

# Geochemical modelling of alteration through sulphur-bearing fluids and origin of Meridiani bedrocks

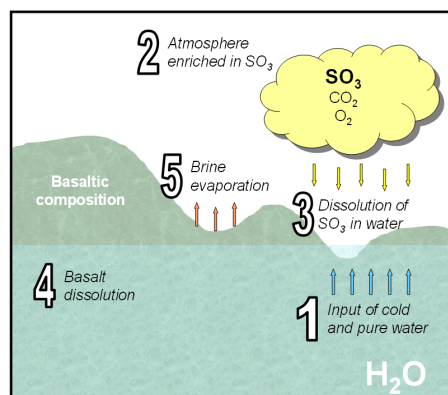
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## Abstract

### 1. Introduction

Instruments onboard orbital and landed Martian missions have underlined the important role played by the sulphur-cycle [1] on Mars, notably showing that sulphates were among the most abundant secondary minerals present on the surface. Understanding how they formed is an interesting challenge as it may yield important clues about the presence of water during Mars' geological history. In this context, data gathered by the instruments of the Mars Exploration Rover (MER) Opportunity about Meridiani Planum sulphate-rich bedrocks [2] provide crucial constraints about the conditions prevailing during their formation.

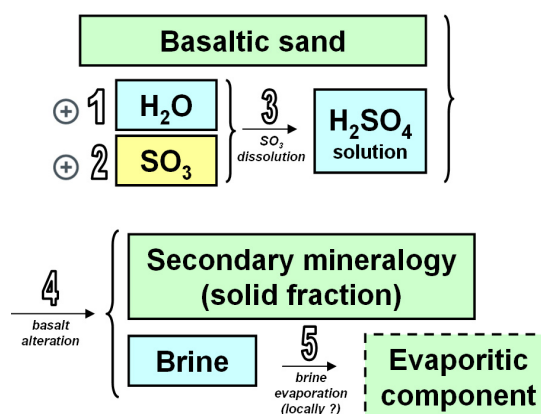
Various interpretations have been proposed. Apart from the impact surge hypothesis [3], most of them involve the occurrence of acidic waters, as supported by laboratory and theoretical studies [4,5]. Some authors have proposed a brine/evaporite scenario [2,6,7], while others favour in-situ alteration, of volcanic material through hydrothermal activity [8] or by cold sulphur-bearing fluids [9,10].



**Figure 1: Illustration for the acid fog alteration model.**

### 2. Model

Aiming at identifying self-consistent scenarios for the formation of Meridiani bedrocks, we have used a geochemical simulator (JChess) [11] to model the alteration of basaltic material through cold sulphur-bearing fluids, originating from volcanic sour gas ( $\text{SO}_3$ ) dissolution into pure water (Fig. 1 & 2).



**Figure 2: Relative timing for the steps of the model.**

The initial basaltic mineralogy under consideration in the model is similar to Adirondack, an unaltered olivine-rich Martian basalt encountered by the MER rover Spirit at Gusev Crater [12]. The initial fluid phase is pure water at  $0^\circ\text{C}$  (produced by melting of near-surface ice). While the main parameter of the model is the quantity of added sulphur, expressed in terms of  $\text{SO}_3$ /basalt mass ratio, several  $\text{H}_2\text{O}$ /basalt (W/R) mass ratios were also investigated. Apart from  $\text{SO}_3$ , atmospheric conditions were chosen similar to current conditions on Mars ( $T = 0^\circ\text{C}$ ,  $P_{\text{CO}_2} = 3.5 \text{ mbar}$ ,  $P_{\text{O}_2} = 7.6 \text{ } \mu\text{bar}$ ).  $\text{SO}_3$  dissolving into water will produce pristine sulphuric acid and alteration of basalt will result in the production of both a solid phase (secondary mineralogy, Fig. 3) and a fluid phase (brine). The final rock composition will therefore lie on a mixing line between the secondary

mineralogy and the composition of the brine (Fig. 4), its position on the line depending on the brine circulation (local evaporation or not) which controls the amount of added evaporitic component (Fig. 2).

Whereas our previous model [9] was assuming either complete alteration of initial basalt or preferential alteration of only certain minerals, our new model [10] takes kinetics fully into account and computes the mineralogy of altered basalt and the composition of the brine as a function of time.

### 3. Results and discussion

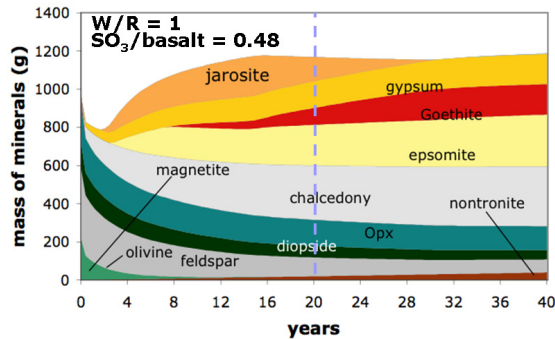


Figure 3: Kinetic model: mineralogy as a function of time.

A first set of calculations was performed with the quantity of added sulphur tuned to match the actual amount of sulphur measured by MER in Meridiani rocks ( $\text{SO}_3/\text{basalt} \sim 0.25$ ). In this case, the results of the model could not simultaneously match both the chemical and mineralogical characteristics of Meridiani rocks measured by the MER rovers [10]. We therefore investigated higher sulphur inputs (implying a necessary loss of at least part of the brine component).

For  $W/R = 1$  and  $\text{SO}_3/\text{basalt} = 0.48$ , the model can reproduce the compositions measured at Meridiani after  $\sim 20$  years and with very little brine contribution (Fig. 3 & 4). It means that the brine had to be removed after  $\sim 20$  years before having the time to evaporate locally. Our model can simultaneously account for most of both chemical and mineralogical observations at Meridiani, but only with a low  $W/R$  ( $\sim 1$ ). In this case, the aqueous solutions are highly acidic ( $\text{pH} < 3$ ) and the lifetimes of liquid water are very short (on the order of tens of years), whereas the evolved fluids (brine) should be removed before evaporation.

Thus, our results suggest an alteration occurring in highly acidic brines and involving small amounts of water over a short period of time or in an intermittent way.

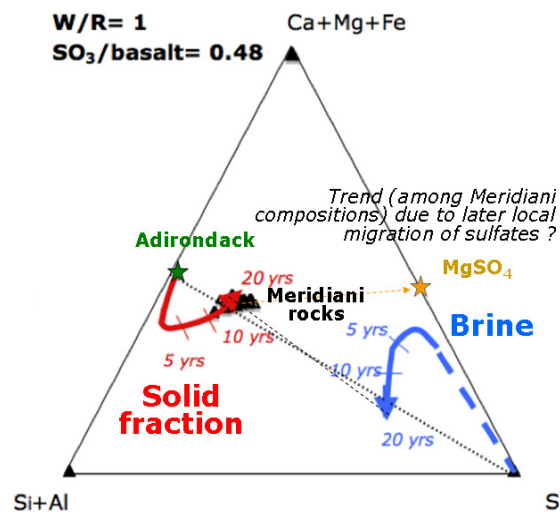


Figure 4: Chemistry for kinetic model.

Moreover, further work investigating the potential mineralogies obtained through our model over a wider range of conditions could explain other compositions observed at the Martian surface. Other initial rock compositions could also be investigated, such as new mafic rocks recently discovered at Meridiani [13].

### References

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