MICROBIAL FOSSILS DETECTED IN DESERT VARNISH. B.E. Flood[1], C. Allen[2] and T. Longazo[3], [1]Texas A&M University at Galveston, Texas 77554, marbi2001@yahoo.com, [2] Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, TX 77058, [3]Hernandez Engineering, NASA Johnson Space Center, Houston, TX 77058

Introduction: Mars Global Surveyor Thermal Emission Spectrometer data indicate regions with significant levels of hematite (_Fe_2O_3). Fe-oxides, like hematite, can form as aqueous mineral precipitates and as such may preserve microscopic fossils or other biosignatures. Several potential terrestrial analogues to martian hematite like hydrothermal vents have preserved microfossils [1]. Microbial fossilization in Fe-oxides is often a function of biomineralization. For example, goethite (FeO_2H) encrustation of fungal mycelia from the mid-Tertiary preserved fungal morphologies such that their genera could be determined [2].

Another terrestrial analogue to martian hematite may be is desert varnish. Desert varnish is a thin coating on rocks in semi-arid to arid regions [3,4]. The coloration, thickness, texture, and chemical composition of desert varnish varies spatially down to the nanometer-scale. Additionally, regional variations also exist. Desert varnish is composed primarily of Mn-oxides, Fe-oxides, and clays but also contains trace amounts of organic and detrital components. The most likely elemental source for desert varnish is wind-blown dust. The metal constituents of the dust are taken into solution and then selectively precipitated onto the substrate or attached clays at concentrations orders of magnitude higher than normal dust concentrations. This process may be aided or completely mediated by a variety of microorganisms that inhabit varnish surface and matrix [3,4].

The most common desert varnish inhabitants are epilithic, slow-growing, melanin-pigmented microcolonial fungi (MCF, also known as meristematic fungi which includes black yeasts), and typical soil inhabiting actinomycetes and nonmotile endospore-forming gram-positive cocci [4,5]. Dozens of cultured strains of varnish microorganisms oxidize Mn and/or Fe [3,5,6]. These microorganisms include members of the bacterial genera *Micrococcus*, *Arthrobacter*, *Bacillis* and the actinomycetes *Geodermatophilis.* Unfortunately, the study of MCF has proven to be inherently difficult and little is known about them [3,5]. One SEM study [7] found Mn present only within the center of an MCF and not in the surrounding varnish. However, they were unable to culture the specimen for further investigation. Speculation exists that the melanin-pigmented, thick and multi-layered walls of MCF would enhance the biosorbtion of metals [5].

The purpose of this study is the examination of the potential of desert varnish in preserving microfossils or other biosignatures. Two previous studies have found evidence of fossilization. Krinsley's study [4] determined small coccoid and granular structures within the varnish matrix have a much higher concentration of Fe and Mn than the surrounding matrix and may in fact be bacterial casts, hyphae, buds, or bacterial precipitates. Probst *et al.* [8], found "biofabric," which appeared to be varnish that surrounded voids where presumably bacteria formerly resided.

This study examines samples from two regions, where the rates of varnish formation appear to be quite different. The first set of samples were a Tertiary volcanic tuff unit collected from bluffs exposed by construction in the mid-1930's above the shores of Lake Mead, near Hoover Dam in southern Nevada. The pore spaces between the volcanic tuff substrate and the varnish layers were actively filling in with caliche ($CaCO_3$). The second set of samples coated rocks of foliated granitoid composition from the Pilbara region of Western Australia. These rock surfaces have been exposed to weathering and, presumably, desert varnish formation for thousands of years.

Samples and Methods: Chips were collected using sterile collection techniques. In hand sample, the appearance of both varnish types resembles ridge and valley structures on a micrometer scale. The entire surface was dominated by clay textures and fungal bodies were predominantly in the valley-like features.

Small chips were examined utilizing a JEOL 6340F field emisson scanning electron microscope (SEM) and a JEOL 5910 SEM. Both systems were equipped with IXRF energy dispersive spectroscopy (EDS) analysis operating at 15KV accelerating voltage. The Pilbara chips were mounted on SEM stubs using carbon paste and coated with 100Å of conductive platinum. The Hoover Dam samples were coated in both 200Å of conductive silicon and 100Å of conductive platinum while conductive platinum wire and wire copper tape surrounded each chip. The mounted samples were stored at room temperature in a laboratory dessicator.

Varnish Mineralogy: The varnish from the Pilbara region was lamellate and was typically 75-150 _m thick. The surface layer was smooth and consisted of clays with low concentrations of Fe-oxides. The concentrations of Fe and Mn varied within the depth of the varnish. Occasionally, K and Ti were also detected. The varnish was on a heavily weathered rind. The varnish from the Hoover Dam region was also lamellate and was 1-30 _m thick. On the surface, layers were often reminiscent of slightly detached pancakes on top of the surrounding varnish. Unlike the samples from Pilbara, Mn was often observed at the surface layer. The varnish sometimes included Mg, K, Ca, Na, Cu, and Ti. Both sets of samples exhibited higher concentrations or Mn and/or Fe in discrete nod-

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ules either within the matrix of the varnish or loosely bound to detrital grains. These nodules were usually a micron or less in length. Sometimes the nodules had higher carbon content than the surrounding varnish.

Biological Activity: Black MCF were observed inhabiting varnish from both regions, although the Pilbara samples had much greater concentrations of the fungi. The MCF were often partially of completely encased in clays with low amounts of Fe-oxides. MCF were not associated with Mn-oxides. Occasionally, fungi were encountered with a single spherical object associated with them. The chemical compositions of these objects varied from high levels of Ti and Fe-oxides to low levels of Fe-oxides and various cations. Carbon was detected in only low amounts. Some fungal bodies and rods, possibly ascospores, appeared to be precipitating calcium waste products on their exposed surfaces.

The samples from Pilbara also had a high number of a different species of MCF on and within the non-varnished substrate. The fungi appeared to be contributing to the weathering of the substrate by creating large micropits. The same trend was true for the Hoover Dam samples except some pits within the caliche and the substrate contained an actinomycetes species and one contained a bacterial colony. While fungi were common, visual confirmation of bacterial presence within desert varnish was rare.

Fossilization: Bacterial casts and fossilization of fungal bodies were observed on samples from the Pilbara region; however none were found in the samples from the Hoover Dam region. One completely intact bacterial cast was observed. The bacterial cast appeared to be have been formed recently. A significant amount of carbon was detected on the cast and the cast was on an exposed surface of the varnish. Similar partial casts were also observed.

Complete mineral replacement of a fungal sporoform appeared to be occurring on the surface of the Pilbara sample. The mineralized spore had only low levels of Fe-oxides and no Mn-oxides, which was consistent with surface varnish. One side of the spore was weathered away, revealing complete internal mineralization.

A portion of a hymenium of a MCF was also undergoing mineral replacement. The hymenium was 20 _m below the surface and was probably exposed at a natural microfissure. Mapping of the most dominant elements revealed the concentrations of carbon were relatively low in comparison to the concentrations of Al, Si, O, Mn, and Fe. The amount of carbon detected was not much higher than typical levels detected in varnish from Pilbara. The "biofabric" observed in the Sonoran Desert samples by *Probst et al*. [8] was not observed in the study. However in the areas of the samples where the bacterial casts and the fossilized hymenium were detected, a more complex texture was seen that is suggestive of a former bacterial presence.

Discussion: All samples showed evidence of microbial life, but at differing concentrations. The lack of observable bacterial colonies is consistent with previous investigations [3,4]. The reduced number of MCF and the lack of fossilization on the Hoover Dam samples may be explained by several factors. 1) The Hoover Dam hand samples were selected because few MCF were observed. 2) The varnish has existed for less than seventy years and therefore, fewer MCF have had the opportunity to settle and grow. 3) Conditions were not supportive for more MCF.

Desert varnish appears to preserve microbial fossils, although the duration of their existence is unknown. All observed fossilization appeared to have been located on the surface of the varnish or in natural breaks. Therefore, their formation was probably fairly recent. In agreement with the observations of Krinsley [4] our study observed many nodules high in Mn and Fe oxides. Krinsley provided a mechanism for their formation in his "biodiagenetic model." In this model, bacterial casts and wastes products are formed by biomineralization. Then Mn and Fe-oxides become remobilized and eventually become redistributed in the matrix of the varnish clays. The nodules may be bacterial casts or waste products slowly being weathered away. Krinsley explained the process could occur via organic acids excreted by MCF or completely inorganic means. If the "biodiagenetic model" is correct then the process would eventually destroy most fossilized structures. As such, long-term preservation is generally poor. However, elsewhere on Earth or Mars environmental conditions conducive to desert varnish formation may be sufficient to preserve definitive evidence for life.

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