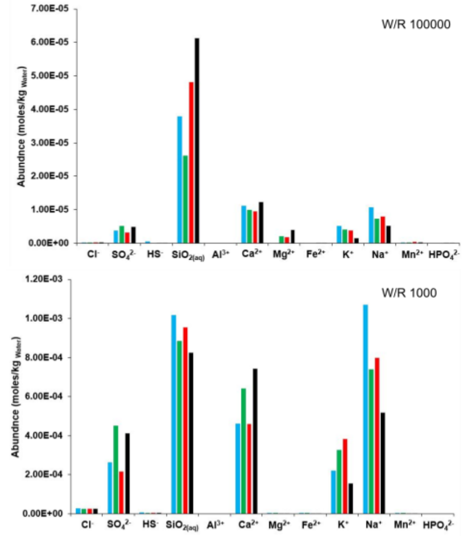

Fig. 3. *Fluid chemistries at W/R ratios of 100000 (top) and 1000 (bottom) derived from the new simulants: Rocknest (blue), Paso Robles (green), Haematite slope (red) and shergottite (black).*

Summary: At high W/R ratios, thermochemical models of all four simulants show chlorites are the most abundant group of minerals precipitated. At low W/R ratios, chlorites are the most abundant precipitated minerals for Rocknest and Paso Robles, but smectite clay minerals are dominant for shergottite and for Haemetite slope both smectite clays and chlorites form in similar proportions However, the overall types of minerals precipitated are dependant on initial reactant chemistry, e.g. Paso Robles results in a high proportion of pyrite and apatite forming, reflecting the high P and S contents of the simulant. Fluid chemistries also show the proportion of ion species are representative of the initial simulant chemistries. These results will help us simulate different chemical and aqueous environments for microbial growth experiments to determine the boundaries of habitability on Mars.

Acknowledgements:NKR would like to thank the Leverhulme Trust for funding this work.

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