**THE MOJAVE DESERT: A MARTIAN ANALOG SITE FOR FUTURE ASTROBIOLOGY THEMED MISSIONS.** E. Salas[1], W. Abbey[1], R. Bhartia[1], and L. W. Beegle[1], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA, 91109-8099.

**Introduction:** Astrobiological interest in Mars is highlighted by evidence that Mars was once warm enough to have liquid water present on its surface long enough to create geologic formations that could only exist in the presense of extended fluvial periods. These periods existed at the same time life on Earth arose. If life began on Mars as well during this period, it is reasonable to assume it may have adapted to the *sub*surface as environments at the surface changed into the inhospitable state we find today. If the next series of Mars missions (Mars Science Laboratory, ExoMars Trace Gas Orbiter, and near surface sample return) fail to discover either extinct or extant life on Mars, a subsurface mission will be necessary to attempt to “close the book” on the existence of martian life.

Mars is much colder and drier than Earth, with a very low pressure $CO_2$ environment and no obvious habitats. Terrestrial regions with limited precipitation, and hence reduced active biota, are some of the best martian low to mid latitude analogs to be found on Earth, be they the Antarctic dry valleys, the Atacama or Mojave Deserts. The Mojave Desert/Death Valley region is considered a Mars analog site by the Terrestrial Analogs Panel of the NSF-sponsored decadal survey; a field guide was even developed and a workshop was held on its applicability as a Mars analog (see Table 1). This region has received a great deal of attention due to its accessibility and the variety of landforms and processes observed relevant to martian studies (Figure 1).

**Mission Description:** Until recently the only exploration of Mars has been confined to scratching the surface. Viking, Phoenix and MER have studied the surface and near surface, and both appear to be very inhospitable to life. If the surface *was* once habitable and life originated there, it is reasonable to assume that, to survive, life had to adapt to the more hospitable environments in the subsurface. These habitable niches would have to have access to liquid water and an energy source for extant life to still be viable. However, as the migration into the subsurface occurred, evidence would be preserved through chemical and mineralogic signatures that could be explored with a drilling mission. This drilling mission would have to be able to access sufficiently deep into the subsurface, 10’s to 100’s of meters.

**Science Merit:** In nature, microorganisms occur as communities where diverse types of microbes co-exist as cohesive colonies, especially when they exist in extreme conditions [1]. The number of habitats known to support microbial communities has steadily increased in recent years and now includes environments once thought anathema to life. Microbes have been discovered inhabiting uranium mines [2], rocks up to 3 km below the surface [3], and oceanic crust 150 m below the sea floor [4]. However, the subsurface microbiology of arid regions has yet to be fully characterized.

In terrestrial ecosystems, within the vadose zone, microbial biomass is found to correlate with factors such as carbon availability [5], terminal electron acceptor availability [6], nutrient availability [7], pH [8] and temperature [6]. The composition of terrestrial subsurface communities has also been found to be strongly depth dependent; communities tend to lose cell

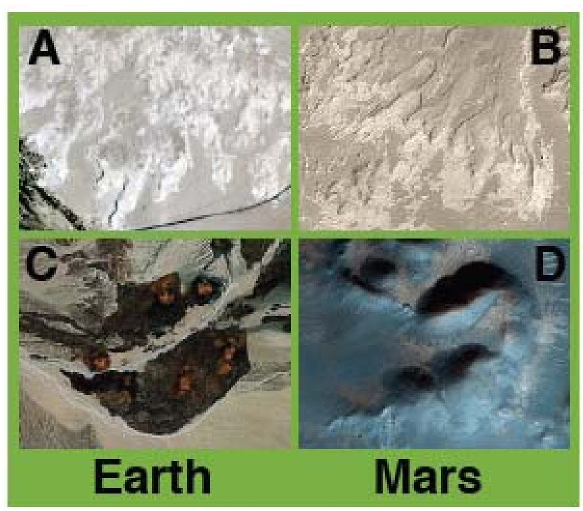


**Figure 1.** A) Alluvial fan deposit near Shoshone, CA; B) MOC image of a dried river delta in Eberswalde Crater, Mars; C) Lava formation at Cima, CA; and D) A HiRISE IRB color image of the Nili Fossae Trough, an MSL candidate landing site.

numbers, as well as phylogenetic and metabolic diversity, with depth [7, 9, 10]. Studying the variability of organisms in vadose zones within the same climate but in different geological contexts, constrains drilling scenarios on future missions. This includes understanding the variability of within a potential landing site (i.e. understanding the differences, if any between here and 100 meters ways), and depth required to fully understand microbial potential.

**Most Important Questions Answered by Site:** The Mojave region is an ideal place to perform subsurface investigations as there is an incredible amount of terrain, landform and geologic diversity within a very limited geographic area. There are multiple sites with a fluvial history and orbital geologic features that would make it a likely target site if the same features existed on Mars. Additionally, these sites have experienced the same general climate since the last glacial maximum [11]. At that time, the area was much different, with an ample supply of fresh water from a cooler, wetter climate and from ice melting off the nearby Sierra Nevada. Age dating of subsurface pore waters near this region indicate that the last major wetting of deep soils (>5 m) was at ~14 ka [12]. When the region began to dry the chemistry of the subsurface invariably changed; any organisms that could not adapt to the changing environment would have died off, leaving nutrients and a supply of organic matter for those able to adapt. Any subsequent variation in these subsurface habitats can reasonably be attributed to intermittent hydro-geologic events or local mineral and chemical differences in these environments.

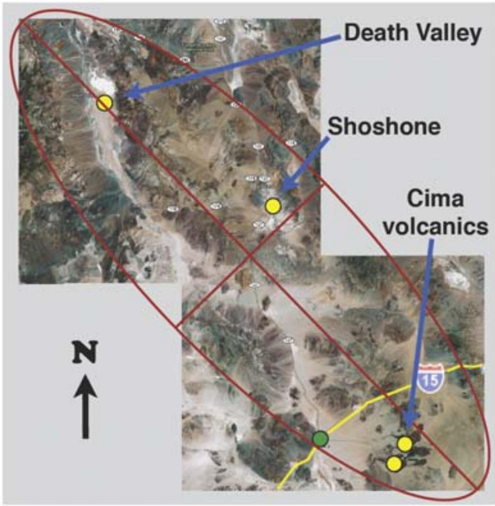


**Figure 2.** Sites within the Mojave Desert National Preserve & Death Valley National Park. Pale gold dots are proposed drill sites (northern site is DV; southern sites are Cima volcanics; middle site is near Shoshone, CA). Green dot is Baker, CA. Major axis of hypothetical landing elipse is 100 km.

Figure 2 has called out three distinct sites. The Death Valley site was chosen as a field site because its geology has been well characterized, providing a strong foundation for our study [13]. Also, a wide variety of mineralogically distinct evaporite deposits are present within a small area, including gypsum which was recently observed on Mars [14]. At this site we are primarily interested in drilling into an areally extensive gypsum deposit of varying depth and stratigraphic composition.

The second site is an extensive delta deposit located near Shoshone, CA, just outside the boundaries of Death Valley NP. In the Mojave these exposed pediments can vary widely in age, some dating back to well before the region became arid [15], with the older deposits naturally exhibiting a marked increase in well developed soil profiles, which likely has a dramatic effect on the ability of microbes to uptake vital nutrients.

The third field site is the Cima Volcanic Field located 20 km south of Baker, CA , and consists of a lava flow over desert paleosol. This location was chosen because it has experienced multiple volcanic events over the last several million years [16] making it an ideal location to investigate the ability of near subsurface microorganisms to survive extreme catastrophic events. It is expected that the thermal wave penetrated several meters into the soil, approximately the depth of the root zone, at a time when there was abundant vegetation present [17]. These events yielded one of three possible outcomes for the microbial communities present at the time of the eruptions: 1) greatly reduced metabolism in an effort to survive; 2) death of the microbial community due to heat from the lava flow or the newly created energy/nutrient limiting environment; or 3) alteration of the community structure to take advantage of previously less than desirable energy sources.

Understanding the variety in this region enables us understand what might have occurred on Mars during its own 'drying out' period.

**Logistics and Environmental Constraints:** There is excellent accessibility to the Mojave/Death Valley region. It is within easy (<4 hours) driving distance from several major airports, and is connected via a series of roads to the I-10, which runs right through the region. Most of the land is Bureau of Land Management, with minor areas in the Mojave National Preserve, Death Valley National Park, as well as private hands. Temperatures during the height of summer (Aug-Sep) can limit access. The average rain fall is on the order of 250 mm, with most of it occurring in the winter. During these rain storms there are sites that become dangerous due to flash flooding.

**Table 1:** Example table required for any analog site proposed.

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|---|---|
| Site Name | Mojave Desert/Death Valley |
| Coordinates<br>Latitude, Longitude | Between ~35.18° & 36.30°N and -115.76° & -116.86°W |
| Elevation | 0 to 2 km above sea level |
| Areal Extent | 100 km by 20 km |
| Prime Science Question | How do microorganisms evolve as the climate changes from high aqueous to dry, and what evidence do they leave behind as they evolve?. |
| Accessability | Most sites accessible by 1-2 km of driving from major roads. Major airports ~100 km drive, from both Las Vegas, NV and Ontario, CA. |
| Environmental Characteristics | Max temp: ~49°C<br>Min temp:<-15°C<br>Precipitation: <254 mm/yr<br>Vegetation coverage: Desert with minimal vegetation |
| Previous Studies at Analog Site | Farr, T.G., (2004); Greeley, R., et al., (1978); Howard et al. (2001) [18-20]. |
| Primary Landing Site | Eberswalde Crater and Nili Fossae Trough |
| Other | Evaporite lake beds suggested at both Gusev Crater and Meridiani Planum. |

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