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Antarctic Dry Valleys: Geological Processes in Hyperarid, Hypothermal Environments and Implications for Water on Mars

J. Head (1), J. L. Dickson (1), J. S. Levy (2), D. M. H. Baker (1), and D. R. Marchant (3)

(1) Brown University, Geological Sciences, Providence, United States (james_head@brown.edu, +1 401 863-3978), (2) Oregon State University, College of Earth, Ocean and Atmospheric Sciences, Corvallis, United States (jlevy@coas.oregonstate.edu), (3) Boston University, Department of Earth Sciences, Boston, United States (marchant@bu.edu)

The Antarctic Dry Valleys (ADV) are characterized by mean annual temperatures (MAT) well below the freezing point of water and are among the coldest and driest environments on Earth. In spite of these extreme conditions, seasonal temperatures (ST) and peak daytime temperatures (PDT) can locally exceed the melting point of water in certain settings in certain microenvironments. Three major microenvironments (upland stable zone, inland mixed zone, coastal thaw zone) are defined in the ADV on the basis of measurements of atmospheric temperatures (MAT/ST), soil moisture and relative humidity, and the concurrent availability and mobility of water; these microenvironments show variations in the abundance and character of different geomorphic features. For example, in the coldest upland stable zone melting is almost non-existent and sublimation polygons dominate; ice-wedge polygons occur in the coastal thaw zone where seasonal temperatures can exceed the melting temperature of water; sand-wedge polygons occur in the inland mixed zone. The ADV are characterized by a regional permafrost layer and a shallow ice table. In contrast to more temperate latitudes on Earth where the hydrological system and cycle are vertically integrated, the ADV hydrological system consists of a horizontally stratified hydrological cycle; the regional permafrost layer precludes vertical exchange of surface water and deep groundwater below the permafrost. Local near-surface meltwater is produced seasonally, flows across the surface to create gullies, channels and small fluvial features, and soaks into the dry upper part of the permafrost, running downslope along the top of the ice table in a perched aquifer. In this context, melting of seasonal and perennial surface and very near surface snow and ice deposits during peak seasonal and peak daytime temperatures causes a range of fluvial and liquid water-related features in the coastal thaw zone and inland mixed zone. Among the features and processes that we have analyzed and instrumented over numerous field seasons in the ADV are rock-weathering processes, debris-covered glaciers, viscous flow features, polygons, active gullies, recurring slope lineae, fluvial channels, and small ponds and lakes. Key to understanding these features in the ADV has proven to be: 1) location of surface microenvironments that sequester seasonal and perennial snow and ice, 2) understanding the importance of peak daytime and seasonal temperatures, in contrast to MAT, 3) the role of the shallow ice table in producing a perched aquifer in the dry part of the soil layer above the top of the ice table, 4) understanding the importance of short-term peak melting events (revealed by time-lapse images and environmental instrumentation), 5) measuring seasonal rates of vertical propagation and depths of penetration of the melting geotherm, 6) determining the role of salt exchange in hyporheic zone processes and alteration of rocks and soils, and water chemistry, and 7) analysis of the role of insolation and slope orientation in melting processes. These factors also have important implications for the study and interpretation of water-related features and the climate history of Mars. Similarities are observed between the ADV microenvironments and latitudinal zones and geomorphic feature distributions on Mars.