UPHEAVAL DOME, AN ANALOGUE SITE FOR GALE CRATER. P. G. Conrad[1], J. L. Eignebrode[1] [1]NASA Goddard Space Flight Center, Code 699, Greenbelt, MD 20771
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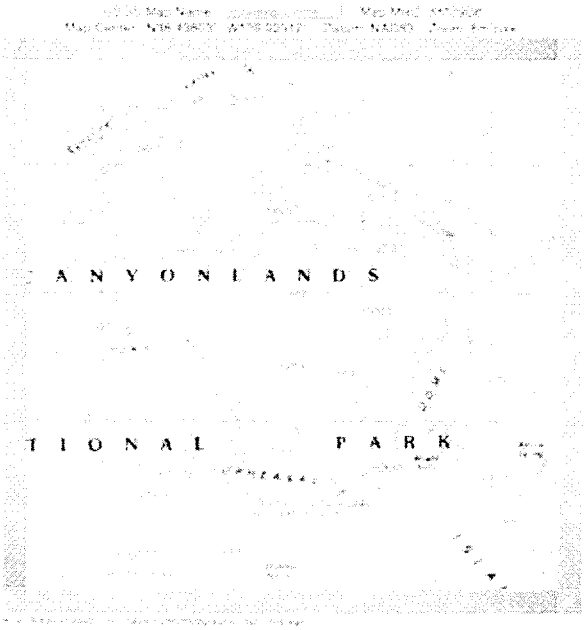
Introduction: We propose Upheaval Dome in southeastern Utah as an impact analogue site on Earth to Mars Science Laboratory candidate landing site Gale Crater. The genesis of Upheaval Dome was a mystery for some time—originally thought to be a salt dome. The 5 km crater was discovered to possess shocked quartz and other shock metamorphic features just a few years ago, compelling evidence that the crater was formed by impact [1], although the structural geology caused Shoemaker and Herkenhoff to speculate an impact origin some 25 years earlier [2]. The lithology of the crater is sedimentary. The oldest rocks are exposed in the center of the dome, upper Permian sandstones, and progressively younger units are well exposed moving outward from the center. These are Triassic sandstones, siltstones and shales, which are intruded by clastic dikes. There are also other clay-rich strata down section, as is the case with Gale Crater. There is significant deformation in the center of the crater, with folding and steeply tilted beds, unlike the surrounding Canyonlands area, which is relatively undeformed. The rock units are well exposed at Upheaval Dome, and there are shatter cones, impactite fragments, shocked quartz grains and melt rocks present [3]. The mineral shock features suggest that the grains were subjected to dynamic pressures > 10 GPa.



The site, because of its location in a National Park, requires a permit, which typically takes about a month to obtain. The overall crater morphology has good fidelity to Gale Crater and the thick sedimentary strata are analogous to the sedimentary structure. The mineralogy is not an exact match, however there are clays (kaolinite), micas (muscovite), hematite, quartz and calcite observations from AVARIS flyovers [4], which provide an opportunity to correlate morphology and remotely sensed mineral data with on-the-ground measurements.

Mission Description: For Mars Science Laboratory, one of the advantages of the Gale Crater site is its thick stratigraphic section of diverse minerals that may appear cyclically [5]. The landing ellipse for Gale is such that it is a "go to" site, so an analogue investigation of the extent of the footprint of the eroded central mound at its base would be informative with respect to what can be learned immediately after traverse at the most approachable targets.

Science Merit Related to Mission Objectives: Upheaval Dome has been extensively studied because it is one of the best-exposed large impact craters in the world [3]. It provides an opportunity to discover how well the chemical and physical evidence of a habitable environment survives a large impact event. As such, it could help us model the stability fields of various habitability signatures with respect to high-pressure shock

(> 10 GPa). The deeply eroded crater also provides access to evaporites, though not the putative sulfate diversity thought to be representative of Gale Crater strata.

As already stated, there is remote sensing data, structural data, stratigraphic and mineralogical data from Upheaval Dome (see references) and it is an easily accessible site that does not require special support.

Most Important Question Answered by Site: What does the mineralogical, textural and geochemical character of the central mound feature tell us about the processes and the gradient of these attributes from edge to center? How well are the indicators of habitability preserved over 300 million years? Chemical signatures of habitability may be more subject to attack on Earth from aqueous processes, though these may be less harsh than the ionizing radiation and putative chemical oxidant of the martian surface.

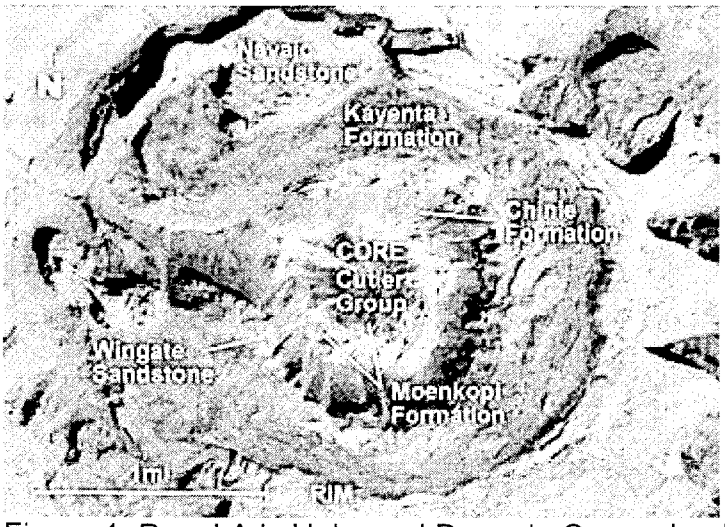
Logistic and Environmental Constraints: This is an accessible site although it is in a National Park and permits are required. There is limited camping available within the park, although camping and motels are available in nearby Moab, Utah, which is the nearest city served by air (Great Lakes Aviation). One can connect from Salt Lake City, Denver or Grand Junction, CO. Alternatively; one can drive (4 hrs from Salt Lake City, 1.5 hrs from Grand Junction). The drive to the site from Moab is about 40 minutes (according to the park web site). It is cold in the winter and hot in the summer (see Table 1), but because of the low annual precipitation, temperature is the defining comfort and safety factor. Very little vegetation obscures the excellent exposure of this analogue site.

Standard Information Required for Analogue Sites:

Table 1: Summary of Upheaval Dome Facts

Site Name	Upheaval Dome, Utah
Center Coordinates Latitude, longitude	Latitude: 38.4247054 Longitude: -109.9309568
Elevation	1.8 km
Areal Extent	Crater is about 5 km diameter and central uplift feature is about 2.5 km diameter
Prime Science Questions	How is the geochemical, mineralogical and textural character distributed through the crater from the edge through the central dome? How far do you have to go in a "go to" site to get a look at (a) primary rock (b) impact generated products and (c) sedimentary in-filling?
Distance of Science Targets from nearest road or airstrip	Autos and 4WD are available in MOAB You can drive to a trailhead at the edge of the crater and hike in.
Environmental characteristics	Max temp: 43 °C (mid summer noon) Min temp: -18 °C (midwinter night) Precipitation: quite arid (US southwest) Vegetation coverage: bedrock is more than 75% exposed
Previous studies at analogue site	see references below
Primary Landing Site Target	Gale Crater
Other	National Park Service permit required

A



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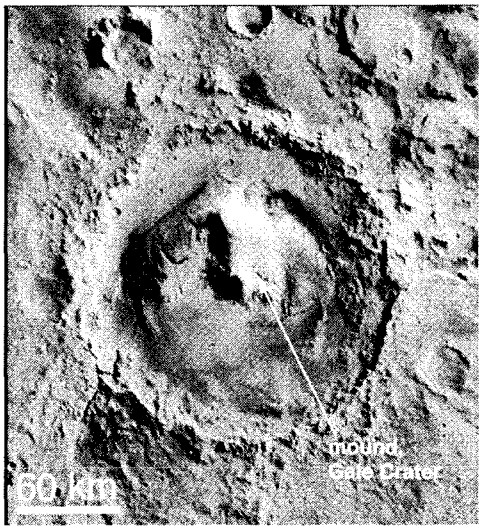

Figure 1: Panel A is Upheaval Dome in Canyonlands National Park in Utah, USA. Panel B is Gale Crater, one of the four candidate landing sites for Mars Science Laboratory.

References:

[1] Buchner, E and Kenkmann, T (2008) Upheaval Dome, Utah, USA: impact origin confirmed, *Geology,* **36,** 227-230. [2] Shoemaker, E. M., and Herkenhoff, K. E. (1983) Impact origin of Upheaval Dome, Utah (abstract), *Eos Trans. AGU, **64,*** 747. [3] Kriens, B., Shoemaker, E., and Herkenhoff, K. E. (1999) Geology of the Upheaval Dome impact structure, southeast Utah, *JGR Planets,* **104,** 18867-18887. [4] Gaddis et al. (1996)Decomposition of AVARIS spectra: extraction of surface-reflectance, atmospheric and instrumental components, *IEEE Trans. Geosci and Rem. Sens.,* **34** pp 163-178. [5] Milliken, R. E., J. P. Grotzinger, and B. J. Thomson (2010) Paleoclimate of Mars as captured by the stratigraphic record in Gale Crater, *Geophysical Research Letters,* v. 37, L04201