Detecting Biosignatures for Chemosynthetic Life Forms on Mars Using Geological Mapping Data

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ABSTRACT

The search for extant life on Mars critically depends on the mapping of life-sustaining environmental niches. These niches can be identified by sensing biogenic biomarkers, on the basis of sources of solar, chemical or radioactive energy. This communication postulates exploratory techniques based on historical evidence using USGS data. The authors outline existing regions in the Martian geography, which have already been mapped abundant with these biomarkers, and may be promising for future explorations.

(Keywords: extant life, Mars, remote sensing, biomarkers, Martian geological data)

INTRODUCTION

The search for extraterrestrial extant life extensively relies on the assumption that a specialized environment to provide the basic requirements of life exist on Mars. It is therefore essential for there to be access to the requirements of life in this supposed environment. However, there is still no consensus regarding these requirements.

Data from the NASA-funded United States Geological Survey (USGS) geologic mapping project enables the identification of morphologic, topographic, spectral, thermophysical, radar sounding, along with other observational methods to allow for the integration, analysis and interpretation of data.

These techniques may be integral when considering the possibility for carbon-based anaerobic systems to thrive in such a niche with or without liquid water. Moreover, excavation missions have yet to dig underground and as such, there is a possibility an ecosystem for extant life exists beneath Martian surface relying on chemical energy, which can be detected by several of these techniques.

Characteristics of Life-Sustaining Niches using Topographic, Spectral, Thermo-Physical, and Radar Sounding Methods

Traditionally, there are seven characteristics associated with living things including: nutrition, respiration, movement, excretion, growth, reproduction and sensitivity. While water has commonly been recognized as a requirement for life on Earth, according to Benner *et al.*, there are only two absolute requirements for life to sustain these functions: (i) an energy source, such as light from the Sun or radioactive decay and (ii) a stable and suitable temperature range which can allow for chemical bonding.

As such, the primary and foremost step in the search for extant life is to identify features, which could be utilized by topographic, spectral, thermophysical, and radar sounding to characterize these life-sustaining environmental niches. Current USGS data has extensively characterized and mapped these niches.

Characterizing Niches Requiring Solar Energy with Infrared and Spectroscopic Methods

One approach was to precisely identify locations on Mars consistent with Benner and colleagues' definition. For instance, locations on Mars' surface receiving solar irradiance could be scouted using USGS maps that trace seasonal irradiance. Photosynthetic processes may additionally result in gas exchange, which could also be monitored through infrared and spectroscopic methods designed particularly to identify gas byproducts such as CO_2 or water vapor.

Characterizing Niches Requiring Chemical Energy Using Radar Sounding, Infrared, and Radiation Techniques

Chemosynthesis as opposed to photosynthesis, is also a means for primary energy production on Earth. There are certain lithotrophic microorganisms that survive in ecosystems which rely on inorganic compounds such as elemental sulfur, sulfur oxide, hydrogen sulfide or iron originating from hydrothermal vents on the ocean floor to meet their energy demands.

Moreover, chemo-lithoautotrophs depend on inorganic compounds such as sulfur to be oxidized through a chemical reaction to generate energy. As such sources of inorganic compounds may become an optimal niche for organisms relying on the chemosynthesis for energy consumption. While largely unexplored, this provides a basis for scanning similar surfaces on Mars using infrared techniques, where microorganisms have access to inorganic compounds such as sulfur which can be oxidized to produce energy.

Chemical Energy in the Core

Mars' core could additionally be a location of interest based on the requirement for energy. The core of Mars is hypothesized to consist of a mixture of iron, sulfur and perhaps even oxygen. These would be ideal for lithotrophic microorganisms. The USGS has previously used techniques such as the Mars Reconnaissance Orbiter (MRO) to map buried ice sheets, which could be useful in the search for other biosignatures.

Volcanic surfaces may also be a source of interest particularly with the abundance of gases and compounds such as sulfur and iron for chemolithotrophs. The MRO's Shallow Radar (SHARAD) instrument could be used to map out these regions. While excavation missions have yet to dig past a layer of gravel to determine the composition or presence of life underneath soil, another source of energy which could be harnessed by life forms on Mars is radioactive decay, which may critically be involved in generation of heat in the core. As such, remote sensing of radiation may also be critical in characterizing these hotspots.

Characterizing Biomarkers for Extant Life using USGS Data

The reduction-oxidation (REDOX) reaction itself involves formation of byproducts, which could potentially be used in the detection of extant life. For example, a common pathway seen in chemosynthetic bacteria found in hydrothermal vents involves the carbon dioxide and hydrogen sulfide as reactants.

The products of this reaction are carbohydrates and water and waste sulfur, which may be expelled or stored in the cytoplasm. However, chemosynthesis is not restricted to this pathway alone. In fact, certain bacteria are additionally able to utilize oxidizing and reducing agents including hydrogen and oxygen, divalent iron ions, ammonia and nitrates to produce energy. On Mars, waste byproducts of these reactions such as sulfur or other oxidized compounds may be detected using infrared, thermophysical, and radar sounding techniques, enabling extant life detection.

Potential Regions to Search using USGS Methods

With the vast and diverse geographic and topographic mapping of Mars, identifying life-sustaining niches involves determining and targeting locations where these specific chemosynthetic organisms are able to thrive. A promising area are the polar ice caps along with regions characterized by surface frost and water ice glaciers, particularly because the presence of water in itself, is known to be key to life, although there are several hypotheses suggesting the feasibility of extraterrestrial extant life with a source of energy and stable environmental conditions alone.

Volcanic surfaces may also be a source of interest particularly with the abundance of gases such as methane, hydrogen, and hydrogen sulfide, as well as elemental compounds such as sulfur and high iron content for chemolithoautotrophic microorganisms. The heat of geothermal activity may play a role in melting permafrost or other subsurface sources of water for a subsurface microbial community. Additionally, areas rich in iron oxides, once hypothesized to be Martian 'continents' and characterized by an intense reddish color, can also be mapped out through aerial imaging using remote drones.

Historical Evidence and Techniques

There have been several features previously utilized in the search for extraterrestrial extant life on Saturn's moon, Titan. In the Cassini-Huygens missions, aerial imaging was used for the identification of water ice and black methane lakes. These were identified polar regions of the moon. A similar approach can be used on Mars in the search for lake-beds of an essential compound for life. While several historical missions have determined no signs of water on Mars, sophisticated satellite imaging still reveal areas where rivers, lakes or ice in the ground or on glaciers could have existed.

CONCLUSION

The search for extant life on Mars critically depends on the mapping of life-sustaining environmental niches. These niches can be identified by sensing biogenic biomarkers, on the basis of sources of solar, chemical or radioactive energy, and based on historical evidence using USGS data. Furthermore, there are existing regions in the Martian geography, which have already been mapped abundant with these biomarkers, which are promising for future explorations.

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