THE SOILS OF MARS; A. Banin, Dept. of Soil and Water Sciences, Hebrew University, P.O. Box 12, Rehovot 76100, Israel.

Soil on Mars can be defined as "The top non-consolidated layer of weathered and partly weathered rocks of the Martian lithosphere that is exposed to atmospheric effects". The Martian soil covers large portions of the planet surface as one "soil unit" (1), and constitutes a loosely-packed nonconsolidated porous body of very fine particles. Soil material appears to have been thoroughly mixed and homogenized on the global scale by dust storms. Evidences for homogeneity are: (a) the similarity of spectral reflectance fingerprints of large areas on Mars designated as the "bright" regions that appear to represent the more oxidized and weathered rock materials (1,2); (b) the similarity of phsical-mechanical properties of the soil in the two Viking landing sites (3,4,5), and (c) the almost identical bulk-elemental chemical composition of the fine soil studied in the two Viking landing sites (6,7,8).

These fine soil materials are major participants in present-day, planet-wide surface-atmosphere interactions through dust storm activity, volatile balances and land-forming processes. The volcanic history of Mars and the weathering conditions on its surface have left their fingerprints on the soil. Furthermore, the soil may hold clues to the processes that shaped the early history of Mars including abiotic evolution and the possibilities of primitive biotic evolution. Thus, soils are very appropriate candidates for sample-return from Mars, and, because of their spread on the planet's surface, can be an integral part of almost any Mars Rover/Sample Return (MRSR) mission. The current knowledge of the properties of the soil will be briefly reviewed in the following, and open questions that may be answered by thoroughly studying a returned sample will be outlined.

Morphological, Physical and Mechanical Properties: At the two Viking Lander sites a fine reddish soil material is surrounding and covering non-weathered blocks, boulders and cobble-sized rocks. Bulk densities of 1.2 to 1.6 g/cm^3 and low cohesion of $\leq$10kPa characterize the soil (3,4,5). Interparticle cementation by recrystalized salts (chlorides and sulphates) is causing crust and clod formation (5,6). Soil stabilization by salt migration shall be further studied as it relates to aeolian depositional rates and water movements in present-day Mars.

Chemical Composition: The soil analyzed by the two Viking Landers (6,7,8) is relatively rich in silicon and iron, low in aluminum and contains relatively high sulfur and chloride concentrations. Elements directly analyzed account for about 50% of the soil weight (6); if all the detected elements except Cl are assumed to be in their common oxide forms, the total accounts for about 90% of the soil weight (7). The remainder was attributed to: (a) compounds of the elements P, Mn, Cr and possibly Na, which could have been detected but could not be determined unambiguously by the Viking XRF instruments. The amount was estimated to be 2%. (b) Compounds of elements that could not be detected by the Viking XRF; these include water, carbonate, and nitrate, and may account for 8% of the soil's weight (7).

Assuming SNC meteorites are indeed Martian rocks, recent detailed analyses of these meteorites are invaluable in broadening our chemical data-base on Mars rocks and soils (9,10). A combination of the directly measured compositional average data for the Mars soil with SNC analyses is given in Table 1 as a proposed working model for the Mars soil chemical composition. In future studies of Mars this and other models shall be validated by detailed direct analyses. Furthermore, it shall be correlated with source-rock composition to clarify soil formation scenarios and climatological evolutionary pathways on Mars.

The presence of organic matter in the soil, a critical component in relation to exobiology on Mars, is still an open question. The Viking GCMS did not detect any organic material in the soil (11,12); the high redox potential of the soil, shown in the Viking biology experiments and depicted also by the abundance of ferric iron, may have caused the oxidative-decomposition of any organic matter synthesized in the soil or imported by meteorites. However, the Viking landers have sampled the top 0-10 cm of the soil and performed only four analyses. It is of great interest to extend the sampling to greater depths and to various locations where paleosoils may have been shielded from atmospheric and radiative effects and residual organic matter may have been preserved.

Mineralogical Composition: The mineralogical composition of the soil has not been directly analyzed yet. Many candidate minerals have been proposed on the basis of various measured properties that are related to or affected by the soil mineralogy (13). On the basis of the chemical composition it was proposed initially (6,7) that the soil contains smectite clays mixed with kieserite, calcite and rutile. Thermodynamic modelling of the atmsophere-rock equilibria, gave somewhat conflicting results. One study (14) predicted the presence of only simple oxides, carbonates and silicate minerals mixed with soluble salts. Another study (15) suggested that the soil contains high proportion of smectite clays (mostly montmorillonite) mixed with other phyllosilicates (talc), quartz, hematite and anhydrite.

Spectral reflectance has been used to identify mineral components in the Martian soil. In the visible and near IR range (0.4-1.3 μm) the Martian reflectance spectrum (1,2) is characterized by absorbances due to ferric iron which is not present in a well crystalized environment. It can be simulated by the iron-rich montmorillonite clays (16), various amorphous iron oxyhydroxides (17,18) and by palagonite (19). Other candidate minerals that have been proposed on the basis of spectral evidence include talc and serpentine (20) and anatase (21).

Simulation of the main features of the Viking Biology experiments was achieved with iron enriched montmorillonite (22-26). However, it was also proposed that Viking Biology results can be explained assuming the presence of recent weathering products of mafic minerals in the soil (27).

In summary, we propose a mineralogical model for the Mars fine soil that includes as major components smectite clays adsorbed and coated with amorphous iron oxyhydroxides and perhaps mixed with small amounts of better-crystalized iron oxides as separate phases. Also present as accessory minerals are sulfate minerals such as kieserite ($MgSO_4 \cdot H_2O$) and/or anhydrite ($CaSO_4$), rutile (TiO_2), and maghemite (Fe_2O_3) or magnetite (Fe_3O_4), the last two as magnetic components. Carbonates may be present at low concentrations only (less than 1-2%). However, a prime question to be addressed by a MRSR mission shall be related to the mineralogical composition of the soil, and its spatial variability.

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Table 1. Average Chemical Composition Model of the Fine Martian Soil

Oxide	Selected Average Concentration %	Oxide	Selected Average Concentration %	Compound	Selected Average Concentration %
SiO_2	43.4*	K_2O	0.10**	SO_3	7.2*
Al_2O_3	7.2*	P_2O_5	0.68**	Cl	0.8*
Fe_2O_3	18.2*	MnO	0.45**		
MgO	6.0*	Na_2O	1.34**	CO_3	<2***
CaO	5.8*	Cr_2O_3	0.29**	NO_3	?
TiO_2	0.6*			H_2O	0-1†

*Based on direct soil analyses by Viking XRF (6,8). **Based on SNC meteorite analyses (9,10). ***Estimated from LR simulations (24,28). †Varying content.