Site Selection Criteria

- Diversity
- Context
- Habitability
- Preservation

- Habitability – OMEGA, CRISM and HiRISE have already touched on some of the stated MSL goals
  - Inventory the chemical building blocks of life (carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur)
  - Investigate the chemical, isotopic, and mineralogical composition of the Martian surface and near-surface geological materials
- Studies of terrestrial microbes increasingly show the viability of finding habitable environments on Mars
- Huge range of temperatures at which life can survive (from -20 deg C to 121 deg C)
- Life can survive through the entire pH range
- Can survive even in the presence of toxins
- Can survive in highly saline environments (but note sulfate/chloride difference for Mars)
- Can survive UV exposure (Deinococcus could grow on the outside of a spacecraft)
- Can handle widely varying O2 concentration
- Can live deep beneath the surface of the Earth surviving both high temperature *and* pressure

Diversity

- To mitigate the risk of disappointment and ensure the greatest chance for science success, we want the greatest number of possible science objectives at a chosen landing site.
  - We need multiple science targets, and these targets should be as strongly differentiated as possible. Thus, a landing site with both morphologic and mineralogic evidence for past water is better than a site with just one of these criteria.
  - Furthermore, a site with spectra indicating multiple hydrated minerals is better than a site indicating just one.
  - A site with multiple styles of stratigraphic expression and inferred depositional mechanisms is better than a site with a single mode of stratigraphic expression.
    - For example, a site with stratigraphically differentiated spectroscopic evidence for both clay minerals and sulfate salts would constitute a rich site.

There are other reasons to pick a Diverse site…

Context

- Rocks and soils investigated by MSL must be put into a larger, more regional context.
  - This regional context is important for constraining past processes which may have led to habitable environments.

- Our ability to do this will depend on how well rock units can be traced or otherwise correlated based on physical and textural attributes, as well as mineralogic signatures.

Habitable Environment

- An environment that can support life.
- The presence of water, an energy source (sunlight, thermal, chemical), and carbon (for life as we know it on earth) are all required.

Habitability

- Not all outstanding questions concerning the geologic history of Mars lead *directly* to understanding its environmental history, and therefore prospects for habitability.
  - Almost all planetary processes, those on Earth included, can be viewed in a general way as contributing toward understanding its environmental history.
  - Consequently, to be meaningful for MSL it is essential to adopt a more focused view that makes specific predictions that can be incorporated into an exploration strategy for MSL.
- The essential issue here is to identify a particular geologic environment (or set of environments) that would support microbial life.
  - The spacecraft can then be directed to interrogate promising rock and soil masses for clues that might lead to the detection of chemical, mineralogic, and textural features than would confirm the presence of a habitable environment at the landing site.

Preservation (Taphonomy)

- *Taphonomy*: subdiscipline of paleontology that investigates the processes of organism preservation and their influence on biologic information in the rock record.
- Processes that affect the transferral of organic matter (including molecular biomarkers) from the biosphere to the lithosphere, and physiochemical interactions from the time of burial until collection.
- *Taphonomic Window*: A particular set of environmental processes that is favorable for fossil and/or biomarker preservation. For microbes, the taphonomic window is dominated by biogeochemical and thermal processes.

Fossil/Biosignature Preservation

- On Earth, the preservation of fossils and other biosignatures depends on particular physico-chemical conditions that result in early mineralization of organic matter to preserve, or entomb morphologic and chemical fossils in the rock record.
  - The early diagenetic history of clay minerals is critical to their ability to sequester organic substances.
  - These conditions embrace a very specific subset of the much broader set of conditions that enable life to be present in any given geologic environment. Simply put, life may be present everywhere on Earth's surface, but only rarely does it get fossilized.
- On Mars, how might have early preservation of organic matter and/or delicate textures proceeded?
  - Hematite, other iron oxides, sulfate minerals, phyllosilicate minerals, silica, and possibly chloride minerals have all been suggested as possible substrates for fossil preservation.
  - Indeed, all are known to facilitate the preservation of fossil morphologies and molecules on Earth. Some – iron oxides, sulfate salts – additionally can preserve isotopic signatures of biogeochemical processes.

Evaluation questions for voting:

How diverse is the site?

A high score should be awarded for sites that show strong evidence of rich mineralogy as well as rich geomorphology and stratigraphy, and that both of these attributes be clearly related to the presence of water.

1) Can multiple rock units be observed from orbit?
2) Do these units have well defined stratigraphic and/or cross-cutting relationships?
3) Are these units differentiated on the basis of diverse mineralogic features? Are systematic trends present?
4) Are these units differentiated on the basis of diverse geomorphic features? Are systematic trends present?

- Ideal Example: a site with strong mineral signatures, expressed in discrete stratigraphic sequences, in which the mineralogy varies from unit to unit, and in which different units contain geomorphic evidence for subaqueous processes.

Evaluation questions for voting:

How refined is the geologic context?

A high score should be awarded for sites which have a clear geologic context and which offer the rover a well-defined set of objectives. The mission can always hope to count on “surprises” as a back up for discovery, but its best to have a hypothesis-driven framework to begin with at the outset

1) How much of what will be observed by the rover can be placed into a geologic framework before landing?

2) Can local observations be placed into a more general regional context and, if this is possible, how confidently can this be done?

.

• Ideal Example: Two groups of rocks can be inferred to have formed by aqueous processes, and one is clearly Hesperian age, the other Noachian age, and these units can be shown to have a superposed, unconformable relationship. Internally, one or both groups of rocks can be further subdivided and its internal stratigraphy and mineralogy, if studied by the rover, are representative of similar types of rocks at other locations on Mars; the discoveries of the rover can be extended more broadly away from the landing site.

Evaluation questions for voting:

How habitable was the environment(s) represented by the landing site?

Do the minerals and morphologic/stratigraphic relationships provide strong and direct evidence for habitability? What do theoretical considerations of these observations suggest?

1) Does mineralogic/geomorphic evidence indicate a particular habitable environment?

2) Can minerals or geomorphic features detected from orbit be used as reliable indicators of past:

   a. duration of water

   b. water pH

   c. water/rock ratio

   d. water activity (salinity)

- Ideal Example: High silica content rocks are observed in mound-shaped structures consistent with spring deposits. Phyllosilicate/sulfate/silica enrichment in layers contained within enclosed basin; composition varies from layer to layer.

Evaluation questions for voting:

How high is the fossil preservation potential?

The goal here is to evaluate what mineral(s) may have precipitated early, or other processes such as clay mineral adsorption, would have caused entrapment of organic compounds and/or preservation of biogenic textures. Also, what processes would have destroyed fossil preservation?

1) Are the observed mineral phases early and contemporaneous with sedimentation and/or rock alteration?

2) What is the particular mechanism/process involved in fossilization?

3) Could the inferred habitable environment be detrimental to the preservation of organic matter or other biosignatures due to high water/rock ratio and/or oxidizing chemical reactions during diagenesis?

- Ideal Example: Precipitation of mineral at low temperature that impregnated cellular structure to entomb organics; mineral aggregate has such low permeability that oxidation during contemporaneous or subsequent pore fluid circulation is excluded.

Summary

- We have 7 fabulous landing sites.
- Their hypotheses can be evaluated by the MSL payload or they wouldn’t have made it this far.
- Now we need to fine tune: which sites are the best for specific MSL goals using the established criteria?
- Terrestrial analog studies and field methods provide guidance for how this might be done with MSL.

“Rig 65”
Sultanate of Oman

“Rig 65”
Sultanate of Oman

Well Selection depends on:
Multiple Objectives (Diversity), Clear Geologic Framework (Context),
Collaboration between geologists, geophysicists, and engineers
(Teamwork)