RAMAN ANALYSIS OF WEATHERED ROCKS FROM THE FIDO MARS ROVER TEST SITE, SILVER LAKE, CALIFORNIA. B. Jolliff, A. Wang, K. Kuebler, L. Haskin, and R. Arvidson. Dept. of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington Univ., St. Louis, MO 63130. (blj@levee.wustl.edu)

Introduction. FIDO is the prototype rover for the Mars 2003 mission, complete with an Athena-like science payload [1]. FIDO will be deployed in April 1999 for a series of tests at Silver Lake, CA [2]. In preparation for these tests, we have examined a suite of rocks collected at the site to anticipate the problems expected in field analyses on available rock surfaces as opposed to surfaces that have been prepared in the laboratory for optimal analysis conditions. The results presented in this abstract are qualitative. We are also conducting systematic analyses to quantify the Raman spectral characterization of specific minerals and rock types, including igneous, metamorphic, and sedimentary varieties, under field conditions.

Silver Lake test site. The focus of the 2003 and 2005 Mars rover missions is to traverse across sites and collect samples from areas that may have been ancient shallow seas or lakes, or perhaps hydrothermal systems. The theme is to acquire data and samples to test the hypothesis that Mars once supported warm, wet conditions and that organic materials and perhaps microorganisms developed in such environments. The Silver Lake area, located north of Baker in the Mojave Desert, CA, is an excellent analog for rover trials because of evidence for lacustrine, fluvial, and groundwater processes [3] that were more extensive during the wet Pleistocene glacial epochs and occasionally during the Holocene (e.g., [4]). The features include a break-out channel that catastrophically drained the lake, beach ridges, soil profiles, alluvial fans, and caliche deposits. Furthermore, bedrock near the site ranges from metamorphosed rocks such as quartzite and gneiss to meta-andesite, to dolostones and limestones. Cobbles of crystalline rock are included in carbonate-cemented gravels and desert pavement.

Samples. The variety and setting of different rocks occurring at the Silver Lake test site are described in [3]. Individual cobbles used in our analyses were collected from surfaces of alluvial fans on the northwestern side of the playa. They typically have three distinct coatings. Tops of the cobbles have a dark-gray, glossy, thin coating of desert varnish. Bottoms, which were sitting in fine-grained aeolian accretion mantles, have a red varnish. Both coatings are inferred to be fixed to rock surfaces by bacterial action [4]. Further, a number of the surfaces are coated by thin caliche deposits.

Results. Analysis by laser Raman spectroscopy, especially when employed in a linear traverse – point-counting mode [5] allows mineral identification, quantification of mineral modes, grain size, rock texture, identification of organic compounds, and characterization of surface coatings, including varnish. From mineral identification and modal analysis, rock types can in many cases be surmised.

Among the suite of rocks from the Silver Lake area, the different main classes of rocks are readily distinguished as follows: Carbonates yield spectra of calcite and/or dolomite, which have similar spectral patterns, but are distinguishable by peak positions (Fig. 1). In some cases, the exposed surfaces yield high fluorescence that requires short counting times to avoid detector saturation. In these cases, Raman peaks may be suppressed. In some other cases, the rough, solution-pitted surfaces entrain small detrital grains of wind or water-born sediment; however, the pattern of abundant carbonate spectra with an occasional quartz or feldspar grain during a linear traverse remains diagnostic for a carbonate rock. The carbonate cobbles typically do not show varnish or red coatings. Quartzite is also readily identified by its Raman spectra, and silicic crystalline rocks such as the granitic gneisses are distinguished by abundant quartz and feldspar spectra. More mafic crystalline rocks have amphibole, mafic phyllosilicates, epidote, apatite, anatase, and Fe oxides. Conglomerates are identified by the alternation of sets of carbonate spectra and those of minerals of the crystalline rocks. Although the darker rocks typically have thin, varnish glazes, for the rocks we examined, these coatings were essentially transparent to the laser Raman spectrometer. Red-coated surfaces typically exhibit the spectra of hematite and the stronger Raman scatterers, but such surfaces can pose problems for rock identification, as discussed below.

Sample 3242 (T5_121597), a dark, fine-grained metamorphosed crystalline rock, has a variety of surfaces that yield different Raman results. A fresh-cut surface yields diverse mineralogy and spectra with good signal to noise (S/N) ratio, including plagioclase, quartz, biotite, muscovite, apatite, magnetite, and anatase. A fracture surface containing slightly coarser minerals yields sharp spectra, as does a dark, thinly varnished surface. A red varnished surface, however, yields only the spectra of hematite and anatase, and the spectra are of poor (low S/N) quality. A light-brown coated surface yields spectra of quartz, feldspar, hematite, and anatase, and the spectral peaks are weak.

A second example, a cobble of gneiss (3262c), yields a major mineralogy of quartz, K-feldspar, and plagioclase, and minor epidote, anatase, biotite, and clinozoisite (Fig. 2a). A dark-coated surface yields the same major minerals, plus anatase, calcite, and a phyllosilicate clay (saponite). The red-coated surface, however, yields only hematite, quartz, and feldspar of poor (low S/N) quality (Fig. 2b).

In a third example (sample 3264), a metabasalt, fresh and dark-gray varnished surfaces yield spectra for a similar set of minerals – feldspar, amphibole, epidote, biotite, quartz, apatite and several accessory minerals, yet the reddish-brown coated surface yields spectra mainly of quartz, feldspar, hematite, and calcite or dolomite. The carbonates identified on this surface reflect an evaporative (caliche) component on the sides of the rock where it was partially buried.

Discussion. Given the different rock types and surface coatings present on rocks at the Silver Lake site, we can make several generalizations. (1) Rocks such as the carbonates, which can not sustain a stable surface and thus do not develop varnish coatings, present no obstacles to the determination of their intrinsic mineralogy. High fluorescence backgrounds, however, occur on weathered carbonate surfaces, and we are investigating their causes. (2) Rocks that develop dark gray or black coatings yield a good representation of their intrinsic mineralogy as long as the coatings are thin. These glossy surfaces have also been abraded by wind blown silt, and the coatings tend to be only a few µm thick [6,7] except where there is local microrelief in the surface [e.g., 6]. (3) Coated surfaces where the coatings are more than a few tens of µm thick present a challenge to determining intrinsic mineralogy, but they provide insight to important atmosphere-rock interactions. In the case of red coatings, hematite, which is a strong Raman scatterer, is commonly observed. This reflects the oxidation of iron and is consistent with the observation that such surfaces develop within the accretionary mantle where water may persist. As a result of their formation within the mantle where the coatings are protected from wind abrasion, these coatings tend to be thick enough to obscure much of the rock's intrinsic mineralogy. Where it is thick enough, desert varnish produces a weak Raman spectrum with broad peaks resulting from a mixture of poorly crystalline Mn and Fe oxides and phyllosilicate clays [6]; nevertheless, these are informative based upon the specific makeup of the coating material. In the case of evaporative coatings, the interaction of water is evident in these rocks by the presence of carbonates. (4) The quality of the spectra along a traverse also reflects the nature of the rock surface; fresh surfaces yield excellent spectra (high S/N) whereas oxidized and otherwise coated surfaces typically yield poorer S/N spectra (Fig. 2). (5) Important additional information is obtained from multiple vs. single-mineral spectra. This relates mainly to grain size relative to the size of the excitation laser spot. The well crystallized rock samples yield a high proportion of single-mineral spectra, whereas the aphanitic varieties typically show multiple-mineral spectra. The minerals that occur together within a given spectrum also provide information about mineral associations, and therefore rock textures. Our method of multi-point traverses is key to exploiting this information.

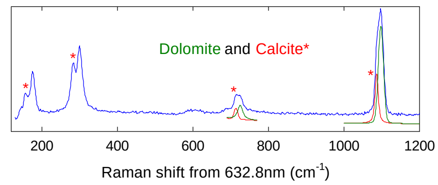

Figure 1. Raman spectrum showing dolomite and calcite peaks from the weathered surface of a carbonate cobble.

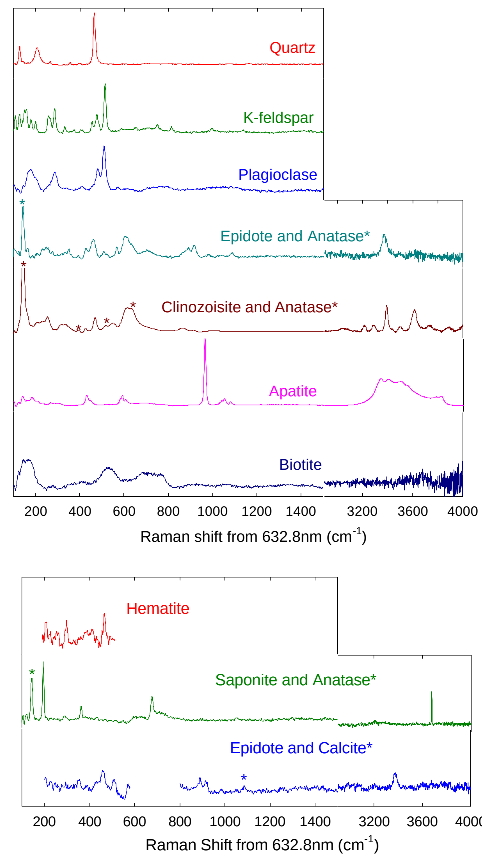

Figure 2. Typical Raman spectra of minerals identified from a cobble of gneiss (3262c): (a) on a fresh surface; (b) on red (hematite) and dark gray (others) varnished surfaces.

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References. [1] Arvidson et al. (1999), *LPSCXXX*, this volume. [2] http://wundow/fidotest [3] http://wundow.wustl.edu/rover/report.htm [4] Enzel et al. (1992) *Quaternary Research* **38**, 60–73. [5] Haskin et al. (1997) *JGR.* **102**, 19,293–19,306. [6] Israel et al. (1997) *JGR* **102**, 28,705–28,716. [7] Guinness et al. (1997) *JGR* **102**, 28,687–28,703.