LOW-TEMPERATURE, AQUEOUS ALTERATION OF SOIL IN WRIGHT VALLEY, ANTARCTICA, COMPARED WITH AQUEOUS ALTERATION ON MARS.

S. J. Wentworth,[1] E. K. Gibson, Jr.,[2] and D. S. McKay[2], [1]Lockheed Martin Space Operations, C23, 2400 NASA Rd. 1, Houston, TX, 77058 (susan.j.wentworth@jsc.nasa.gov), [2]NASA Johnson Space Center, Houston, TX, 77058.

Introduction: The Dry Valleys of Antarctica are possibly one of the best analogs on Earth of the environment at the surface of Mars. Many types of research have been focused on the Dry Valleys, partly because of the potential application to Mars, and also because of the importance of the Dry Valleys in understanding the characteristics and development of terrestrial polar deserts. In 1983, we published a detailed study [1] of weathering products and soil chemistry in a soil pit at Prospect Mesa, Wright Valley, as a possible analog to Mars. Much more is now known about Mars, so we are re-examining that earlier work and comparing it with newer martian data. The Mars information most pertinent to this work includes (**A**) the strong evidence for recent aqueous activity on Mars reported by [2], along with more recent evidence for present-day, near-surface water ice on Mars [3, 4]; and (**B**) the identification of meteorites from Mars [5] and the subsequent, definitive proof that low-temperature, aqueous weathering has occurred in these meteorites prior to their ejection from Mars [6-8].

Soil column, Wright Valley: The samples used in the Dry Valleys study [1] were taken at irregular intervals from the soil pit shown in Fig. 1. The soil column consists of a permanently frozen zone below ~40 cm depth overlain by an active/seasonally frozen zone.

Results of the Wright Valley work seem to be consistent with what is now known or postulated about Mars. Orbital data indicate the presence of water ice just beneath the martian surface, especially at high latitudes [2, 3].

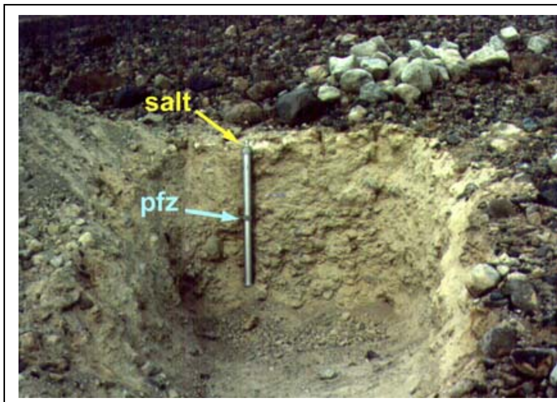

Figure 1: Soil pit, Prospect Mesa, Wright Valley, Antarctica. Drive tube=78 cm long. Yellow arrow points to salt-rich zone just beneath surface (~2-4 cm depth). Top of permanently frozen zone (pfz) is at ~40 cm depth; after [1].

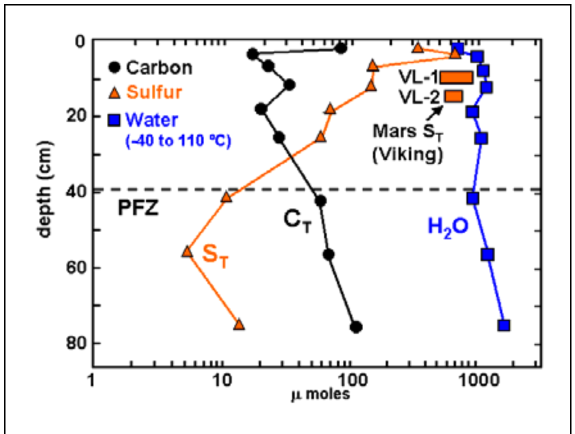

Figure 2: Total water, C, and S in soil pit, Prospect Mesa, Wright Valley; dashed line marks top of permanently frozen zone (pfz); after [1].

Similarly, Fig. 2 demonstrates that the water content (from -40 to +110 deg C) of the Wright Valley soil is much lower at the surface than at depth. This upward decrease in water occurs even within the permanently frozen zone.

In the Wright Valley soil column, water-soluble (salt-forming) species generally increase upward, with a salt-rich zone at ~2-4 cm depth and a dramatic decrease in salts at the surface of the soil (Fig. 3). Mars remote sensing data suggest that total amounts of alteration of original igneous rocks on Mars may be low [3]. The duricrust found just beneath the surface during Viking lander experiments, however, indicate that subsurface salts analogous to those in the Wright Valley soils are likely present on Mars although their possible abundance and distribution are unknown.

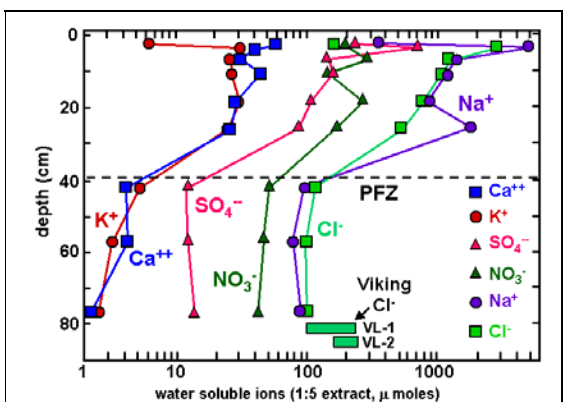

Figure 3: Water-soluble ions in soil pit, Prospect Mesa, Wright Valley; after [1].

Aqueous alteration and secondary phases: SEM studies of the Wright Valley soils [1] showed that aqueous alteration of detrital silicate grains and the formation of secondary phases occurred throughout the soil column, including the permanently frozen zone. Similar features are also present in martian meteorites, and various lines of evidence have shown that some of this alteration occurred on Mars [8, 9]. Examples of typical silicate dissolution in the Dry Valleys soil and a Mars meteorite (Shergotty) are shown in Fig. 4. These features are quite similar to each other. They are typical of chemical weathering of such silicates but are not diagnostic of the mode of alteration. Note that the Wright Valley grain (Fig. 4A) came from the permanently frozen zone of the soil, demonstrating active, although probably slow, alteration processes.

The Wright Valley soil (again, including the permanently frozen zone) and the martian meteorites also contain secondary salts. Secondary carbonates, Ca-sulfate, and halite are found in the Wright Valley soils and the martian meteorites, although not all the meteorites contain all these minerals. A martian origin has been well established for some, but not all, of the secondary phases in martian meteorites. Various means have been used to determine a martian origin for secondary phases; e.g., carbonates in meteorite ALH84001 were quantitatively identified as martian because of their ~3.9 Ga age (ALH84001 itself is 4.5 Ga old) [7]. The origin of many other secondary phases in other meteorites is less certain, however.

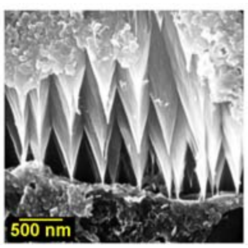

Figure 4A: SEM image of amphibole from Wright Valley soil pit sample WV-221 (permanently frozen zone) showing dissolution features typical for silicates; after [1].

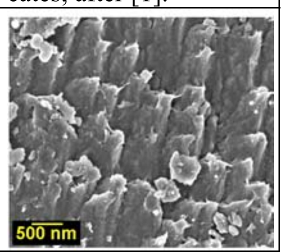

Figure 4B: SEM image of pyroxene from martian meteorite Shergotty (observed fall) with dissolution features and incipient phyllosilicates.

Recent orbital data have suggested the possible presence of a zeolite such as chabazite in Mars dust [10]. Chabazite is present as an authigenic mineral throughout the Wright Valley soil column (Fig. 5) in the Antarctic soil. This is consistent with the suggestion by [11] that chabazite may store water on Mars, especially near the equator. More work is needed to determine whether zeolites are not present in the existing martian samples, or whether they simply have not been found yet.

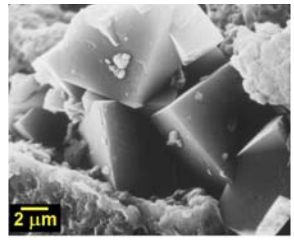

Figure 5: SEM image of authigenic chabazite in Wright Valley soil pit sample WV-221 (permanently frozen zone); after [1].

Conclusions: Aqueous alteration in Mars meteorites and the Wright Valley soil are quite similar with respect to type and degree of weathering of the primary silicates, and also to the nature and distribution of secondary phases. Alteration in the Dry Valleys soils occurs even in the permanently frozen zone, suggesting that similar alteration probably occurs on Mars. Alteration can occur gradually in permanently frozen material because of a liquid-like thin film of water that seems to persist at very low temperatures [12]. Freezing-point depression in brines could also cause weathering at low-temperatures; the salts in the Mars meteorites point to the existence of such brines. The low total amount of alteration of the martian meteorites, along with the presence of secondary phases only in trace amounts, seems consistent with such a process. Transient heating events (e.g., impacts and volcanic activity) have probably been responsible for some weathering on Mars. The Mars meteorites probably do not reflect strong heating events because significant alteration would be expected, at least in close proximity to the heated areas. The seasonal behavior of water ice at the martian poles and possibly elsewhere indicates that water (liquid or vapor) is available for periodic episodes of weathering, even if effects are concentrated mostly on wind-blown dust. Whether or not Mars was once wet and warm, or if it was always cold and dry as suggested by [13], it is clear that weathering and salt deposition have occurred in some form. If the cold, dry Mars model is correct, then the Dry Valleys of Antarctica may be a good analog for most of Mars for most of geologic history.

References: [1] Gibson et al (1983) Proc. LPSC 13, A912-A928; [2] Malin and Edgett (2000); [3] Boynton et al. (2002) Science 297, 81; [4] Christensen (2003) 6th Mars Conf. #3126; [5] Bogard and Johnson (1983) *Science*, 221, 651; [6] Gooding et al. (1988) *GCA* 52, 909; [7] Borg et al. (1999) *Science* 286, 90; [8] Wentworth et al. (2003) *Astrobio*, in revision; [9] Gooding et al. (1991) *Meteoritics* 26, 135; [10] Ruff (2002) *Eos* 83, 1059; [11] Bish et al. (2003) *LPS XXXIV*, 1786; [12] Anderson (1981) *NASA TM 84211*, 292.