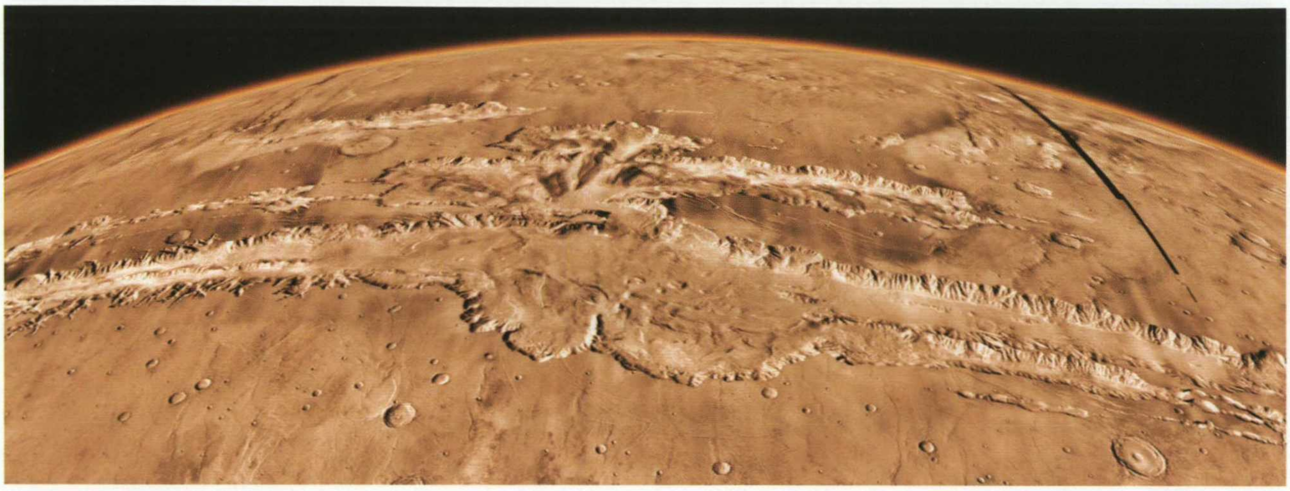

The Valles Marineris canyon system on Mars

Secrets of the Red Planet

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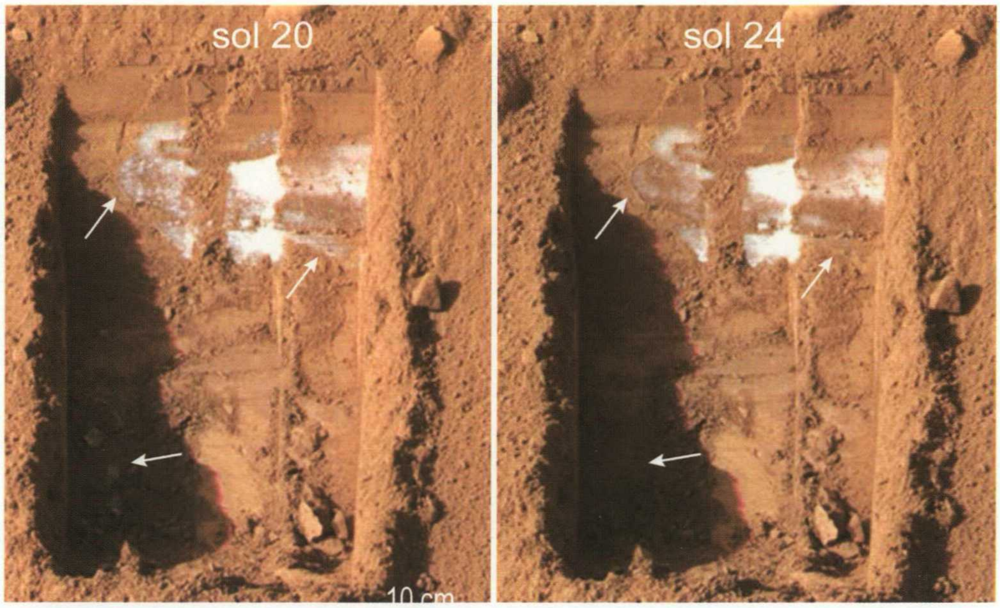
During the last decade of humankind's exploration of Mars, a succession of American and European missions have sent back vast volumes of data about the planet's surface and atmosphere. And yet many questions remain unanswered. This has provided the incentive to design an innovative mobile platform, called the Highland Terrain Hopper, being developed jointly by planetary geologists and engineers

Most of the analysis of the surface of Mars conducted thus far has been based on remote sensing data. This involves studying objects from a significant distance away by measuring and recording energy in one or more parts of the electromagnetic spectrum. We have high resolution images obtained by the Mars Reconnaissance Orbiter and Mars Express missions, which we can use to create digital elevation models. We also have spectrometric data in the visible, near infrared, and thermalinfrared, allowing us to determine the physical properties and mineralogical and chemical composition of the surface. Finally, we also have radar data, opening up the possibility of subsurface analysis. Such efforts aim to better understand the influence of geological processes on the present-day Martian landscapes, and determine their succession and surface lithology - the properties and composition of Martian rocks.

Measurements

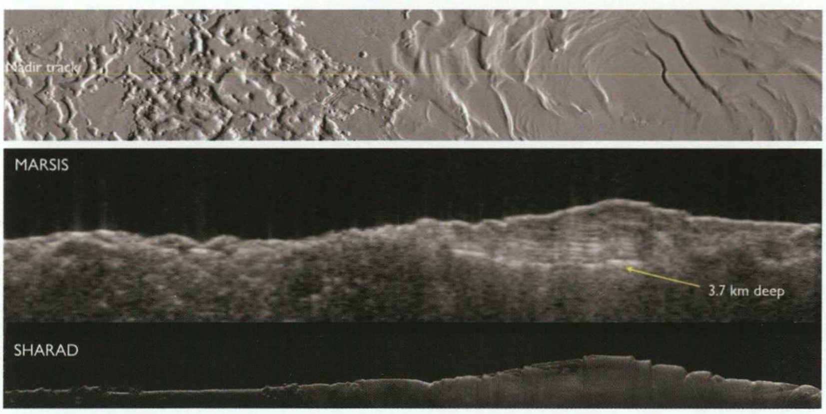
During early stages of remote sensing data interpretation, we have to assume that the processes that led to the formation of the surfaces of Mars and Earth were driven by similar mechanisms. This gives us many directions to explore Mars, extrapolated from the information we have about our own planet. Yet in subsequent stages of interpretation, we also need to bear in mind that even when extremely similar effects are observed, such as specific landforms or mineral composition of the surface, they are not necessarily driven by the same processes.

The spectrometers carried by Martian probes perform analysis of the radiation reflected and emitted by the planet's surface and atmosphere. The total emission and reflectance signal registered by an orbiting spectrometer originates both from the planet's surface itself and from the entire column of atmosphere between the detector and the surface. The first step before further spectral analysis can be performed, therefore, is to distinguish between the surface and atmospheric components. Mineralogical analysis of the surface can be conducted using spectroscopic methods in the visible and infrared



Sublimated water ice in photos taken by the Phoenix lander over the course of four Martian days

NASA/JPL-Caltech/University of Arizona/Texas A&M University



Subsurface analysis using radar data. Cross-section views of the Martian north polar cap; data obtained by the MARSIS/MEx (analysis at greater depth) and SHARAD/MRO (analysis at higher resolution) instruments

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range, since many minerals exhibit diagnostic absorption and emission bands in these wavelengths. Each material emits a spectrum exhibiting a unique combination of bands. The spectrum of a given remotely-sensed object of an unknown composition can then be compared against reference spectra in order to identify the material. There are many databases (spectral libraries) of laboratory and experimental spectra of the minerals and rocks found on Earth. By comparing them against spectra of the Martian surface collected by orbiters' spectrometers we can identify the minerals present and their relative proportions. Various mixtures of minerals are also analyzed in the lab in order to evaluate how individual components affect the final spectrum.

Spectrometric measurements critically need to be performed at the right resolution, both spatially and spectrally. If the spatial resolution is too low, the diversity of materials within a single measurement spot cannot be apprehended. High spatial resolution is therefore essential to analyze precisely the materials within a small area. A high spectral resolution, in turn, makes it possible to differentiate between responses from two spectral lines close to one another, as at lower spectral resolutions the signal covers a wide spectral range, cumulating responses from several spectral lines. By analyzing datasets covering various spectral ranges and characterized by differing spatial and spectral resolution, it is possible to obtain an accurate identification of mineral phases and their spatial distribution.

Water

The presence of water on Mars during past geological eras is a key fact in the planet's evolution. Various landforms observed on Mars's surface, such as valley networks and outflow channels, can only be relics of the ancient presence of liquid water. Yet today there is almost no water on the planet's surface, with the exception of an ice at the poles; the atmosphere contains only trace amounts of water vapor and clouds of water ice crystals. Even when we take into account that some amount of water may have escaped into space, the question remains as to what happened to the rest of it. That is what makes it so important to obtain further, indirect evidence of the presence of water, such as hydrated minerals in old rock strata. Clay minerals and other hydrated silicates, sulfates, carbonates, chlorides and perchlorates have been found at numerous sites on the Martian surface using data from infrared spectrometers. The gamma-ray spectrometer of the Mars Odyssey mission has provided important data on the presence of hydrogen

in the subsurface. Analyses performed by the Phoenix lander revealed the presence of water ice just beneath the planet's surface, while radar data obtained by SHARAD (Mars Reconnaissance Orbiter) and MARSIS (Mars Express) instruments have made it possible to search for water ice in the subsurface on a planetary scale.

Life

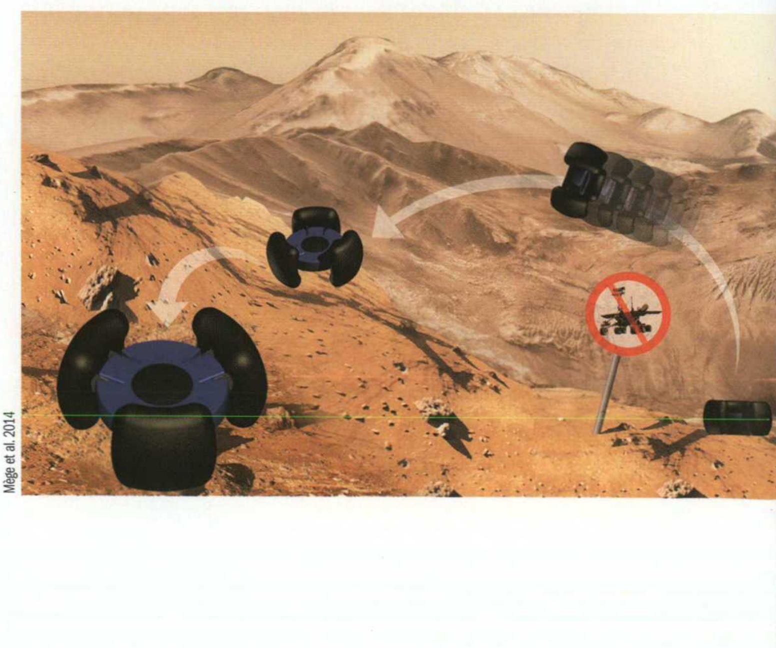
The only missions to date that specifically searched for life on Mars were Viking 1 and 2, launched by NASA in 1975. However, the organic molecules they detected - chloromethane and dichloromethane - have been interpreted as terrestrial contamination picked up during the probe preparation to launch. When the Phoenix lander detected magnesium perchlorate in Martian soil - which can destroy organic molecules - researchers were encouraged to analyze once again the results obtained by the Viking missions. Samples heating during the experiment may have potentially caused perchlorate to react with any organic molecules possibly present and break them down. Furthermore, methane detected on Mars may be indicative of possible life, perhaps just beneath the surface, since we know that living organisms are the leading producers of methane on Earth. The aim of the ongoing Mars Science Laboratory mission (Curiosity rover) is to find evidence that the past conditions on Mars could have fostered life. The search for life is one of the priorities for the next decade of Mars exploration.

Terrestrial analogues

On Earth, field observations usefully complement remote sensing analysis, especially of imaging data, and improve the accuracy and reliability of interpretations. On-site observations also allow researchers to accurately correlate actual rock formations with their view from satellites.

Such data obtained directly from the Mars surface are limited to the sites of the Viking 1 and 2 and Phoenix landers, and the areas visited by Mars Pathfinder, the two Mars Exploration Rovers, and the Mars Science Laboratory rover. This is why for regional and global interpretations of data obtained by the Martian orbiters the analysis of regions that are potentially analogues on Earth is useful - for the moment this is one of the few ways that can help us understand the nature and course of processes involved in the genesis of the current Martian landforms. The long list of terrestrial regions sharing similarities in terms of geological com-

The Highland Terrain Hopper in the Valles Marineris region - an artist's view



Mège et al. 2014

Mège D., Bourgeois O. 2011

Postglacial gravitational deformation of mountain ridges - examples from Geryon Montes (Valles Marineris, Mars) and Bodeneck (Austrian Alps, Earth)

position and climatic conditions includes, for instance, the Columbia River Plateau in the US, Devon Island in Canada, the eastern Sahara, and basalt lavas in Hawaii.

Reciprocally, in order to better explain geological processes occurring here on Earth, it is also useful to analyze ones that have shaped other terrestrial planets. Mars can be used as a natural laboratory to help us find answers to important geological questions. Because of the low erosion and absence of vegetation on Mars, we can observe the succession of geological structures that developed over four billion years at least. Understanding the events that have played a key role in Mars evolution may also help us explain similar processes on Earth, such as stretching of the crust, volcanism, landslides, or glaciations.

Canyons

The greatest system of canyons in our Solar System, Valles Marineris, stretches over more than 2500 kilometers along the Martian equator. From a geological perspective, it is a unique structure offering insight into processes occurring on Mars now and in the past. This deep cut in the crust makes it possible to study the oldest rock strata, located at a depth of several kilometers. The walls and floors of the canyons provide an excellent record of the planet's geological history, and their dimensions reflect the diversity of geological processes within the region.

The operation of Martian rovers is limited to flat surfaces. Although the canyons of Valles Marineris are fascinating, they are largely inaccessible due to these technological limitations. Stratigraphy within Valles Marineris and in the Gale crater (the study site of the Mars Science Laboratory) is relatively similar, although Valles Marineris covers a significantly greater rock age span; research conducted there would be useful to extrapolate results obtained by the Curiosity rover to a global scale. A mission to Valles Marineris would provide the first full stratigraphic profile of Mars obtained in situ.

Planetary geologists from the PAS Institute of Geological Sciences are involved in a project that will define the scientific objectives and mission scenarios for the Highland Terrain Hopper mobile exploration platform, now being designed by engineers from the PAS Space Research Centre. This vehicle will move around by hopping, allowing it to jump over natural obstacles and reach areas inaccessible to rovers. Due to the lower gravity on Mars's surface, such hops could reach heights of up to four meters. Testing the new vehicle on similar terrain on Earth will help researchers prepare it for future operations on Mars, including the Valles Marineris region. ■

The project "Mars: Another Planet to Approach Geoscience Issues," conducted at the PAS Institute of Geological Sciences, Research Centre in Wrocław, is financed by the Foundation for Polish Science as part of the TEAM program (TEAM/2011-7/9).

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