Improving the chance of finding fossil microbes on Mars

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All life on Earth requires the presence of liquid water [1]. Evidence that Mars once had liquid water for extended periods of time is growing and is keeping alive the possibility that life may once have started on Mars [2]. We are using infrared spectroscopy of Mars to search for minerals indicative of the past presence of liquid water. If we can locate regions containing such minerals, these would be promising locations to search for fossil microbes.

The early models of Mars range from a warm, wet, water abundant, earth-like planet to a cold, dry planet similar to the Mars we see today [3]. Under present pressure and temperature conditions on Mars, liquid water is not stable at the surface [4]. However, this is not necessarily true of the past. The morphology of Mars implies a warmer past with a thicker atmosphere and a channel forming fluid. Channels and valleys have been photographed by orbiting spacecraft [5]. These are normally interpreted as being due to the action of water, but suggestions have been made that they could be caused by processes involving carbon dioxide gas [5]. Mars also displays large-scale surface variations, with low-lying northern plains and great southern highlands. These northern plains have been explained as floodplains and a possible location for a past ocean, but detailed analysis has cast doubt on the disputed shorelines [6].

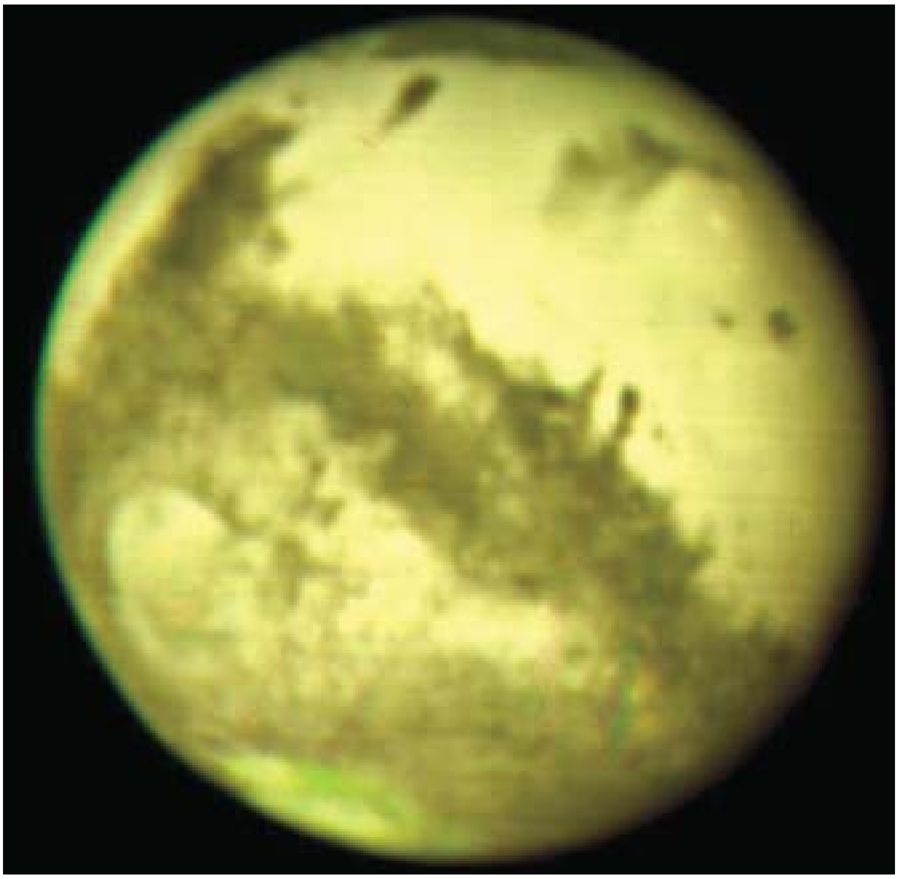

Image of Mars in the near-IR obtained with the United Kingdom Infrared Telescope (UKIRT) on 17 August 2003. The image is a composite of observations in three narrow band filters.

The question then is how can we conclusively say that the features seen were caused by liquid water? The key to this is looking for aqueously altered minerals that should have been formed on Mars. If liquid water had been present, there should be evidence of carbonates, since the Martian atmosphere is composed of 95% carbon dioxide [7]. Water soluble salts should be present either as evaporates or as precipitates [8] and, finally, hydrated clay minerals should be present due to the weathering breakdown of rock and the trapping of water molecules in aqueous environments [9].

Using both Landers and orbiting spectrometers, evidence for and against the past presence of liquid water has been found. Viking Landers 1 & 2 sampled the soil at both sites and found equal levels of chlorine and sulphur [10]. This was interpreted to be chloride and sulphate, both salts that are soluble in water. The similar abundances of each at both landing sites was taken to mean that these ions were highly mobilised with the likely medium of liquid water, which corresponded to the implication of precipitate salts found in some of the Martian meteorites.

The Mars Global Surveyor was launched in 1996, with the instrument TES (Thermal Emission Spectrometer) on board. Different minerals from the Martian surface emit heat at specific and individual infrared wavelengths. These emission signatures were detected by TES for most of the Martian surface between 1997 and 2001 [11].

Carbonates were looked for, but found in only trace amounts, too small to require the presence of liquid water, though carbonates found in Martian meteorites seem to be in conflict with this result.

Other interesting discoveries were made including beds of crystalline grey haematite and the abundance of olivine in basalts at the surface, each with implications to the past presence of water on Mars. On Earth, crystalline grey haematite has six possible formation processes, five of which include chemical precipitation from liquid water. The sixth involves thermal oxidation of magnetite rich lavas which, given the geological settings of the beds[12], can be ruled out. The olivine that was mentioned previously provides evidence against widespread oceans across Mars; pockets of abundances up to 10-15% have been found in the basalts that have been exposed on the surface for long periods of time[11]. Since olivine is highly reactive in aqueous environments, it would only be present for very short geological time periods before it weathered away.

Information on surface minerals can also be obtained by looking for spectral absorption features in reflected sunlight at short infrared wavelengths (from 1-2.5µm). In contrast to the longer IR wavelengths observed by TES, this wavelength region has been little studied by spacecraft, largely due to the failure of several Mars missions which have carried near-IR instruments (such as Phobos 2 and Mars 96). However, this wavelength region is particularly useful for the detection of minerals indicative of aqueous alteration and is frequently used in remote-sensing studies of minerals on Earth.

We have taken advantage of the close approach of Mars to Earth in August 2003 to obtain near-IR spectroscopy of Mars using the United Kingdom Infrared Telescope (UKIRT) at Mauna Kea in Hawaii. This telescope was chosen because the high altitude site offers excellent image quality, and because it has a modern IR spectrograph. Using a ground-based telescope allows us to use a higher resolution spectrograph than could easily be carried on a spacecraft.

We obtained several excellent sets of spectroscopic imaging of Mars during August and September 2003. Before we can use the data to search for the weak spectra features due to minerals, we need to remove the effect of the absorption due to the atmospheres of both Earth and Mars. We will use radiative transfer models for the planetary atmospheres to remove the atmospheric contributions and determine the surface reflectance. The results can be used to confirm or refute previous assumptions about the surface minerals according to past observations, and constraints can be placed on the extent of past aqueous activity on Mars, thus pinpointing the most likely locations to search for fossil microbes. Detailed analysis of the data is now underway.

If we are successful, the results may help to choose the landing sites for future space missions such as ESAs planned 2009 ExoMars mission; this will place a high-mobility rover on the surface of Mars to search for evidence of past or present life, and the follow-up Mars sample return mission with the aim or returning Martian samples to Earth.

References

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