

DESERT SOILS AND MARS

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The soils of the hyperarid deserts of Earth are the fundamental analogues for many Mars soils because they have formed in the near absence of life, over time spans up to 10^7 y, and under a very limited availability of liquid water. They are also very geochemically similar to many of the soils examined on Mars [1].

Many attempts have been made to model the geochemical evolution of Martian soils using closed system geochemical models, or one step reactions, with varying results. However, from hyperarid soils on Earth, we know that (1) soil formation is an open system process resulting in chemical and isotopic fractionation during chemical weathering and leaching, (2) climatic boundary conditions undergo large changes over time, resulting in complex weathering histories in any given soil, and (3) these soils nearly always contain incompatible chemical signals of both losses of rock forming elements combined with the later additions of solutes derived from atmospheric deposition and modest downward aqueous redistribution.

An apparent conundrum now exists regarding the spatial variation of Martian soil geochemistry: the vast accumulations of S and Cl in equatorial soils (and the absence or near absence of carbonate) have long been interpreted as indicating an acidic weathering environment, while the recent data from the polar Phoenix lander reveals alkaline pHs and perchlorate. These signals can reflect long term changes in climate and the resulting imprint on old (equatorial) vs young (polar) surfaces. However, there have been no pH measurements made on equatorial soils, and except for the presence of jarosite in distinctive geological deposits, the mineral assemblages provide little direct evidence of acidic conditions. In hyperarid deserts on Earth, soils gradually accumulate S and Cl (from both marine and volcanic sources), have the salts vertically redistributed based on solubility, have neutral pHs, have almost no carbonate due to the low soil CO₂ partial pressures and the competition for Ca by sulfate [2], and can contain considerable quantities perchlorate (as well as nitrates, etc). Thus, the assumed dissimilarities between the Martian soils can also be interpreted, using Earth, as part of a global pedogenic set of processes that have impacted all soils to varying degrees.

A key lesson from hyperarid soils on Earth is the fact that they commonly reflect multiple phases of chemical processes accumulated during climate change. We have shown that using Ti as an index element, that Mars soils at Gusev and Pathfinder sites (like many on Earth) contain evidence of both early stage weathering losses of rock forming elements and late stage additions of atmospheric solutes [1]. While dust influx (and meteorite input in the case of Ni) have been argued as the key source of Martian soils, (1) dust influx into desert soils on Earth invariably leaves a distinctive morphological feature (desert pavement and gravel-free dust below), (2) soils on Mars are apparently chemically weathered relative to reported dust sources, and (3) the use of Ti to normalize soil data reduces the apparent Ni enrichment to much more modest levels (suggesting that some Ni is a weathering residue).

Finally, the source and direction of water movement on Mars is a long source of debate. However, the chemical signature of downward movement of water in Earth soils is a well studied pedogenic and hydrological process. Using this knowledge, shallow soil exposures at Guseve are suggestive of very modest late stage downward movement of water (and redistribution of salts), and the deep exposure at Endurance crater has S, Cl, and Br profiles suggestive of very modest, and late stage, downward movement of water [1,3].

Taken as a whole, there is considerable need to expand the use of, and research on, our most accessible Mars analogue: the soils of Earth.

References:

- [1] Amundson, R. et al. (2008), *Geochim. Cosmochim. Acta*, VOL 72, 3845-3864.
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- [3] Squyres et al. (2009), *Science*, VOL 324, 1058-1061