Was ancient Mars warm and wet or cold and icy? Mineral signatures of climate in rover, orbiter, and terrestrial analog studies

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Ancient valley networks and lake deposits on Mars are clear evidence that liquid water was once abundant on the surface, but whether the climate was warm and wet or cold and icy is poorly understood. We suggest that the mineralogical record of Mars may provide new constraints on the paleoclimate. Here we report on a series of studies using samples from Mars analog terrains on Earth to better understand the effects of climate on weathering mineralogy.

Weathering in alpine glacial settings of the Oregon Cascades is driven by frequent melt, and water and sediments have low residence times in the glacial system. Abundant alteration products in proglacial terrains include silica coatings on bedrock and poorly crystalline silicates in glacial sediments. Preliminary results from mafic sediments at cold-based margins of the Antarctic ice sheet also show poorly crystalline silicates, consistent with weathering by transient melt. In contrast, sediments from warm-based zones show enrichments in crystalline clay minerals, which we hypothesize form due to longer residence times under the ice sheet. Similar trends are observed in terrestrial mafic soils, from crystalline clay minerals in warm climate soils to poorly crystalline phases in cold climate soils.

Silica signatures have been identified from orbit on Mars in Amazonian periglacial terrains, and the Curiosity rover has identified silica-rich poorly crystalline materials in Hesperian lake sediments in Gale crater. We suggest that these amorphous phases on Mars could have formed in cold climates during punctuated melt events. However, the most common Noachian alteration signatures are crystalline clay minerals in compositionally zoned stratigraphies, for which the closest terretrial analogs are deep weathering profiles only known to form under persistent rain-dominated climates. These observations suggest at least one long-lived climatic optimum in the Noachian, but in situ analysis of Noachian detrital sediments by Mars 2020 will be necessary to determine if icy conditions otherwise prevailed.