ANTARCTIC DRY VALLEYS: MODIFICATION OF ROCKS AND SOILS AND IMPLICATIONS FOR MARS: David R. Marchant and James W. Head. 1Department of Earth Sciences, Boston University, Boston MA 02215 marchant@bu.edu. 2Department of Geological Sciences, Brown University, Providence, RI 02912

Introduction. Rocks exposed to salt-weathering, wind-erosion, and thermal stresses over million-year time scales in the Dry Valleys region of Antarctica are morphologically similar to rocks observed at lander/rover scales on the martian surface (Fig. 1 and 2). In upland regions of the Dry Valleys, including areas that lack traditional active layer processes (such as buoyancy-driven convection, lateral and vertical sorting associated with the growth of near-surface ice, and seasonal creep [1]), surface rocks are fixed and stable; they are modified solely by salt weathering, wind deflation, and thermal stresses. Here we outline some of the key characteristics of surface rocks and near-surface sediment in the upland regions of the Dry Valleys that may help provide clues to the origin of surface features observed at lander/rover scales on Mars (Fig. 1 and 2).

Salt weathering. The geomorphic impact of salt weathering is readily visible as pits, micro-rills, and channels on the surface of low albedo rocks. The sulfates, chlorides, and nitrates that together produce salt encrustations on rock surfaces in the Dry Valleys originate from minor melting of snowfall that collects in rock depressions on solar heated, low albedo rocks (Figs. 3, 4). Snowmelt may occur even when ambient air temperatures are <0 °C (Fig. 4). Repeated cycles of melting and concentration of ions through water evaporation in pits are sufficient to produce visible salt encrustations. Micro-fracturing and undercutting of rock minerals by the growth and hydration of these salts creates pits that, through positive feedback, attract more snow, producing more salts. Over million year time scales, this process can produce a network of pits and micro-rills on the surface of rocks. The micro-rills (Fig. 4) form where rock surfaces are inclined such that meltwater spills out from pits and flows down the rock surface. The micro-pattern of rock removal may resemble the development of buttes and mesas as seen in large-scale bedrock forms of the American southwest, but more commonly emerges as a series of deep, isolated pits on the rock surface (Figs. 2, 3, 4). Pit diameter varies from 1 mm to as much as 5 cm and from 1 mm to 3 cm deep. Coarse-grained rocks are generally more susceptible to salt weathering than fine-grained rocks (i.e., with crystals < 1 mm), regardless of lithology.

Thermal stress. In concert with the development of salt encrustations, rocks in the Dry Valleys experience thermal changes on a variety of timescales (hourly, daily, seasonally, etc.). For dark basalts with measured albedos as low as 0.07 (ratio of reflected to incoming short-wave radiation), surface temperatures may vary daily as much as 23° C [2]. Some fractures exploit visible planes of rock weakness (i.e., joints) but others occur despite visible weaknesses. Rock fragments produced by thermal fracturing can be pieced together seamlessly (Fig. 5), suggesting that material along fractures has not been lost as might be expected from salt-weathering. Preliminary data suggest that thermal fracturing is most effective on rocks that exceed 20 cm in diameter and that gravels < 4 cm in diameter are little effected by this process.

Wind erosion. One observed effect of wind erosion in the Dry Valleys is the displacement and transport of particles at rock surfaces weakened by salt weathering and thermal contraction. Small pebbles trapped in pits produced by salt weathering may help carve hollows in rocks, in a manner analogous to the development of potholes in high-energy streams. The style of wind erosion varies according to lithology. In weakly cemented sandstone bedrock, wind erosion is accomplished through grain-by-grain deflation. In competent rock, such as basalt and diorite, wind erosion elongates pits produced by salt weathering and creates distinct fluting on the rock surface (Fig. 1). Such flutes are parallel with the trend of measured katabatic winds. Sand blasting associated with saltating grains of sand (and gravel) smooths rock surfaces, creating facets that dip at shallow angles towards dominant wind directions (Fig. 1). In regions of high winds, these gently sloping surfaces lack desert varnish, even though the remainder of the rock surface may contain varnish up to 5 mm in thickness. Salt weathering, in concert with wind deflation, may produce small upstanding pedestals of desert varnish on rock surfaces between intervening areas of degraded rock (erosional remnants of varnish may show from 1mm-to-5-mm relief). The intricate stratigraphy and geometry of desert varnish pedestals, along with small scale surface features such as glacial striations, suggest multiple periods of varnish formation, stripping, and renewed development of desert varnish.

Thermal contraction in near-surface soils. Thermal contraction in near-surface soils creates a network of interlocking polygonal cracks. These vertically oriented cracks, which may be as much as 2 cm wide when first formed [3], outline multi-sided polygons in plan view (Fig. 6). Average polygon diameter varies from 5 m to > 20 m [3]. If near surface materials are dry and non-cohesive (a situation not satisfied everywhere in the Dry Valleys, see Duricrust), then loose sands may filter down into cracks creating funnel-shaped, surface depressions (Fig. 6).

Duricrusts. One characteristic of many soils in the Dry Valleys is a semi-indurated, surface duricrust (Fig. 7). These crusts, which may be up to 2-cm thick, form in a variety of micro environments, but are favored in regions that experience minor snowmelt. Salts produced in association with snowmelt may be one mechanism that helps bind loose grains that form the crust. In the Dry Valleys, wind sculpting may create small micro-relief or “micro-yardangs” (1 to 2 cm relief) etched within top surface of the duricrust.

Implications and conclusions. The hyper-arid, cold desert conditions of upland regions of the Dry Valleys of Antarctica (mean annual air temperatures ≤ 30°C and near-surface soil moisture < 5%) foster the development of a
unique suite rock features, including pits, facets, and linear fractures, as well as evidence for thermal contraction in near-surface soils. These features appear morphologically similar to those on rocks and sediment on Mars observed at lander/rover scales. A better understanding of these Antarctic landforms will help shed light on the origin and evolution of small-scale landforms on Mars.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7