

## Exploring Mars for Evidence of Habitable Environments and Life

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The climate of Mars has been more similar to that of Earth than has the climate of any other planet in our Solar System. But Mars still provides a valuable alternative example of how planetary processes and environments can affect the potential presence of life elsewhere. For example, although Mars also differentiated very early into a core, mantle and crust, it then evolved mostly if not completely without plate tectonics and has lost most of its early atmosphere. The Martian crust has been more stable than that of Earth, thus it has probably preserved a more complete record of its earliest history.

Orbital observations determined that near-surface water was once pervasive. Orbiters have identified the following diverse aqueous sedimentary deposits: *layered phyllosilicates, phyllosilicates in intracrater fans, plains sediments potentially harboring evaporitic minerals, deep phyllosilicates, carbonate-bearing deposits, intracrater clay-sulfate deposits, Meridiani-type layered deposits, valles-type layered deposits, hydrated silica-bearing deposits, and gypsum plains*. These features, together with evidence of more vigorous past geologic activity, indicate that early climates were wetter and perhaps also somewhat warmer. The denser atmosphere that was required for liquid water to be stable on the surface also provided more substantial protection from radiation.

Whereas ancient climates might have favored habitable environments at least in some localities, clearly much of the Martian surface for most of its history has been markedly less favorable for life. The combination of dry conditions, oxidizing surface environments and typically low rates of sedimentation are not conducive to the preservation of evidence of ancient environments and any biota. Thus a strategy is required whereby candidate sites are first identified and then characterized for their potential to preserve evidence of past habitable environments. Rovers are then sent to explore the most promising candidates.

The Mars Exploration Rover (MER) Opportunity revealed that water once flowed to the surface across the vast Meridiani plains, creating saline lakes whose waters were roiled by ancient winds that also sculptured their salt deposits into sand dunes. Opportunity then drove more than 30 km to explore even older deposits on a crater rim. MER Spirit found evidence that thermal waters (heated by volcanism or by impacts?) altered rocks to create sulfate salts, and siliceous sinters.

These discoveries indicate that an early hydrological cycle apparently sustained precipitation, streams and lakes. Liquid water participated in rock weathering reactions, such as iron and sulfur oxidation, that created distinctive weathering regimes. Volcanism, impacts, groundwater and ice interacted at least locally. Redox chemical energy from volcanism, hydrothermal activity and weathering of crustal materials would have been available for any life. Thus conditions might have supported life in the past, at least locally.

The main objective of the Mars Science Laboratory (MSL) Curiosity rover is to determine the extent to which Gale crater hosted environments capable of supporting microbial life. The rover has already found stream gravels as well as sediments that might have been deposited in an ancient lake. The rover is now traversing to Mt. Sharp, a 5 km-high mound that is located on the crater floor and that exhibits layered sedimentary rocks having diverse minerals (sulfates and clays) that apparently formed in the presence of liquid water. This rock sequence was deposited over an extended time period in diverse potentially habitable watery environments. Curiosity is poised to characterize a well-preserved rock record of hundreds of millions of years of diverse environments and profound climate change.