EXPERIMENTAL EVIDENCE FOR WEATHERING AND MARTIAN SULFATE FORMATION UNDER EXTREMELY COLD WATER-LIMITED ENVIRONMENTS.  P. B. Niles¹, D. C. Golden², and J. Michalski¹;¹, ¹Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, TX (paul.b.niles@nasa.gov); ²ESCG, Houston, Texas; ³Planetary Science Institute, Tucson, Arizona. ⁴Dept. of Mineralogy, Natural History Museum, London, United Kingdom.

Introduction: High resolution photography and spectroscopy of the martian surface (MOC, HiRISE) from orbit has revolutionized our view of Mars with one of the most important discoveries being widespread layered sedimentary deposits associated with sulfate minerals across the low to mid latitude regions of Mars [1, 2]. The mechanism for sulfate formation on Mars has been frequently attributed to playa-like evaporative environments under prolonged warm conditions [3]. However, there are several problems with the presence of prolonged surface temperatures on Mars above 273°K during the Noachian including the faint young Sun [4] and the presence of suitable greenhouse gases [5]. The geomorphic evidence for early warm conditions may instead be explained by periodic episodes of warming rather than long term prolonged warm temperatures [6].

An alternate view of the ancient martian climate contends that prolonged warm temperatures were never present and that the atmosphere and climate has been similar to modern conditions throughout most of its history [6]. This view is more consistent with the climate models, but has had a difficult time explaining the sedimentary history of Mars and in particular the presence of sulfate minerals.

We suggest here that mixtures of atmospheric aerosols, ice, and dust have the potential for creating small films of cryo-concentrated acidic solutions that may represent an important unexamined environment for understanding weathering processes on Mars [7, 8]. This study seeks to test whether sulfate formation may be possible at temperatures well below 0°C in water limited environments removing the need for prolonged warm periods to form sulfates on early Mars.

Methods: To test this idea we performed laborator-
Significantly lower dissolution rates are observed at -60°C for both olivine and pyroxene which indicate that as the system moves below the eutectic, weathering drops off very quickly. This result validates our experiments, essentially providing a blank analysis where it is clear that the weathering we do observe at -40°C is not occurring at some other time in the experimental procedure.

Implications: These results demonstrate that low-T weathering is a viable process for producing sulfate minerals from a silicate protolith in the presence of sulfuric acid on Mars. The presence of large deposits of mixed ice and dust on Mars is undisputed. The presence of substantial sulfur-rich volcanism, and sulfur-rich surface deposits also makes it very likely that sulfate aerosols have also been an important component of the martian atmosphere [8]. Thus mixtures of ice, dust, and sulfate aerosols are likely to have been common on the martian surface.

The variation in orbital obliquity on Mars through history requires that at certain periods of high orbital obliquity the polar regions received greater solar insolation than the equatorial regions [11]. This high orbital obliquity would almost certainly result in the movement of ice away from the modern poles to lower latitude regions [12]. It seems likely, given the frequency and magnitude of the obliquity variations, that a substantial sedimentary record could be produced by this process if the ice deposits contained substantial amounts of dust, and provided a means for altering and cementing that dust.

Analogs on Earth and Mars: The current polar regions of Mars provide an interesting analog that can be used for a comparison. Large regions of sulfate-rich material have been detected on and around the modern north polar region of Mars [13]. The prevalence of ice-dust mixtures in this region and the existence of sulfates within the ice cap itself are strong evidence for the origin of the sulfates from inside the ice deposits [13].

There is also evidence for the ice weathering process on Earth. Sulfates have been found in ice deposits in Greenland and Mount Fuji on Earth that have been attributed to forming within the ice deposit [14-16]. These sulfates can form either through interaction with dust particles in the atmosphere or through weathering inside the ice itself [14-16].

Gale Crater and MSL: Gale crater provides an opportunity to test this hypothesis in a new way using the Mars Science Laboratory (MSL) rover. The crater contains a large sedimentary deposit that has many characteristics in common with other large low latitude deposits on Mars including ILD’s in Valles Marineris, crater mounds in Arabia, and the layered sediments at Meridiani Planum [7, 17].

Conclusions: The weathering rates measured in this study suggest that fine grained olivine and pyroxene on Mars would weather into sulfate minerals in short time periods if they are exposed to H_2SO_4 aerosols at temperatures at or above -40°C. Given the abundance of ice and dust on the surface and the fact that it is not difficult to achieve surface temperatures above -40°C on Mars throughout its history, it seems likely that sulfate formation is controlled by the availability of sulfate aerosols and not by the martian climate.