

CHEMISTRY OF SEDIMENTS AND AQUEOUS FLUIDS PRODUCED BY CHEMICAL WEATHERING IN COLD, ARID SYSTEMS

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Introduction: Recent studies suggest that Mars may have hosted mid-to low latitude glacial systems in the relatively recent past [1-3]. Glacial systems contribute significantly to physical weathering fluxes on Earth, creating large volumes of unsorted sediment dominated by small grain sizes relative to other physical erosion mechanisms [4], even in cold-based glaciers [5]. This suggests that periglacial chemical weathering on Mars may be an important process during periods of mid-to-low latitude glacial activity.

While chemical weathering in glacial systems has long been presumed to be minimal owing to the requisite low-temperature conditions (and hence lower chemical reaction rates), recent studies have demonstrated that glacial systems contribute significantly to global chemical weathering processes. In addition, chemical weathering in terrestrial periglacial systems produces sediments with different chemical weathering signatures relative to sediments produced in nonglacial systems, largely due to the production of fresh mineral surfaces [6-7]. Since weathering rate is directly controlled by the availability of fresh surface area to react with the surrounding water, sediments with high surface area (fine grain sizes), will exhibit enhanced differences in observed reaction rate between mineral phases compared to those with lower surface areas.

In addition to erosion rates and surface area production, dilute pore waters and their short residence time within glacial sediments are key attributes of high-latitude systems [8], including those of cold-based glacial systems [9]. Indeed, chemical weathering occurs even in Antarctica, where liquid water is present only during the brief Austral summer [10-13]. This study examines the sediment and aqueous products of these brief periods of chemical weathering in small catchments in Taylor and Wright Valleys to better characterize the nature and extent of chemical weathering in cold, arid, periglacial systems, similar to those which may have been present on Mars during periods of high obliquity.

Field and Laboratory Methods: Field work was conducted in January, 2010 to collect sediment and water samples from catchments draining granitic be-

drock in Taylor and Wright Valley. Transects were conducted beginning at the exposed source bedrock (or glacial terminus) and extending approximately 5-7+ km downstream within the depositional system. Along the transect samples were collected at approximately 500-1000 m intervals from fine-grained deposits within slackwater channel deposits and/or bar-tops of recently abandoned channels from active parts of the depositional system. Water samples were collected using a 25 ml pipette and were acidified in the field. Sampling localities and surrounding deposits were mapped and samples of bedrock and/or glacial drift were collected to determine the effect of the primary lithology on sediment and aqueous geochemistry. Water and sediment samples were also collected from a drainage basin with similar bedrock lithology in the Wichita Mts, OK, to compare the products of a cold, arid climate with a temperate system. Once the frozen samples were returned to the laboratory in April, the aqueous samples were filtered through 0.2 micron cellulose filters and the water cation and anion chemistry was determined using ICP-MS analysis. Sediment samples were sieved to determine the relative grain size proportions. The fine-grained fraction was used for further grain size (laser particle size), surface area (nitrogen adsorption BET), mineralogical (powder X-ray diffraction), and bulk chemical (acid digestion and ICP-MS) analyses. Grain mounts were produced from the sand-sized fraction and thin sections made from bedrock and drift samples for point counting. Owing to the large volume of data, analysis is ongoing and only preliminary results of the study are presented here.

Results: Kinetic modeling of low-temperature, high-surface-area proglacial chemical weathering conducted prior to the study, and field observations of solutes reported in the literature, suggest that K^+ concentrations will be elevated in glacial weathering fluids. This hypothesis was confirmed in the aqueous chemistry data (Figure 1). In addition, we observed increasing concentrations of Na^+ , Ca^{2+} , and Mg^{2+} with distance in the depositional system, suggesting that significant chemical weathering is occurring in the system. The decrease in total iron concentration is likely due to the oxidation and subsequent precipitation of

ferrous iron released beneath the glacier under anoxic conditions.

Given the efficacy of glacial systems in producing fines, and the high reactive surface area of fines, we postulate that most of the chemical weathering occurring in the Dry Valleys affected the fine-grained fraction. Results from laser particle-size analysis and BET surface-area measurements of the silt and clay fraction confirm that the percentage of fine-grained sediments decreases downstream (Figure 2), suggesting that the dissolution of the fine grained portion of the sediment may be dominating the weathering signature.

Conclusions: Preliminary analyses of sediments and aqueous products of chemical weathering in the Antarctic Dry Valleys affirm that significant chemical weathering is occurring in these cold, arid, proglacial systems. The chemistry of the fluids and texture of the sediments produced suggest that chemical weathering processes in the Dry Valleys differ from those observed in more temperate terrestrial systems. This may be due to the high surface area produced as a result of physical weathering in glacial systems. Further analysis of the mineralogy, texture, and bulk chemistry of the sediments is currently underway to elucidate the processes responsible for these differing trends in chemical weathering products and textures in cold, arid systems.

The results of this study suggest that chemical weathering in proglacial systems on Mars should be considered as a potentially important component of geochemical cycles on Mars.

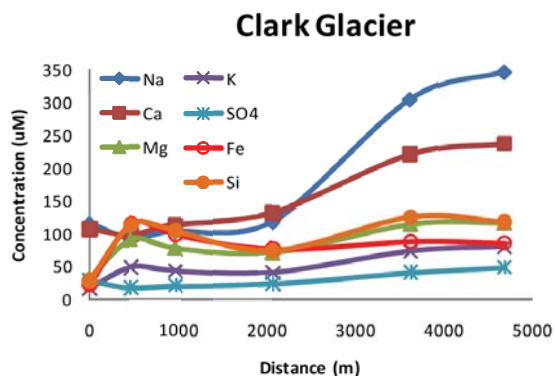


Figure 1. Aqueous chemistry of Clark Glacier stream, Wright Valley, Antarctica. Increasing concentrations in cations suggest that silicate phases are chemically weathering, despite cold, arid conditions.

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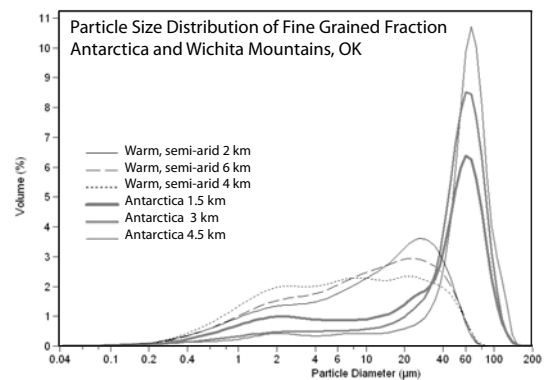


Figure 2. Grain-size distribution in fine-grained fraction of proglacial samples from the Antarctic Dry Valleys and the warm semi-arid Wichita Mts. (Oklahoma). Dry Valley sediments show a decrease in the fine-grained component with distance downstream, suggesting preferential dissolution of fine particles. Wichita Mt. sediments show an increase in fine particle size downstream from precipitation of secondary weathering products.