RELATIONSHIP BETWEEN ROCKS AND SOIL AT THE PATHFINDER LANDING SITE AND THE MARTIAN METEORITES.

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The most important result of the APXS (Alpha-Proton-X-ray Spectrometer) analyses of the Mars Pathfinder Mission (1) was the significant chemical differences between rocks and soil at the Ares Vallis landing site (Fig. 1). The soils at the Pathfinder and Viking sites are quite similar in composition including their high sulfur concentration of about 2.4 %. Since the Viking mission the origin of the high sulfur and also high chlorine concentrations in the martian soils are under discussion. The most plausible suggestion is the interaction of volcanic gases with the surface material forming sulfates and chlorides (2).

In the 5 analyzed rocks at Pathfinder site the sulfur contents range from 0.3% up to 1.6%. This is higher than is normally accommodated in magmas or igneous rocks and reflects the fact that all rock surfaces are partly covered with dust. With a linear regression calculation for plots of each element versus S the composition of a "soil-free rock" was calculated. The rocks that most closely match this composition are Barnacle Bill and Shark (1), see Table.

Compared to the soils the rocks contain less Mg, Ti, Cr, and Fe but more Si and K as illustrated in Fig. 1. Consequently, the martian soil cannot be made directly from the nearby rocks through weathering processes even if an addition of SO_2 and HCl from volcanic gases are taken into account. Components much richer in Mg and Cr, richer in Fe and Ti but somewhat lower in Si and much lower in K have to be added. Fig. 1 shows the element concentrations of soil-free rock and soils of the Pathfinder landing site in comparison with the composition of martian meteorites grouped by their ejection events and rock types (3). From this figure it appears that the soils could be explained as a mixture of weathered local rocks and more mafic rocks, like the martian meteorites. These individual meteorites reflect the compositional variance of martian surface rocks (Fig. 1).

The close relationship of martian meteorites and Pathfinder rocks is demonstrated in the plot of Mg/Si versus Al/Si ratios (Fig. 2). Pathfinder rocks, soils (MPF soils), the calculated soil-free rock and the Viking soils match the Mars mantle - crust fractionation line as derived from the martian meteorites. This may indicate that shergottites and Pathfinder rocks are derived from primitive melts of very similar composition, where the latter are significantly more evolved. The basaltic shergottites (QUE 94201, Shergotty, and Zagami), which form a second fractionation line (Fig. 2, dashed line), could be rocks derived from younger intrusions into the older martian crust. As they all are assumed to have been ejected from Mars in one event about 2.8 million years ago (3), they must come from one location and might represent related flows derived from a common source, containing increasing portions of cumulus pyroxenes and increasing concentrations of elements with large ionic radii like K or La, inversely correlated with their Al content.

The modeling of the partial melting processes (4) with the codes PARMEL and COMAGMAT starting from the composition of the primitive martian mantle (5) shows that the direct production of shergottite-like melts with its obvious Al-depletion from its original lherzolitic source is not possible. Therefore, a subtraction of garnet, possibly in an early global magma ocean, has been proposed (4) for the magma generation in the martian mantle resulting in an Al- and HREE-deficient material ("ShM" in Fig. 2). Relatively high silica contents in shergottites require low pressure for their generation. In order to accommodate the polybaric decompressional generation of shergottite-like magmas in the region of low pressures, it is necessary to assume that not only Al, but other basaltic components were also lost from their source during the early stages of magma generation. The most probable composition of the martian asthenosphere is therefore harzburgitic ("MA" in Fig. 2), derived by the repeated partial melting of the primitive fertile lherzolites with the removal of magma to the continuously growing crust. In this case, the originally LREE-enriched material ("ShM") would preferentially lose its LREE inventory into liquid phase, resulting in a harzburgitic residue ("MA") with a flat REE pattern.

Element	Barnacle Bill	soil-free rock	soil - avg.
Na_2O %	3.2 ± 1.3	2.6 ± 1.5	2.4 ± 1.0
MgO	3.0 ±0.5	2.0 ± 0.7	7.8 ± 1.2
Al_2O_3	10.8 ± 1.1	10.6 ± 0.7	8.6 ± 0.9
SiO_2	58.6 ± 2.9	62.0 ± 2.7	48.6 ± 2.4
SO_3	2.2 ± 0.4	0	5.9 ± 1.2
Cl	0.5 ± 0.1	0.2 ± 0.2	0.6 ± 0.2
K_2O	0.7 ± 0.1	0.7 ± 0.2	0.3 ± 0.1
CaO	5.3 ± 0.8	7.3 ± 1.1	6.1 ± 0.9
TiO_2	0.8 ±0.2	0.7 ±0.1	1.2 ± 0.2
FeO	12.9 ± 1.3	12.0 ± 1.3	16.6 ± 1.7

The result of moderate degree of partial melting of "MA" composition is melt composition "Liq1" from which fractional crystallization between 1305 -1238°C at 1 bar and QFM (quartz, fayalite, magnetite) oxygen buffer produces "Liq2" = Shergotty composition (Fig. 2). Cooling down of "Liq1" to 1120°C would result in a Barnacle Bill-like melt ("Liq3").

In order to obtain the "MA" composition a removal of about 20% basaltic material from the primitive mantle is necessary. If all this basaltic material was transferred into the crust of Mars, then the crustal thickness would be close to 200 km, excluding a possible eclogitisation.

Calculated moment of inertia coefficients (I/MR^2) derived from martian mantle and core composition with a core mass of 21 % containing 14% S (6), yield 0.354 (7) and 0.357 (8). Both authors had to assume a crustal thickness of 250 km, which is well justified by the above considerations.

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