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Sulphate-rich bedrocks at Meridiani Planum, Mars: Constraints and modelling
Sulphate-rich bedrocks at Meridiani Planum, Mars: Constraints and modelling

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The sulphur-rich nature of Martian soils is known since the Viking missions [1]. Data from recent orbital and landed missions have confirmed the important role played by the sulphur cycle on Mars [2] by showing that sulphates were among the most abundant secondary minerals on the Martian surface. Understanding which geological processes led to their formation is of particular interest as it may yield important clues about the presence of water during Mars' geological history. In this context, data from the Mars Exploration Rover (MER) Opportunity provide crucial constraints on the conditions prevailing during the formation of Meridiani Planum sulphate-rich bedrocks. Terrains visited by Opportunity at Meridiani appear to be sulphur-rich (up to 25 % SO3) layered rocks covered by basaltic soils [3]. Outcrops are exposed by impact craters, allowing their analysis by the rover's instruments. Another notable feature of these plains is the ubiquitous presence of mm-sized spherules, containing hematite, observed in both the rocks and the soils. Some mafic constituents are also present in the rocks.

In addition to hypotheses formulated before the beginning of on-site observations, such as subaqueous sedimentary deposition [4], various formation scenarios have been proposed (or significantly refined) since the landing of the rover: impact surge [5], weathering of dust-ice deposits [6], alluvial deposition of exogenous materials [7], groundwater diagenesis of evaporitic sandstones [3,8], volcanic processes [9], and alteration of basaltic material through sulphur-bearing fluids [10,11]. It is worth to note that these models are not necessarily all mutually exclusive. Numerous constraints exist as regards these hypotheses, relative to the chemical/mineralogical compositions (including variations within the investigated layers), the provenance of the constituents involved in the formation scenario (including water, if needed), the textural observations, etc. The large-scale geological context, known from orbital data, has also to be taken into consideration [12], especially as the rock layers investigated by Opportunity only represent a small part of the full stratigraphic sequence of sulphate-bearing layers at Meridiani.

All the proposed scenarios have their own advantages and issues. The model of alteration of basaltic material through cold sulphur-bearing fluids [10,11], using a geochemical numerical simulator, provides particularly interesting results. Here, acidic fluids are assumed to originate from volcanic sour gas dissolution into pure water and the main parameter of the model is the quantity of added sulphur, expressed in terms of SO3/basalt mass ratio. The role of brine circulation is also taken into account. A good match with MER observations at Meridiani is obtained for a particular adjustment of the model parameters suggesting an alteration occurring in highly acidic brines and involving small amounts of water over a short period of time (or in an intermittent way). Additionally, the potential mineralogies obtained through this model over a wider range of initial conditions could also explain compositions encountered in other Martian regions.

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