SILICATE WEATHERING AND DIAGENESIS IN AN ANTARCTIC SOIL-MARS ANALOG

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Data on the nature and rate of chemical weathering in very cold or frozen soils is extremely important in a Martian context and is also relevant to some satellites and small bodies. As part of a study of the Dry Valleys, Antarctica, as Martian analogs (with E. K. Gibson of JSC), we have been investigating features associated with chemical weathering and diagenesis in a sequence of 10 samples from a soil pit on Prospect Mesa in Wright Valley. The general description and major element and soluble ion compositions of these samples are given in (1,2).

We have studied soil samples from the 80 cm-deep pit by optical petrography and SEM. The coarser fraction (>250 μm) is predominantly composed of lithic fragments, including granitic, metamorphic, and sedimentary bedrock fragments and microbreccias (well-indurated soil clumps). The 20-250 μm fraction consists primarily of mineral and microbreccia fragments. Relative mineral abundances for the 50-250 μm fraction, determined by optical petrography, are shown in Figure 1. Silicate abundances are normalized to eliminate the effects of varying salt abundances. The inverse correlation of total ferromagnesian silicates and Fe hydroxide (altered ferromagnesian minerals) indicates that weathering increases toward the surface. Feldspar (plagioclase and K-spar) abundances increase toward the surface; the proportion of feldspars to ferromagnesian minerals also increases, suggesting that the feldspars are less affected by weathering than the ferromagnesian minerals. The abundance of calcite fragments generally decreases from bottom to top in the soil profile; the trend is present in the so-called 'permanently frozen zone' (below 40 cm), where the temperature never exceeds 0°C. Salt abundances (primarily halite) are extremely high at the 2-4 cm depth (salt layer) and decrease systematically downward, fitting an exponential regression curve with $R^2 = 0.97$. The systematic decrease of halite and general increase of calcite with depth, with no break at 40 cm, suggests that chemical activity and ionic transport occur throughout the entire length of the soil column, even in the permanently frozen zone.

Rock-forming silicates throughout the pit show evidence of chemical weathering; most mineral grains are at least partially altered. Feldspars, amphiboles, and pyroxenes exhibit dissolution features that are also characteristic of weathering in temperate climates (3,4). Partial coatings of clay minerals and authigenic salts are common (5). In addition to salts, apparently authigenic zeolites are found in pores in microbreccias (Fig. 2). Analysis by XRD indicates that they are chabazites (6).

It is not clear whether the alteration effects observed in these samples, especially for the minerals in the permanently frozen zone (below 40 cm), are the products of present-day chemical weathering. The presence of delicate dissolution features on mineral grains and delicate secondary minerals, however, suggests that chemical water-ice-soil interactions are taking place, possibly even within the permanently frozen zone. Recent work (7) supports the possibility of present-day weathering: at temperatures as low as -80° C, an interfacial water layer with liquid-like properties persists in soils, permitting both mass transport of water and ionic transport through frozen ground.

If chemical weathering and near-surface diagenesis are presently occurring in Antarctic soils, then it is likely that analogous reactions are also occurring on Mars, as it is probable that a subsurface system of ice and/or water exists (8) to aid in the weathering process. Our Antarctic studies in

dicate that even starting with a relatively simple suite of rock forming minerals, the weathering process on Mars is likely to create a very complex mixture of secondary minerals, evaporite minerals, and partly-weathered primary minerals. As previously suggested (9), simple models for the mineralogy of the Martian regolith need to be re-evaluated.

The zeolites in the permanently frozen zone of the soil pit, if authigenic, may have important implications for the Martian regolith. Sedimentary zeolites are often found in terrestrial soils in arid climates and are also common in soils formed from volcanic glass (10). Soils rich in zeolites are often reddish-brown (10). It seems possible that zeolites may form in the Martian regolith; if so, their gas exchange properties might strongly affect regolith-atmosphere interactions and the zeolites might serve as a CO_2 reservoir.

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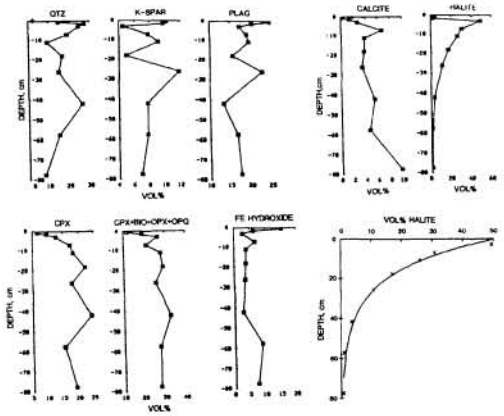

Fig. 1

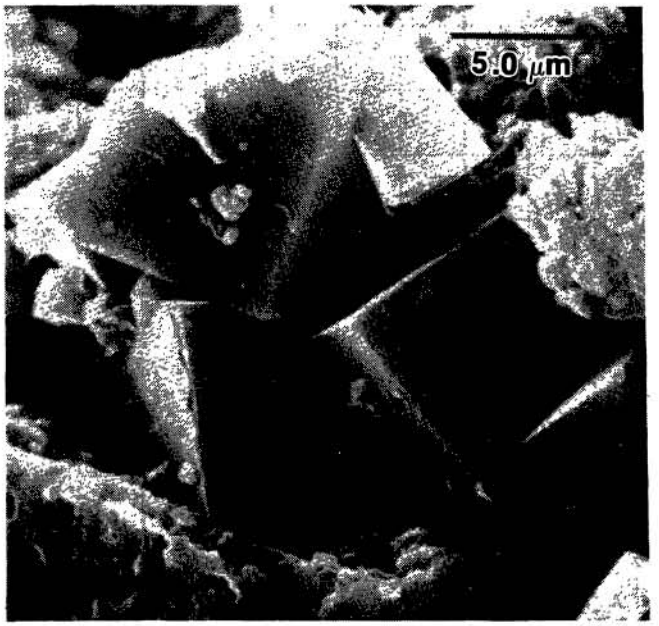

Fig. 2