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Antarctic Dry Valley Streams and Lakes: Analogs for Noachian Mars?

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Recent climate models suggest that Noachian Mars may have been characterized by a "cold and icy", rather than a "warm and wet" climate. Noachian valley networks and open basin lakes have been cited as key evidence for a "warm and wet" early Mars. We investigate fluvial and lacustrine processes in the Mars-like Antarctic McMurdo Dry Valleys (MDV) to assess whether such processes, which take place in the absence of pluvial activity and with mean annual temperatues (MAT) well below zero, can serve as informative proxies for Noachian Mars. In contrast to temperate climates, fluvial processes in the MDV (and thus a host of weathering, erosion and transport processes there) are severely limited by the lack of rainfall. The limited sources of meltwater provide very local streams and hyporheic zones, serving to concentrate chemical weathering processes and biological ecosystems. The horizontally stratified hydrologic system means that localized meltwater is constrained to flow in a very shallow and narrow aquifer perched on top of the ice table aquiclude. Lakes and ponds in temperate areas are largely of pluvial origin and characterized by abundant vegetation, large drainage basins and higher order streams delivering rainwater. In contrast, the hyperarid, hypothermal conditions in the MDV mean that there is no rainfall, water sources are limited primarily to meltwater from the surface of cold-based glaciers, and drainage into lakes is seasonal and highly variable, being related to changing and sluggish response to surface ice hypsometry, itself a function of changing climate. Lake surface fluctuations are caused by imbalances between meltwater input and sublimation from the lake surface ice and this sensitive balance tends to magnify even minor climate signals. Where does the lakewater come from and under what conditions is excess meltwater produced to cause modifications in their levels? The dominant means of supply (meltwater) and loss (ablation) are clearly seasonally and climatically controlled. Throughout their recent history it is clear that small perturbations to the climate can result in large changes in the lake systems, often in non-intuitive ways. The main source of meltwater supply in the MDV is from surface melting of glaciers and snowbanks. The observed positive correlation between increased lake levels and streamflow is thought to represent a complex relationship with the climate-related behavior of glaciers, specifically depending on the distribution of glacier area with elevation in the watershed. As the H_2O melting temperature rises seasonally in altitude, glaciers begin melting in a complex non-linear manner, feeding streamflow. The rate of streamflow will increase as seasonal warming brings the melting temperature up to the specific elevation that represents the maximum glacier area per elevation contour in the ablation zone. This framework of seasonal melting and fluvial/lacustrine processes in an otherwise hyperarid, hypothermal Mars-like Antarctic cold-based non-pluvial environment provides a baseline of environmental conditions to test the hypothesis that a "cold and icy" Noachian Mars might produce the observed fluvial and lacustrine features during transient warming periods.