THE METEORITIC INPUT ON MARS – INFLUENCE ON ORGANIC GEOCHEMISTRY

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Abstract. Pristine, cosmic material, which is continuously delivered to the Martian surface through meteoritic dust infall, contains considerable quantities of organic matter – the prerequisites for the evolution of life. Organic material has, however, not yet been detected on the surface of the planet. The lack of organic material on the Martian surface despite of the continuous meteoritic delivery is ascribed to the reactivity of the Martian soil and to the processes related to entry and impact of meteoritic matter. We present a study of regolith mixing relationships, in particular stressing the meteoritic contribution in the Martian soil. According to the inferred meteoritic contribution, about 0.8 to 0.5 wt% C is missing in the Martian soils at the top level and should be present in deep soils, respectively. Based on the organic carbon content of carbonaceous chondrites [1], vertical soil profiles can be simulated.

Introduction

Due to the cessation of consumptive plate tectonics several billion years ago, the Martian sedimentary record represents a long-term archive of exogenic processes. Anticipated low soil formation rates on the order of meters per billion years [2] as well as the closeness of Mars to the asteroid belt (2.6 times the impact rate of bolides in comparison to Earth; [3]) should cause relatively large amounts of meteoritic accumulates in the Martian soil.

Method

The mixing relationships, in particular the meteoritic contribution in the Martian soil were determined by means of least squares (LS) analysis of chemical data from APXS-*Mars-Pathfinder (MPF)* [4] and XRF-*Viking* [5] measurements. In our LS analysis 13 major elements were taken into account. Despite of other possible soil formation processes, the soil composition may be represented as a mixture of primitive cosmic material (CI-chondrite, [6]), the *MPF*-Soil Free Rock (SFR) [4] and physical weathering products of *MPF*-andesites. Prior to LS analysis a CIPW normative calculation was done on the SFR chemistry. In analogy to Antarctic weathering scenarios, minerals with high susceptibility to physical disintegration were assigned to a fraction of detritus PWP according to their normative ratios in parent andesites. To account for the uncertainties inherent in analytical data from Mars, the individual element concentrations were weighted accordingly.

Results

The convergence of the regression lines to a single point indicate the existence and the composition of a Global Dust Unit (GDU). GDU material appears to be intimately admixed to *MPF* surface soils and also to *Viking* deep soil samples (Fig. 1).

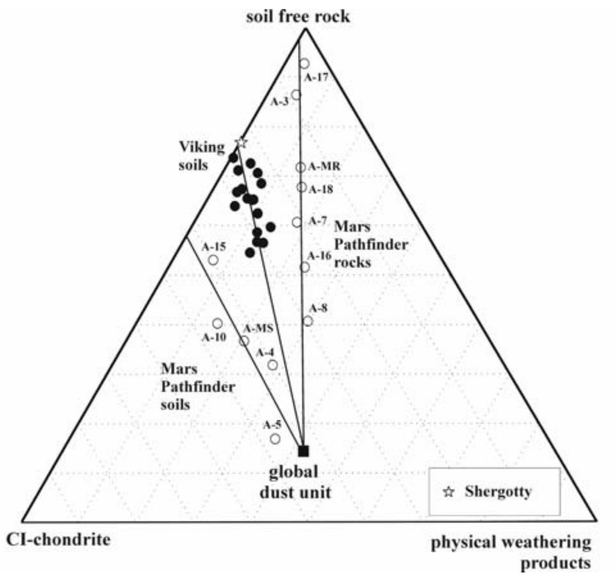

Fig. 1. Distribution of Martian surface compositions within the triangular space of CI-chondrite (CI), Pathfinder Soil Free Rock (SFR) and physical weathering product composition of Soil Free Rock (PWP). Pathfinder soils and –rocks as well as Viking soils plot along trend lines with a common intersection point, which is thought as the composition of the Global Dust Unit (GDU) on Mars.

Some GDU material also appears to adhere to *MPF* rock samples. Based on the component analysis, the composition of the GDU as well as the amount of putative organic matter can be inferred. The carbon content of CI-chondrites is dominated by organic compounds besides of carbonate minerals [1]. Based on the meteoritic content of Viking samples in Fig. 1 and their exhumation depth [5] a soil profile in respect to the extraterrestrial carbon content can be given in Fig. 2.

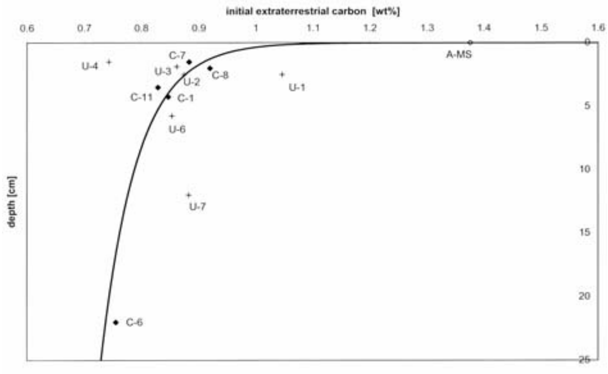

Fig. 2. Initial extraterrestrial carbon depth profile based on the meteoritic component obtained from LS-analysis and collection depths of individual soil samples. Viking 1 samples follow a common trend curve, intersecting the surface top level at about 1.1 wt% carbon. Viking 2 samples show not such a behavior – maybe due to the proximity to the Mie crater.

Implications

[7] identified Interplanetary Dust Particles (IDPs) to be the most important fraction concerning contribution of organic matter to the early Earth due to low entry heating. [8] estimated the amount of cosmic matter in the mass range of 10^{-15} to 10^{1} g arriving Mars not heated above organic pyrolysis temperatures of 900 K [7]. Accordingly, about 20 wt% should reach the Martian surface with leaving organic matter intact and IDPs should accumulate an one order of magnitude higher concentration of carbon on Mars than on Earth due to lower entry heating. [9, 10] measured carbon contents of IDPs, collected from the Earth's stratosphere, and reported 10 to 12 wt% carbon: about 3 times larger than CI chondrites [6].

Assuming that extraterrestrial matter delivers carbon to the Martian surface and that this carbon remains in the particles heated below 900 K (disregarding the kinds of carbon bearing phases, such as organic compounds or carbonates, for the sake of simplicity), about 0.8 and 0.3 wt% of extraterrestrial carbon should be present in *MPF* soils for IDP or CI chondritic matter sources, respectively (after Fig. 1). [11] found about 3.5 wt% $MgCO_3$ in the Martian dust. If it is assumed that these carbonates are of indigenous origin, than an overall range of carbon between 1.3 to 0.8 wt% is to expect for surface soils. [12] reported carbon detection limits for APXS of 0.8 wt%. This equals the lower limit of our estimated range.

However, also *Viking* biology experiments failed to detect organic compounds in the soil. [13] reported no detectable organic matter in Martian surface and deep soil samples, although *Viking 1* and *2* GCMS had detection limits for naphthalene of 0.5 and 0.015 ppb, respectively. [13] measured 1 ppm naphthalene in CI material by means of a lab version of *Viking* GCMS. About 50 ppb naphthalene should have been present in *Viking* deep soil samples, assuming 80 wt% of entry loss and about 25 wt% of CI matter in *Viking* deep soil samples (after Fig. 1). The anticipated value is at least two orders of magnitude larger than actual detection limits.

[14] conducted experiments under Martian atmospheric conditions and found adsorbed superoxide on Martian analogue materials upon UV-illumination. [14] conclude that superoxide might be capable to destroy such organic matter. However, [15] proposed that non-volatile mellitic acids could remain as metastable intermediates of meteoritic organics under oxidizing conditions on Mars and hence were not accessible to *Viking* GCMS.

References

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