MAGNETIC ANALYSIS TECHNIQUES APPLIED TO DESERT VARNISH. E. R. Schmidgall[1], B. M. Moskowitz[2], E. D. Dahlberg[3] and K. R. Kuhlman[4], [1]Institute of Technology Lower Division, University of Minnesota, 6534 Olympia St., Golden Valley MN 55427, schm1063@tc.umn.edu; [2]Institute for Rock Magnetism and Department of Geology and Geophysics, University of Minnesota, 291 Shepherd Labs, 100 Union Street S.E., Minneapolis, MN 55455, bmosk@umn.edu; [3]Magnetic Microscopy Center, Department of Physics, University of Minnesota, Minneapolis, MN 55455, dand@umn.edu; [4]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, kkuhlman@jpl.nasa.gov.

Introduction: Desert varnish is a black or reddish coating commonly found on rock samples from arid regions. Typically, the coating is very thin, less than half a millimeter thick. Previous research has shown that the primary components of desert varnish are silicon oxide clay minerals (~60%), manganese and iron oxides (~20-30%), and trace amounts of other compounds [1]. The composition of the varnish determines its color. Varnish containing comparatively more iron oxides than manganese oxides tends to be reddish in color while varnish containing primarily manganese oxides tends to be black in color [2,3,4].

Desert varnish is thought to originate when windborne particles containing iron and manganese oxides are deposited onto rock surfaces where manganese-oxidizing bacteria concentrate the manganese and form the varnish [4,5]. If desert varnish is indeed biogenic, then the presence of desert varnish on rock surfaces could serve as a biomarker, indicating the presence of microorganisms. This idea has considerable appeal, especially for Martian exploration [6].

Magnetic analysis techniques have not been extensively applied to desert varnish. The only previous magnetic study reported that based on room-temperature demagnetization experiments, there were noticeable differences in magnetic properties between a sample of desert varnish and the substrate sandstone [7]. Based upon the results of the demagnetization experiments, the authors concluded that the primary magnetic component of desert varnish was either magnetite (Fe_3O_4) or maghemite ($\gamma\, Fe_2O_3$).

Samples: Magnetic analysis techniques were applied to two samples of desert varnish. The first is a sample of black varnish found on an old and well-weathered basalt from the Mojave Desert, CA. The second samples are on basalt from the Cima volcanic flow in the Mojave Desert. This second basalt differs from the first in that it has both black varnish on the upper surface and red varnish on the bottom surface. Magnetic analysis techniques were applied to both surfaces.

Methods: These samples were analyzed using a vibrating sample magnetometer (VSM) and a radio frequency (RF) superconducting quantum interference device (SQUID) at the Institute for Rock Magnetism (IRM) at the University of Minnesota. The VSM measures the response of a sample to an applied magnetic field. The sample is placed between two coils of an electromagnet. On either side of the sample are an additional set of coils, called the pickup coils. If the sample is magnetic, the applied field will cause some of the magnetic domains to line up with the field. As the applied field is increased, the number of domains aligned with the field will increase until the material reaches saturation. The vibration of the magnetic sample causes a current to flow in the pick up coils that is proportional to the strength of the sample magnetism. The resulting hysteresis curves provide a great deal of information about the types of magnetic materials present in the sample.

In a typical RF SQUID analysis, a sample is cooled to 10K and a magnetic field applied. The magnetic flux is measured every 5 K as the sample warms to 300K in the presence of the magnetic field. The magnetic field is then turned off, the sample is recooled to 10K, and the magnetic flux of the sample is measured every 5K as the sample again warms to 300K. Finally, a magnetic field is applied long enough to saturate the sample and then removed, creating a remanence magnetization in the sample. The remnant magnetism is measured every 5K as the sample is cooled to 10K. A second remanance is added after the sample has cooled to 10K, and the magnetization is again measured every 5K as the sample warms to 300K. The characteristics of the resulting curves provide clues about the composition of the sample.

Data and Analysis:

VSM Analyses: Vibrating sample magnetometer analysis of the first sample (Figure 1) suggests the presence of a hard magnetic component in both the substrate and varnish because the saturation point is not reached even at an applied field of over 1.7T. The varnish contains no substantial paramagnetic component, as indicated by the nearly zero slope at the extrema of the hysteresis loops. In addition, VSM also shows the presence of a substantial paramagnetic component in the substrate. Measurements made using the RF SQUID indicate that the hard magnetic component is most likely goethite.

RF SQUID Analyses: Analysis of the second sample (Figure 2) using an RF SQUID suggested the presence of both titanomagnetite compounds and goethite in the substrate and black varnish. VSM analysis suggests the presence of both hard magnetic and paramagnetic components to these samples, supporting this interpretation. However, for the red varnish, SQUID analysis suggested the presence of magnetite and maghemite particles with a grain size around 30nm. VSM analysis indicates a low coercivity and substantial paramagnetic component, supporting the interpretation that magnetite is the primary magnetic carrier in red varnish.

Magnetic Force Microscopy (MFM): Sample preparation for MFM proved difficult, due to the fact that the substrate, varnish, and resin mount all polished away at different rates. This difficulty made it impossible to separate sample magnetism from sample topography, so no useful information was provided by MFM analysis.

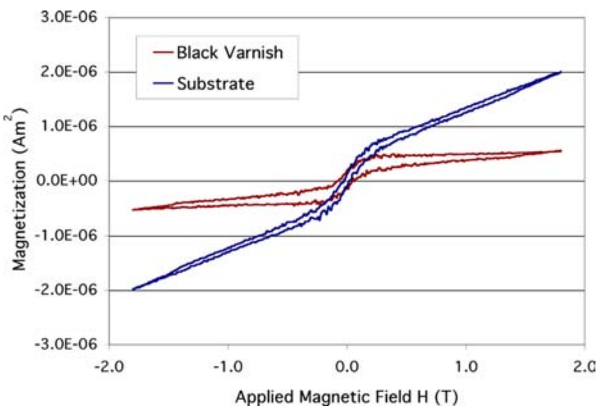

Figure 1: VSM Data from Sample 1 indicating the presence of a hard magnetic component in both the substrate and varnish. SQUID analysis suggests that this material is goethite. (Varnish - black data points, substrate - red data points).

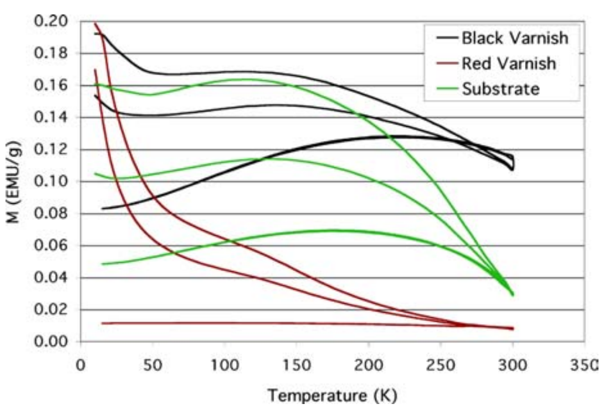

Figure 2: SQUID data from Sample 2. Substantial differences can be seen between the different samples. An apparent transition at ~120K for the red varnish data suggests the presence of small particles of magnetite.

Conclusions: This work indicates that goethite is a magnetic carrier in black desert varnish, in addition to magnetite as previously determined by Clayton, et al. [7]. Magnetite grains about 30 nm in diameter were found to be present only in the red varnish. More importantly, this work demonstrates the feasibility of VSM and SQUID magnetic analysis techniques applied to desert varnish.

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Acknowledgements: This research used facilities at the Institute for Rock Magnetism, University of Minnesota, which is funded by the W. M. Keck Foundation and the U. S. National Science Foundation.