MARS-LAB: FIRST REMOTE SENSING DATA OF MINERALOGY EXPOSED AT SMALL MARS-ANALOG CRATERS, NEVADA TEST SITE.

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Introduction: On Earth and Mars, small craters expose near-surface composition, weathering processes, and layering. The MarsLab project is the first thermal infrared, remote sensing study of the mineralogy exposed by small terrestrial craters (~25–400 m diameter). Small craters are important because they can partially replicate drilling in that they expose near-surface material. On Mars, identification of the minerals on the crater interior wall and in ejecta would uncover currently unknown information on near-surface compositional variations and weathering processes.

Near-surface explosive tests at the Nevada Test Site (NTS) in the Mojave desert created numerous craters that are unique Mars analog sites (e.g., Fig. 1). Infrared remote sensing is a primary method used to identify minerals on Mars; however, the technique has never before been applied to small Mars analog craters. The MarsLab project utilizes thermal-infrared, hyperspectral images from uniquely high quality airborne and field spectrometers.

Related MarsLab studies include Mars analog sites chosen for regional indurated materials, dry lake beds, basalt flows, and rock coatings. Researchers interested in the project are encouraged to contact the authors.

Fig. 1: Watusi, a high-explosives experiment in alluvium by Los Alamos National Laboratory scientists, September 2002. It is ~24 m diameter. Small craters expose near-surface material for identification via infrared remote sensing, both terrestrially and on Mars.

The MarsLab site: The Nevada Test Site (NTS) is a restricted access test facility, managed by the U.S. Department of Energy, in the Mojave desert, ~65 miles northwest of Las Vegas. The Mojave desert has long been used for Mars analog studies due to the dry climate. The NTS is particularly valuable because limited public access preserved locations of interest relatively undisturbed. We selected craters in basalt and alluvium substrates. Table 1 has crater details.

Alluvium sites. These include the craters Watusi (Fig. 1), Sedan (Fig. 2), and Scooter (Fig. 3). We chose Watusi for its young age (~1 year old); Scooter as similar but older (~44 years); and Sedan for its large size (390 m) and obvious layering (Fig. 2). The alluvium is composed of tertiary volcanics, limestone, quartzite, conglomerate, and shale, and it is ~430 m thick at Sedan. The water table is at ~600 m [1], well below the depth of explosion.

Fig. 2: Sedan Crater. The arrow marks one of the layers that is exposed for remote sensing study. For scale, the bush at right is ~1 m tall.

Basalt sites. We selected craters in Buckboard Mesa (Fig. 4), a lava flow described as an olivine basalt, with a silica content of ~53% [2], and ~2.8 million years old [3]. The flow is ~30–60 m thick, overlaying tuffaceous sandstone. Approximately 0.5–4 m of aeolian silt and sand cover much of the flow [2]. Caliche (indurated carbonate) layering occurs in the aeolian deposits. Thin carbonate coatings also occur on the basalt at joints (Fig. 4b) [2]. Most of the basalt is gray or black, but local regions are oxidized to a reddish color (Fig. 5). The water table is ~240 m below the upper mesa [2], well beneath the depth of explosion (Table 1).

We selected the crater Buckboard 12 because it is relatively pristine, and for comparison to the larger, nearby Danny Boy crater (Fig. 4a). Other craters covered are Buckboard 10, Pre-Schooner Bravo, Charlie, and Delta.

Meteor Crater. For comparison, Meteor Crater (Barringer Crater), near Flagstaff, Arizona, is ~1200 m diameter and ~49,000 years old.

Table 1: MarsLab crater details

	Watusi	Scooter	Sedan	B-12	Danny
size (m)	24	94	390	35	66
depth		23	98	11	20
DOB		38	194	13	34
date made	Sep 2002	Oct 1960	Jul 1962	Sep 1960	Mar 1962
charge	18	500	104,000	20	430
SDOB		48	42	48	45
substrate	A	A	A	B	B
type	chem	chem	nuclear	chem	nuclear

size=diameter at inner rim; *depth*=crater apparent depth (m); *DOB*=depth of burst; *charge*=tons TNT equivalent; *SDOB*= scaled depth of burst (m/kt$^{1/3}$); *substrate*: A=alluvium, B=basalt; *type*: chemical or nuclear explosive; *B-12*= Buckboard 12; *Danny* = Danny Boy

Instrumentation: The MarsLab instruments are the only field instruments in use that are high fidelity analogs to current Mars thermal infrared spectrometers.

Mars. The orbited spectrometer data set available is the 1996 Thermal Emission Spectrometer (TES, ~6–50 µm). The 2003 rovers carry the MiniTES (~6–25 µm). Researchers interpret such spectra by comparison to laboratory spectra of proposed analog minerals.

Airborne. SEBASS (~7.5–12.5 µm, 128 bands) is the only airborne spectrometer available that measures spectrometer data similar to TES [4]. Figs. 3 and 4a show example MarsLab SEBASS images.

Rover. Tonka (~7.5–12.5 µm, 512 bands) is the only field spectrometer that raster-scans thermal infrared images like MiniTES [4,5]. Tonka is a van platform, effectively a large rover. Tonka and MiniTES view from ~2.5 and ~1.5 m above ground, respectively.

Laboratory. Our laboratory spectrometers cover the full spectral range measured by both the Mars and terrestrial analog instrumentation.

The Aerospace Corporation owns and operates SEBASS, Tonka, and the laboratory equipment [4,5]. Aerospace is a non-profit government laboratory that is managed by the U.S. Department of Defense.

Discussion. An examination of the craters is just beginning. The MarsLab craters in alluvium show layering at a variety of sizes and clarity of exposure. The craters in basalt exposed oxidized basalt, and caliche-coatings that have been interpreted as forming underground on basalt joints from interaction with water [2].

MarsLab questions include (1) what layering and other mineral variations do the small craters expose; (2) what instrumentation and measurement protocols most effectively identify critical mineralogy, including soil layers, and caliche coatings on basalt; (3) what minerals are present that remain undetected; (4) which sizes/types of craters most effectively expose near-surface processes for study by orbited/airborne and rover instruments? The information will build the first tested foundation for such studies of Mars.

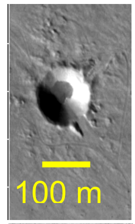

Fig. 3: Scooter. This portion of a MarsLab SEBASS image shows Scooter, which is in alluvium. Measured at 2 m/pixel.

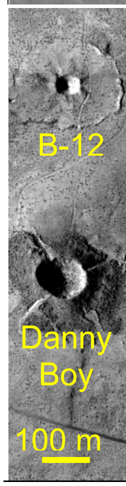

Fig. 4a: Buckboard 12 ("B-12") and Danny Boy, measured at 2 m/pixel. Both are in basalt. The linear features on the Danny Boy flanks are trenches dug to examine the ejecta. The crater ejecta have different appearances, although both are in the same substrate.

Fig. 4b
Danny Boy ejecta with caliche coating

Inside Buckboard 12, Nevada Test Site

Fig. 5: Inside Buckboard 12. The ejecta is basaltic, angular blocks. A whitish caliche (carbonate) weathering coating is commonly visible. Brian Allen is upper left for scale. Image taken from ~east crater rim, looking ~west.

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