CRATERS AS DRILLS ON MARS: RESULTS FROM A MANMADE, 260 METER DIAMETER CRATER IN LAYERED TERRAIN. L.E. Kirkland[1,2], K.C. Herr[2], and P.M. Adams[2], [1]Lunar and Planetary Institute, contact information at www.lpi.usra.edu/science/kirkland; [2]The Aerospace Corporation,.

Introduction: Since the mid-1990's, researchers have explored the surface of Mars with increasing intensity and effort. However, the geologic history of Mars remains intensely debated. Interpretations are particularly wide ranging for the contribution of water.

Interpretation uncertainties remain high for two primary reasons. First, researchers that use the same hyperspectral remote sensing data sets report widely different compositional interpretations. That interpretation divide is particularly strong between researchers who combine laboratory and Mars analog field work, and those who use primarily a laboratory foundation [1]. Interpretations also differ between the thermal-infrared and visible/near-infrared communities. Second, researchers have little information on Mars subsurface materials. Analysis of subsurface materials can address current ambiguities in the role of hydrologic activity, erosion, and available resources [2, 3].

The work presented here addresses the two primary problems described above: (1) We analyze hyperspectral field data in the field; and (2) We test how to use craters as a source of fresh subsurface materials. We use material exposed at unique sites: Manmade, small Mars analog craters (<400 m diameter). Plans for manned missions increase the need for accurate assessments of Mars, yet important questions will remain unresolved until subsurface materials are found and analyzed accurately. Exploration of relevant craters on Earth can build the necessary foundation for the route to discovery and accurate analysis on Mars. We previously reported exploration (ground and airborne) of two unique manmade craters in basalt [4,5]. Here we provide initial results for the manmade crater "Schooner" (Fig. 1), a 260 m diameter crater that was created in layered geologic terrain at the Nevada Test Site.

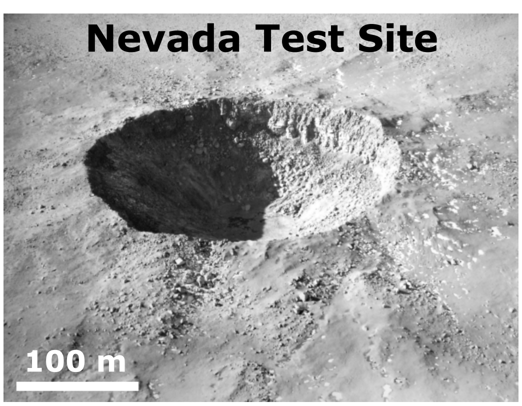

Fig. 1: Aerial image of Schooner Crater at the Nevada Test Site [6].

Schooner: The search for Mars analog craters led us to the Nevada Test Site (NTS). A series of chemical and nuclear craters were created at the NTS in order to study excavation effects. The NTS is a restricted access facility located northwest of Las Vegas, managed by the U.S. Department of Energy, and encompassing ~3500 km^2 [7]. The NTS craters are particularly valuable because controlled access preserved the craters relatively undisturbed, and extensive geologic and drilling studies exist for many of the craters.

The Schooner cratering site was specifically selected to combine strong and weak layering with a water table [2]. Schooner was created on Dec 8th, 1968 using a 31 kt nuclear detonation in layered tuff, with a charge depth of 108.2 m [2, 8]. The layers have an interesting range in density and strength (Table 1). The resulting crater has an apparent depth of 63.4 m [2].

The extensive layering present on Mars [9] makes inclusion of a terrestrial analog crater in layered material important. Schooner differs in several ways from the craters that we have explored in more homogeneous material. Schooner has an unusually flat bottom, steep sides (Fig.1), unexpectedly large volume of ejecta, a bed that is theorized to have fluidized during eruption, a large fraction of fines, and more extensive glassy rinds [2]. Those characteristics make an extension of the cratering study from Buckboard Mesa (basalt) to Schooner compelling.

On Mars, subsurface exploration will similarly need to draw on a range of crater and substrate types [e.g., 9,10]. In order to understand which craters on Mars will provide the greatest exploration return, we are building a foundation by exploring terrestrial analog craters.

Table 1. Schooner layered terrain. (Data: [2], p.301)

layer	depth (m)	density (g/cm^3)	bulk modulus (GPa)	water weight %
densely welded tuff	0-39	2.3	6.3	0.3
weakly welded tuff	39-61	1.6	2.8	8.5
non welded tuff	61-103	1.5	1.5	12.0
densely welded tuff	103-148	2.2	7.9	5.3

Instrumentation:

SEBASS. In June 2005, we flew the airborne hyperspectral imager "SEBASS" over the Schooner crater. SEBASS measures the 3-5 and 7.5-12.5 µm ranges. We imaged Schooner at 2 m/pixel spatial resolution. SEBASS is the only airborne imager used for thermal-infrared, hyperspectral Mars analog studies [1]. SEBASS is the highest sensitivity thermal-infrared hyperspectral imager, a characteristic that is critical for developmental work.

RamVan. The Mars 2003 rover MiniTES is similar to the RamVan and Tonka instruments. All are raster-scanning, thermal infrared spectrometers [11]. RamVan/Tonka measure with higher spectral and spatial resolution and higher sensitivity than MiniTES, but with a more restricted spectral range due to terrestrial atmospheric absorptions [11]. RamVan has scanned several craters at the NTS [4,5]. We plan to scan Schooner in 2006.

Spectral results: We previously reported for the analog craters in basalt that opal coatings were discovered only on the crater ejecta [4,5]. Similarly, at Schooner, materials that would alter the geologic interpretations of the site were detected remotely only in the geologically fresh Schooner ejecta.

At Schooner, SEBASS recorded signatures consistent with rhyolite, rhyolitic glass, opal, calcite (Fig.2), and a spectrally unusual material that is currently unidentified. The rhyolitic glass, opal, calcite, and spectral unknown were detected only in the crater or ejecta. The rhyolite spectral match was detected only very weakly outside the ejecta region, and the signature differed from the signature within the ejecta, possibly due to weathering, coating, or particle size effects. As for the craters in basalt, opal has not previously been reported at these sites. These findings illustrate the importance of geologically fresh craters to exploration.

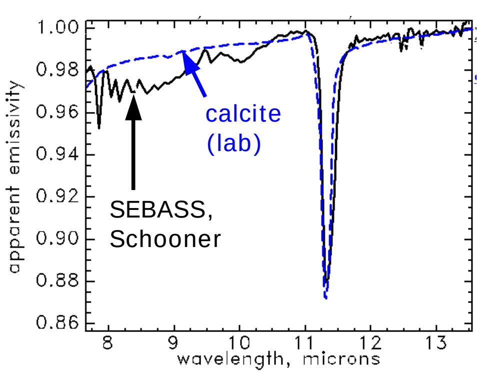

Fig 2. SEBASS match to calcite. For reasons currently unknown, the calcite signature was unusually strong, ~10-15%. Carbonates in the field typically have much weaker signatures [1,11,13]. (SEBASS pixel x1198/y49 and calcite.1s from [12]).

Conclusions and work needed: (1) In order to determine which craters on Mars may offer the greatest exploration return, and to interpret the resulting data sets, we need to build a foundation using terrestrial analog craters. Exploration of NTS craters demonstrates that geologically fresh craters can provide a window into subsurface materials, including in layered terrain. The geologically fresh NTS craters are unique assets for critical Mars analog studies.

(2) At Schooner, hyperspectral imaging identified significant minerals that were otherwise not seen. The minerals would change geologic interpretations of the site, which illustrates a decisive lesson for the exploration of Mars: Critical minerals can be present and remain unrevealed without the correct search strategy and instrumentation.

(3) Identification of the minerals required high sensitivity instrumentation (high signal-to-noise ratio, SNR). The results again illustrate that high spatial resolution is useless without adequate SNR.

(4) The spectrally unknown material illustrates a current limitation in remote identification. If the spectral signature is not in the reference spectral library, then an automated spectral search may not locate it, especially for weak signatures. That issue is a particular concern for the unknown weathering minerals on Mars and for measurements made at the relatively poor sensitivity of current thermal infrared spectrometers at Mars (rms SNR<1000).

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