WHY LANDERS SHOULD EXPLORE FRESH, SMALL CRATERS ON MARS.

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Introduction: Recent interpretations of camera images of Mars are that craters less than 10's of years old are present [1]. Small craters expose near-surface materials that are critical for geologic and astrobiology studies, and they can provide pseudo drills into the surface sooner than manmade drilling can be accomplished on Mars. Manmade craters that range from ~5 to 400 m diameter at the Nevada Test Site (NTS, Fig.1) demonstrate the value added by such craters, and they can be used to optimize exploration by future landers.

There are two primary reasons that access to recently excavated, near-surface material is critical to the exploration of Mars:

1. Ionizing radiation and oxidation are expected to destroy evidence of organic materials and biomarkers unless those materials are below the surface. Parnell [2,3] estimates that at least ~1.5–3 meters below the surface is required for long-term protection. Thus either active drilling or access to fresh craters is necessary for useful biological sampling.

2. It is critical to access underground and buried materials in order to determine the geologic processes present. For example, at the NTS Buckboard and Schooner crater sites, the past interaction of water underground is exposed only by materials excavated by the craters [4,5]. Thus for a remote sensing or lander study at these sites, the underground water activity would remain unknown without access to the recently excavated materials. Similarly, whether recent, near-surface water existed on Mars is a question that exploration of small, fresh craters can address.

The NTS craters can provide field data necessary to learn to effectively exploit small fresh craters on Mars:

1. What size crater should be targeted? Parnell [2] recommend craters of at least ~300 m diameter in order have high confidence of sampling material below 2 m depth. The reasoning is that the depth of a ~300 m crater is ~60 m (1/5 the diameter) and the material ejected is mainly from the top 1/3 of the crater [2], which gives 20 m. Thus most of the ejected material would be from greater than 2 m depth. The NTS Schooner crater is a good analog for testing this crater size. Schooner is ~290 m diameter and ~65 m deep, in layered tuff, and it has abundant fine, coarse, and blocky ejecta for test and development of exploration methods (Fig. 2).

However, our experience with NTS craters is that smaller craters should also provide good results. Smaller craters (~30–100 m) may be preferable for sampling weighted to depths less than ~5–20 m, because the craters both expose the materials and yet do not cover the materials as deeply with ejecta. Further examination of the NTS craters and documentation can provide the community with field test beds and data to determine the optimum crater size vs. sampling depth requirements. Table 1 lists example NTS craters that occur in a range of geologic substrates.

2. How do we determine the depth of exhumation of any given block that a lander might focus its attention on? One route is to measure the crater walls with a hyperspectral imager or LIBS, then match the observed spectral character to ejecta blocks, or vice-versa. This method can be trialed at the NTS craters. NTS craters exist in basalt, layered tuff, and alluvium, which allows for test and development in different substrates. We are testing this methodology using our airborne and ground-based hyperspectral imagery [4,5].

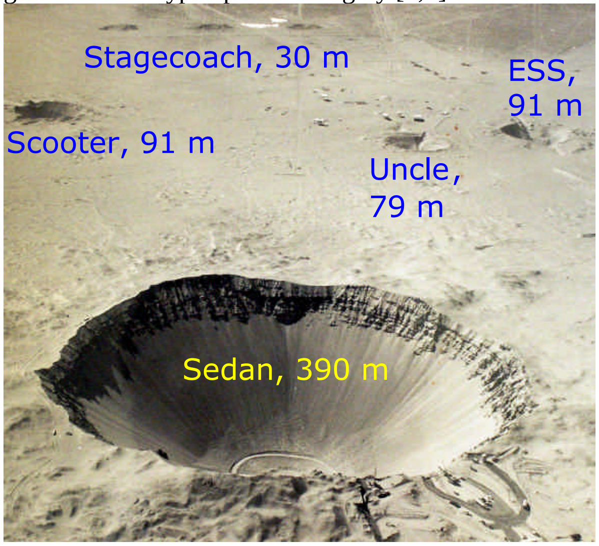

Fig.1: Seven explosion craters in alluvium at the NTS, ranging from 30–390 m diameter [8, image N30024].

3. How do we fold into geologic interpretations the information added by recently exhumed crater materials? Remote sensing studies (ground-based and airborne) of NTS craters in basalt at Buckboard Mesa [4] and in layered tuff at the Schooner crater [5] were that calcite and opal coatings were exposed only in the crater ejecta. The coatings are thought to be caused by and indicative of underground water interacting with rock faces that are then preferentially exposed through spalling during the crater formation [6, 7]. Opal coatings were exposed in ejecta for a 30 m crater ("Stagecoach") in alluvium. Thus these craters provide test

beds to determine what geologic materials are available in ejecta at small craters, and how to fold the results into geologic interpretations for different crater sizes and substrates using the same methodologies that are available for Mars.

References: [1] Malin et al. (2006) *Science, 314*, 1573–1577. [2] Parnell J. and P. Lindgren (2006) *Proceedings of First International Conf. on Impact Cratering in the Solar System*, 147–152. [3] Parnell J. et al. (2007) *Astrobiology, 7*, 578–604. [4] Kirkland L.E. et al (2005) *LPSC XXXVI*, Abstract #2185. [5] Kirkland L.E. et al (2006) *LPSC XXXVII*, Abstract #1864. [6] Hill C. A. and Schluter C. M. (1993), Petrographic description of calcite/opal samples, DOE/NV Report 10461-T61. [7] Lutton R. J. (1968) *Project Dugout*, PNE-602F. [8] From the NTS Historical Foundation Museum, Las Vegas.

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Table 1. Explosion Craters at the NTS

Crater name	Size (dia, m)	Yield (kt)	Type	Year made	Coordinates	Geographic location	Substrate
Pre-Buggy[a]	14		chemical		36.832 / 115.971	Frenchman	alluvium
Watusi	25	0.02	chemical	2002	37.099 / 116.092	Yucca	alluvium
Stagecoach[b]	30		chemical		37.165 / 116.035	Yucca	alluvium
Scooter	91	0.5	chemical	1960	37.171 / 116.038	Yucca	alluvium
Uncle	79	1.2	nuclear	1951	37.168 / 116.043	Yucca	alluvium
ESS	91	1	nuclear	1955	37.170 / 116.045	Yucca	alluvium
Sedan	390	104	nuclear	1962	37.177 / 116.046	Yucca	alluvium
Johnnie Boy	?	0.5	nuclear	1962	37.122 / 116.334	E of Buckboard	alluvium
Buckboard-5	5	0.0005	chemical	1960	near Buckboard-12	Buckboard Mesa	basalt
Buckboard-12	37	0.02	chemical	1960	37.111 / 116.370	Buckboard Mesa	basalt
Danny Boy	81	0.4	nuclear	1962	37.111 / 116.366	Buckboard Mesa	basalt
Dugout[c]	41x87	0.1	chemical		37.094 / 116.345	Buckboard Mesa	basalt
Buggy[d]	76x259	5.4	nuclear	1968	37.008 / 116.372	Area 30	basalt
Cabriolet	55	2.3	nuclear	1968	37.281 / 116.515	Pahute Mesa	rhyolite
Palanquin	73	4.3	nuclear	1965	37.280 / 116.524	Pahute Mesa	rhyolite
Schooner	280	30	nuclear	1968	37.343 / 116.567	N Pahute Mesa	layered tuff

[a] Pre-Buggy has 10 craters in the same region. The sizes vary, with four ~14 m craters and several row (elongated) craters. [b] There are 3 Stagecoach craters, all similar size and location. [c] Dugout is 5 separate charges made along a row; each charge was 0.02 kt. [d] Buggy is 5 separate charges made along a row; each charge was 1.08 kt

Fig.2: Image of Schooner crater (290 m diameter, depth ~65 m), looking south [8, image N30024].