NORMATIVE MINERALOGY AND POSSIBLE ORIGIN OF MARS PATHFINDER SOILS.

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Preliminary analyses of Martian soils by the X-ray mode of the Mars Pathfinder Alpha Proton X-Ray Spectrometer were reported by [1]. The chemical composition of the soil appears to be similar to those measured by the Viking XRF experiments. Two principal geochemical components (rich in Si, Al, Ca and S, Cl, Mg, respectively) identified in Viking soils [2] are also observed in Pathfinder soils. However, the Viking soil data indicate that Fe and Ti are positively correlated with the silicate component [2], whereas in Pathfinder soils Fe and Ti are positively correlated with S. Also, K is correlated with Al. These results suggest the presence of clay minerals, salts including magnesium sulfate and an Fe-Ti oxide or oxyhydroxide phase.

Two different approaches to calculating soil mineralogy, both based on previous studies of Viking soils, were attempted. The first approach recasts soil composition in terms of alteration minerals in SNC meteorites [3], whereas the second uses stoichiometric clay minerals [4]. In both calculations Cl and S are assumed to occur as halite and magnesium sulphate. Also, a third of the Fe is assumed to be sequestered into maghemite based on results of the magnetic properties experiments on the Mars Pathfinder [5,6]. The first calculation uses a combination of the following: smectites from Nakhla, illite from basaltic shergottite, and plagioclase from nakhlites or basaltic shergottites. The second calculation utilizes a mixture of three endmember smectites: nontronite, montmorillonite and saponite. In both cases, the sums of the residuals are unacceptably high. The normative calculations provide no definitive answers about the mineralogic compositions of Martian soils. At best, they allow the possibility that the soils are composed mostly of smectites. Even when the sum of residuals in the multivariate analysis is low, silica, the oxide which defines the lattice structure of the clays, is not satisfactorily balanced. Further, the compositional variability of smectites poses a problem in inferring whether certain components (e.g. TiO_2) are present as a distinct mineral or as a substituted component in one or more Fe-rich clay minerals. We also attempted to deduce a generic clay formula with substitutions that might explain all the Pathfinder soil analyses. This calculation yields a different smectite composition for every soil analysis. Such mineralogic heterogeneity seems unlikely given the spatial proximity of the soil analyses and the evidence of aeolian mixing of dust.

Numerous formation mechanisms that might explain the chemical composition of Martian soils have been suggested. Two broad classes of mechanisms that have found general acceptance are palagonitization and acid fog reactions. Palagonization involves hydrolytic and oxidative alteration of volcanic or impact glass, producing poorly crystalline or amorphous products [7]. Acid fog reactions are driven by volcanic exhalations of S and Cl, which react with atmospheric water vapor to produce sulfur and hydrochloric acids [8,9]. [10] reported the effects of hydrothermal alteration of impact melted rocks, a process similar to palagonization. The predominant geochemical signatures of this alteration were loss of Al and enrichment of Fe and Mg. The inverse correlation expected for palagonization is observed in a plot of MgO + FeO versus Al_2O_3 in Pathfinder soils, though the correlation is not strong. The compositions of basaltic glass undergoing progressive palagonization (more or less equivalent to leaching) were determined by [11] and compositional changes during acidification were determined by [12]. Ca is lost relative to Mg during the earliest stages of palagonite formation, while Fe and Ti passively accumulate; extended leaching results in loss of Fe, while Ti remains inert. Using depletion factors from [11], we are unable to explain readily the composition of Pathfinder soils by invoking palagonization of either a shergottite or the Pathfinder sulfur-free rock composition. Acid fog reaction of shergottite can explain the composition of Viking soils, but not Pathfinder soils. Thus, the mode of origin for the Pathfinder soils is not entirely consistent with either soil forming mechanism and some combination of processes may be required.

References:

[1] Rieder R. et al. (1997) Science 278, 1771.
[2] Clark B. C. et al. (1982) . Geophys. Res., 87, B12, 10083.
[3] Gooding J. L. (1992) Icarus 99, 28.
[4] Baird A. K. et al. (1976) Science 194, 1288.
[5] Gooding J. L. and Keil K. (1978)
[6] Hviid, S.F. (1997) Science 278, 1768.
[7] Knudsen, J. M., personal communication.
[8] Clark B. C. and Baird A. K. (1979) EPSL, 19, 359.
[9] Settle M. (1979) J. Geophy. Res., 84, 8343.
[10] Allen C.C et al. (1982) J. Geophys. Res., 87, B12, 10083.
[11] Staudigel and Hart (1983) Geochim Cosmochim Acta, 47, 337.
[12] Banin A. et al (1997) J. Geophy. Res., 102, E6, 13341.