SUBSURFACE WEATHERING OF ROCKS AND SOILS AT GUSEV CRATER. A. S. Yen[1], D. W. Ming[2], R. Gellert[3], B. C. Clark[4], R. V. Morris[2], D. Rodionov[5], C. Schröder[5], G. Klingelhöfer[5], and Athena Science Team. [1]Jet Propulsion Laboratory, California Institute of Technology, [2]NASA Johnson Space Center, [3]Max Planck Institute for Chemistry, Germany, [4]Lockheed Martian Corporation, [5]Johannes Gutenberg University, Mainz, Germany.

Introduction: Data collected by the Mars Exploration Rover (MER) Spirit at Gusev Crater suggest that enhanced weathering of rocks and soils occurs beneath the immediate surface. We suggest that this alteration occurs over geological timescales under present climatic conditions and is a result of diurnal condensation of thin-films of water on subsurface materials.

Weathering Scenario: The proposed mechanism for enhanced subsurface weathering under present climatic conditions results from cold night-time temperatures and frost formation. Recent temperatures recorded by Spirit indicate that values below -90ºC are regularly achieved. This is well below the frost point. At sunrise, rapid sublimation occurs and high thermal inertia and subsurface materials which remain below the condensation temperature compete with the atmosphere for the released water molecules. Rocks in the near subsurface, the interiors of fractured rocks, and subsurface soils collect H_2O at rates that produce transient, multiple-monolayer films of water that behave as a liquid. Chemical alteration (dissolution, oxidation, reprecipitation, etc.) occurs during the ~tens of minutes each day when the liquid water is available. Acting over geological timescales, including periods of high obliquity when the effects are enhanced, this process is believed to be responsible for the weathered coatings on light-toned plains rocks. This scenario likely contributes to the weathering of subsurface soils and possibly to the alteration of rocks on the Columbia Hills.

Plains Rocks: Images collected from the Gusev plains indicate that light-toned, more dust covered rocks generally have a low profile, while darker rocks are typically taller. Many rocks also have a two-toned appearance with a lighter base and darker top (Fig. 1). These plains have experienced widespread deflation [1], and light-toned rocks have likely been exhumed after an extended period of burial. Images from the Microscopic Imager (Fig. 2) show that nearly all partially buried rock fragments have a light-toned coating, further suggesting that the surface appearance is a result of processes that occur while buried.

Three plains rocks were analyzed in detail: One light-toned rock, "Mazatzal" (Fig. 1) and two darker samples [2]. The interior compositions are essentially identical and representative of unaltered basalts, but "Mazatzal" exhibits an alteration rind where ~10% of the iron is in hematite (absent in the other rocks) [3]. In comparison to the other two rocks, the ferric to total iron ratio is ~two times higher and the measured bromine content is ~three times higher. Bromine is an element which is highly soluble, easily mobilized by water, and consistently enhanced in regions that are likely cold traps for water (Fig. 3). The presence of hematite, the high oxidation state, and the elevated bromine content are all indicators of aqueous activity. We suggest that aqueous alteration of the surface of "Mazatzal" occurred while the rock was buried.

Soils: A similar weathering process may contribute to the alteration of subsurface soils. Three exposures of subsurface fines were produced by trenching with the rover wheels. In two of these cases ("Big Hole" and "Boroughs"), the subsurface materials are considerably more oxidized than surface deposits (~60% increase in Fe^{3+}/Fe_{total}). The subsurface bromine content at "Big Hole" and "Boroughs" are factors of 3 and 10 larger than that measured at the immediate surface, respectively. Furthermore, elemental analyses within these two trenches suggest the presence of magnesium sulfates, a product of aqueous weathering.

In the third trench, "Laguna," the bromine content is comparable to that inside "BigHole" (~60 ppm) but other elemental concentrations and the level of iron oxidation are not significantly different from that measured at the surface. This trench was excavated in a hollow, likely produced by a small impact with subsequent infilling. These deposits are younger and might not have been in place for durations sufficiently long to experience significant alteration.

Hills Rocks: The most highly altered rock in the Columbia Hills is referred to as "Clovis." This low-lying rock is the only sample with a definitive indication of goethite through 360 sols of analyses by Spirit. It also exhibits one of the highest Fe^{3+} to Fe_{total} ratios (~0.9) and Br concentrations in excess of 1000 ppm. The rocks on these hills are clearly older and their origins are more poorly constrained; however, weathering by the process described here is a possible contributor to the highly altered state.

Conclusions: Thin-films of liquid water acting in the near-subsurface environment likely produced the alteration rinds found on light-toned rocks. This process may also contribute to the alteration of rocks in the Columbia Hills and subsurface soils.

References: [1] Greeley, R. et al. (2004) *Science, 305*, 810-821. [2] McSween, H. Y. et al. (2004) *Science, 305*, 842-845. [3] Morris, R. V. et al. (2004) *Science, 305*, 833-836.

Fig. 1: False color Pancam composite of "Mazatzal" (~1.5 meters in width) and nearby rocks. Lower portions of rocks are more dust covered, suggesting that they were once buried.

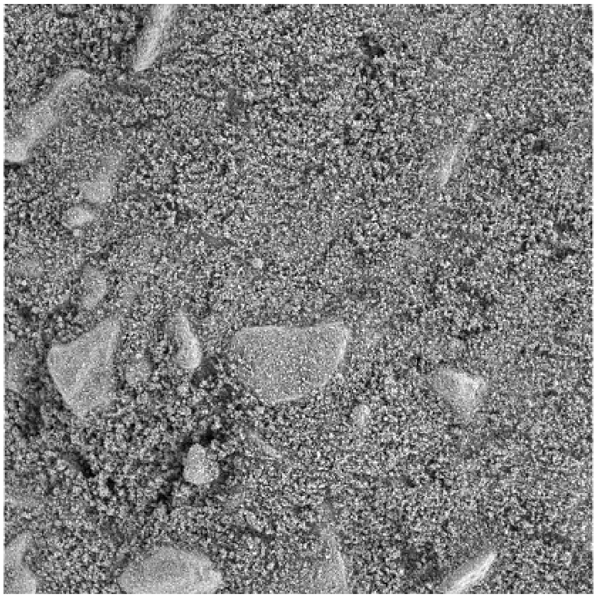

Fig. 2: Microscopic Imager image showing light-toned surfaces of rock fragments. These coatings are likely produced through interactions with thin-films of water in the near-subsurface.

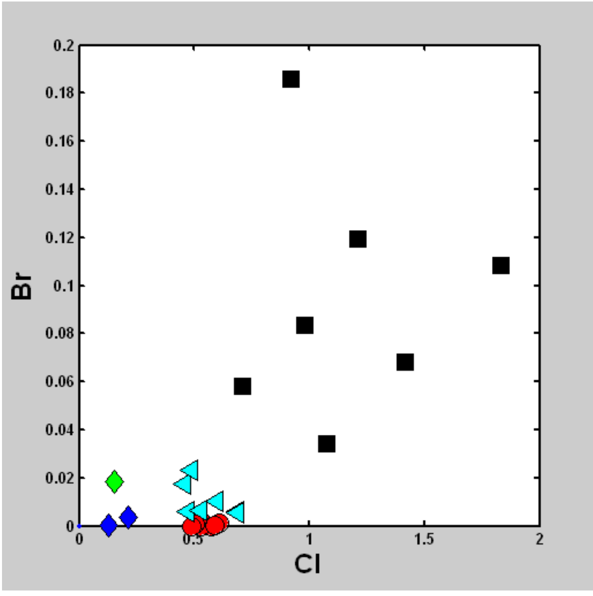

Fig. 3: Bromine versus chlorine weight percentages in surface soils (red), subsurface soils (cyan), Mazatzal (green), other plains rocks (blue), and rocks on the Columbia Hills (black). Enhanced Br concentrations in Mazatzal and subsurface soils are consistent with the condensation of water in localized cold traps.