

Recommended Geoscience Capabilities of Biomorphic Explorers: Lessons from Pathfinder

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The Mars Pathfinder mission was an engineering and scientific success. The geologic information returned by the lander and rover significantly increased our understanding of Mars. At the same time, the acquisition of some geologic data was limited by constraints of the Pathfinder architecture. Here, we discuss the geology uncovered by Pathfinder and how biomorphic explorers may be able to address certain geologic questions that Pathfinder could not.

During its nearly three months of operation, the Pathfinder mission returned important data on the geology of the local Martian surface. These data included: 1) Measurements of the major element abundances of six soils and five rocks from the Alpha Proton X-ray Spectrometer (APXS). 2) The documentation of several rock textures which may be igneous or sedimentary in origin. 3) Evidence for physical and possibly chemical weathering. 4) Documentation of large-scale topography and geomorphic features. 5) Mapping of rock distribution.

Although generally successful, the mission could not completely address the geology of the site due to several problems: 1) Dust could not be removed from rocks, inhibiting spectral and APXS analyses of pristine rock surfaces. 2) There was often insufficient time to assess rover images of geologic areas. Many rocks were deemed worthy of further investigation only after the rover had moved away. 3) Rock interiors, commonly of greatest interest to geologists, could not be sampled. 4) Large rocks presented hazards to the rover and inhibited access to interesting sites. 5) Subsurface soil stratigraphy could not be easily examined.

Biomorphic explorers may be able to address these problems. Two categories of instruments are considered virtually essential for geologic investigation and must be included on biomorphs: 1) High resolution cameras that can see detailed textures and fabrics. Resolution should be on the sub-millimeter scale (equivalent to a hand lens). Multispectral capability to assess mineralogy and oxidation state is strongly desired. 2) Instruments to analyze chemistry of major elements, and possibly minor and trace elements, in situ (e.g., XRF, calibrated APXS., etc.). The small size of the biomorphs makes them suitable candidates for long term, detailed examinations of rocks and soils. Once deployed, the explorers could carefully investigate a region in greater detail than is possible from a rover. A fleet of biomorphs could examine several rocks and soils within a local area, providing much more information than could be obtained from a quick rover reconnaissance. To be effective, the explorers must have the ability to remove dust and other coatings from rocks and, if possible, be able to chip away or drill into the interior of rocks. Biomorphs deployed at soil sites should be able to dig below the surface to investigate subsurface stratigraphy and chemistry.

Because of the limited mobility of biomorphs they would probably best be used in conjunction with a larger roving vehicle. Much like a field geologist who stops to examine an outcrop, a rover could deploy a biomorph at an interesting site and then move

on. Using this approach, both reconnaissance using the rover and detailed studies using biomorphs could be conducted. Geologically interesting areas that are inaccessible to rovers are also obvious biomorph targets. These include steep bedrock walls where stratigraphy is preserved and very rough surfaces such as lava flows.

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Major Points

- Pathfinder a major success
 - important science results
 - verified Discovery program concept (better, faster, cheaper)
- Acquisition of some geologic data limited by constraints of Pathfinder architecture.
- Biomorphs may be able to address certain geologic questions that Pathfinder could not.

Pathfinder Geology: Major results

- Geomorphology and mineralogy (IMP)
- Elemental abundances of six soils and five rocks (APXS).
- Documentation of rock textures, including those caused by aeolian abrasion.
Diagnostic evidence for igneous or sedimentary rock origins is equivocal (rover cameras).

Pathfinder Limitations/ Biomorph Possibilities?

1. Dust on Rocks

- Dust could not be removed from rocks, affecting multispectral and APXS analyses.
- Removing dust is important for investigation of rock surface chemistry and textures
- Possible techniques:
 - brushing
 - blowing of compressed gas
 - digging

Pathfinder Limitations/ Biomorph Possibilities?

2. Rock Interiors

- The interior of rocks could not be examined.
- Rock interiors provide information on:
 - Mineralogy
 - Texture
 - Fabrics (lineation, layering, etc.)
- Possible techniques:
 - hammering/chipping
 - coring
 - sawing

Pathfinder Limitations/ Biomorph Possibilities?

3. Large Rocks

- Large rocks could not be traversed by Sojourner
- Large rocks are potentially the most interesting:
 - Possible outcrops
 - May exhibit heterogeneity
- Desire:
 - Ability to climb and maintain stability on steep slopes and rough surfaces

Pathfinder Limitations/ Biomorph Possibilities?

5. Insufficient Time For In Situ Study

- At most, Sojourner examined a rock for a few days; in most cases data were limited to a few pictures from one vantage point. Many rocks deemed worthy of further investigation after it was too late.
- Capability to examine individual rocks or other features in detail may be necessary.

Pathfinder Limitations/ Biomorph Possibilities?

4. Subsurface

- Subsurface could not be easily examine by Pathfinder
 - Limited capability to dig with rover wheels
- Subsurface may provide information on:
 - Stratigraphy
 - Weathering processes
 - Volatiles
 - “Pristine” rocks shielded from surface environment
- Possible techniques
 - Shoveling/trawling
 - Boring/tunneling

Important Capabilities

1: Imaging

- Science
 - Geomorphology
 - Mineralogy
 - Lithology
- Capabilities
 - Stereo imaging
 - High resolution (sub-millimeter scale)
 - Multispectral

Important Capabilities

2: In Situ Geochemistry

- Science
 - Mineralogy/Petrology
 - Weathering processes
 - Radiometric age?
- Capabilities
 - Abundance of major and minor elements
 - Isotopes?
 - Trace elements?
 - Volatiles

Biomorph Scenarios

- A fleet of biomorphs could examine several sites within an area, providing more info than a quick rover reconnaissance.
- Biomorphs could be combined with a rover mission, allowing long distance reconnaissance (rover) with detailed studies (biomorph)
- Challenging terrains:
 - Canyon walls
 - Craters
 - Subsurface

Conclusions: Pathfinder Lessons

- Important instruments:
 - Cameras (stereo, high resolution, multispectral)
 - In situ geochemistry
- Other desired capabilities:
 - Removal of dust
 - Investigation of rock interiors
 - Investigation of soil subsurface
- Biomorphs, if properly designed, can expand on some capabilities of Pathfinder and overcome some limitations.
- Biomorphs may be useful for detailed studies of small regions or for investigations of challenging terrains.