Where should the ExoMars rover land?

Journal Item

How to cite:

Barrett, Alexander (2018). Where should the ExoMars rover land? Astronomy & Geophysics, 59(5) 5.12-5.16.

Version: Version of Record

Link(s) to article on publisher's website:
http://dx.doi.org/doi:10.1093/astrogeo/aty229

Where should the ExoMars rover land?

Alexander Barrett considers some of the open questions about the martian environment, and how the choice of potential landing sites for ExoMars might help to answer them.

It is a good time to be researching the martian environment. We are living in a golden age of robotic space exploration and are learning more about our neighbouring planets all the time. Over the past few decades, an increasing number of spacecraft have been sent to different regions of the solar system while Mars has remained a popular destination. We know more about the Red Planet than ever before, yet still have many questions about its geological and environmental history – and each step towards answering them raises more questions.

The driving force behind much of planetary science is the search for life. This broad theme facilitates investigations into the present environment of Mars, exploring issues of habitability. It also drives research into Mars's ancient environment. The extent to which Mars is seismically active in the modern day is also of great interest, as are processes that shape its surface and influence the composition of its atmosphere. Several active and upcoming missions will explore these questions, in particular the European Space Agency/Roscosmos ExoMars mission (figure 1) and NASA's InSight lander and 2020 rover. These missions have very different goals.

ExoMars is an exobiology mission, searching for evidence of habitability and organic material. The ExoMars Trace Gas Orbiter (TGO) began studying the minor components of the atmosphere in April this year, searching for the sources and sinks of ephemeral martian methane. The TGO's partners, the ExoMars rover and accompanying surface platform, are due to arrive at Mars in March 2021 and will drill into the subsurface, seeking signs of organic material amid deposits of ancient clays.

NASA's missions, on the other hand, will explore Mars's geological history. The InSight lander will be the first probe to focus on the deep interior of Mars and determine the extent to which the planet is seismically active; it will also measure the meteorite impact rate and the rate of heat flow from the interior. The NASA 2020 rover will collect and store samples, paving the way for a sample-return mission during the next decade.

InSight is due to land in November this year (see article on page 5.17), at about the same time as the final landing site will be selected for the ExoMars rover. Here I review some of the open questions about Mars, with a particular focus on ExoMars, examining how present and upcoming spacecraft hope to shed light on the secrets of the martian environment, and how these questions influence the choice of a landing site for ExoMars.

> "The search for life is a useful drive to assess various aspects of the martian environment"

The search for life

The question that underlies much of the exploration of Mars is that of life: has the Red Planet ever been habitable and can life, or traces of it, be found there today? Answering this question is no easy matter. The search for life beyond the Earth is potentially the biggest question in planetary science – and we may never have a definitive answer.

However, the search for life isn't just a yes or no question. While we as a civilization would love to know whether we are alone in the universe, the true value of exobiology lies in the journey as much as the destination. The search for life on Mars provides a useful drive to assess various aspects of the martian environment, from geology and hydrology to the composition of the atmosphere. By trying to determine whether Mars could be habitable, we learn a lot about how organisms survive in extreme environments and what the limits of habitability throughout the solar system might be. It also allows us to frame our technical questions about Mars in such a way that they have value to society as a whole.

Mars is one of the better candidates for finding alien life in the solar system, but it is fairly unlikely that life is active in the present day. Our search for life on Mars thus revolves around determining which periods of Mars's geological history would have been most habitable, and finding "biomarkers", the chemical signals of past life (e.g. Summons *et al.* 2011, Hays *et al.* 2017).

Past and present

Modern Mars is a cold, dry planet. The mean surface temperature is –70 °C and the atmospheric pressure is only 600 pascals, 0.6% that of Earth (Kieffer *et al.* 1992). The surface of Mars has a very hostile radiation environment that does not lend itself to either extant life or the preservation of organic material.

But Mars was not always so inhospitable. The early Noachian period of martian history from 4.1 to 3.7 Ga (billion years) ago appears to have been much warmer and wetter than the present (e.g. Squyres & Kasting 1994). Determining how Mars got from one state to the other is thus an important question in planetary science. We want to determine the extent to which ancient Mars was habitable and how that habitability degraded as the martian environment evolved.

The evidence of this warm, wet period is still visible in the landscape, which is dissected in many places by branching channels (Carr 2012). Other regions contain sedimentary deposits of the sort produced in aqueous environments on Earth; such locations are a popular target for landing sites. Some researchers have proposed that the low-lying northern plains of Mars might once have formed a large ocean (Baker *et al.* 1991, Head *et al.* 1999), although this hypothesis remains controversial. It is unclear whether large bodies of standing water could have survived for long, even on early Mars, and the evidence is hotly debated.

Modern Mars is far less hospitable, but it is not unchanging. Over the past decades we have built up a long time series of data from both satellites and ground-based rovers. This allows us to see changes in the martian landscape in real time, and see that geomorphological processes such as erosion and deposition continue to shape the landscape today. Often these changes are driven by aeolian processes: dunes slowly migrate across the surface, while the wind produces both localized dust devils and

1 Artist's impression of the three elements of the ExoMars mission (not to scale): rover (foreground), surface science platform (background) and the Trace Gas Orbiter (top). (ESA/ATG medialab)

seasonal dust storms that can engulf the entire planet, redistributing fine-grained material on a global scale.

Other signs of activity have a less obvious cause. The features called recurring slope lineae are particularly intriguing. These are dark streaks that appear on martian hill slopes on a seasonal cycle (McEwen *et al.* 2011, Ojha *et al.* 2014). They seem to develop on warm slopes and grow down-slope, before fading away. The seasonal thawing of water has been suggested as one possible cause (e.g. Chevrier & Rivera-Valentin 2012), but there is also evidence that they could result from dry granular processes (e.g. Dundas *et al.* 2017). Determining what causes these features could thus shed light on the present environment of Mars.

Upcoming missions

The next suite of Mars missions will explore some of these questions. Each will examine a different region of the martian environment, ranging from the heights of the atmosphere to the depths of the planet's interior. Spacecraft are sent to Mars whenever minimum energy launch windows occur. These are the periods, two years and two months apart, when a spacecraft can most easily travel between the two planets. The ExoMars Trace Gas Orbiter was launched during the 2016 window, while NASA's InSight spacecraft launched earlier this year.

The next launch window occurs in 2020. At this time the European Space Agency (ESA) and Russia's Roscosmos will launch the ExoMars rover and NASA will send its next rover. The year 2020 may well be a historic one for Mars exploration: China, India and the United Arab Emirates also plan to launch spacecraft. The exploration of space is very much an international venture. Many of the planned spacecraft have been designed and built as part of collaborations between multiple nations. This is particularly true of the ExoMars mission, which is a collaboration between numerous European nations and Russia. The instruments on the ExoMars rover were built by research groups across Europe, as were many of those on NASA's InSight lander.

NASA's 2020 rover will use a similar configuration to its successful Curiosity rover, but as well as conducting *in situ* examinations of the martian surface it will also store samples that can later be sent back to Earth: "sample return". The variety of analyses that can be conducted *in situ* on Mars is by necessity limited. The analytical instruments placed on landers must be painstakingly miniaturized and built to withstand both the stresses of the martian environment and the journey to get there. The long development cycle for a space mission also means that by the time they reach Mars they are often no longer the state of the art. Samples returned to Earth, however, could be analysed in the best laboratories in the world, using the most up-to-date technologies. Material collected during the Apollo missions to the Moon is still being studied decades later. Material returned from Mars could have a similar longevity.

While these missions are being prepared, we continue to receive data from the six orbiters and two rovers currently operational on Mars. The landers explore small areas of the surface; these *in situ* observations provide "ground truth" for the remote-sensing data. The most recent addition to this fleet is the first stage of ExoMars, the Trace Gas Orbiter, which is now sending back data about the composition of the martian atmosphere. It will also serve as a relay for the ExoMars rover when it lands on Mars in 2021.

Trace gases in the atmosphere

The main objective of the ExoMars – Exobiology on Mars – mission is to look for evidence of life. This is being done in two main ways. The TGO is examining the distribution of trace gases, those that make up less than 1% of the martian atmosphere by volume. It measures the current chemical composition of the atmosphere, mapping the global distribution of these gases in order to determine their sources and sinks. In 2021, it will be joined by the rover, which will look for geochemical traces of past life. In this way ExoMars will study both the modern and ancient environments.

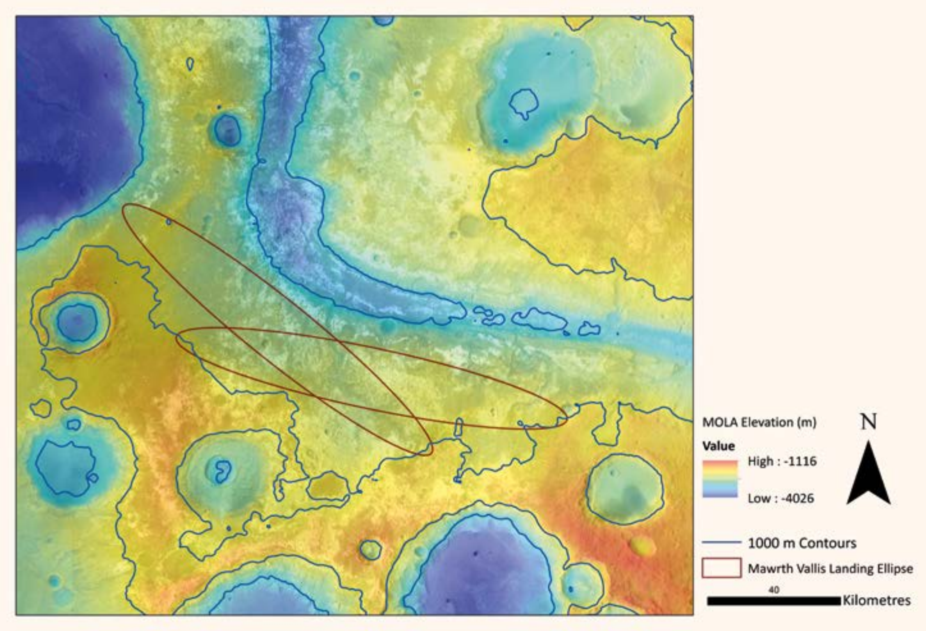
Although trace gases are only present in small concentrations, they provide useful clues as to what chemical or biological processes might be active on Mars today. One of the most significant trace gases to the search for life is methane. This has been detected in the atmosphere of Mars using various methods (Krasnopolsky *et al.* 2004, Formisano *et al.* 2005, Mumma *et al.* 2009), including the analysis of orbiter data, initially from ESA's Mars Express and later NASA's MAVEN spacecraft, measurements by the Curiosity rover, and telescopic observations from Earth.

Detections of methane have proved to be controversial. It appears to have a concentration of 0.2–60 ppbv (Etiope 2018). However, it is not well mixed and appears to have a surprisingly short lifetime in the martian atmosphere (Lefèvre & Forget 2009). It is possible that it remains in the atmosphere for as little as 200 days. Intriguingly, this suggests that there is a continuous process that releases methane into the atmosphere, and this process could still be active today. To explain this short lifetime there must also be a strong sink that removes methane from the atmosphere far more rapidly than would normally be expected.

This has led to substantial debate around the detections of methane. Some researchers (Zahnle *et al.* 2011) suggest that the photochemical processes by which methane is known to be produced and destroyed should not be able to account for so short a cycle. Zahnle *et al.* state that "extraordinary claims require extraordinary evidence" and that such sound data have not yet been provided to demonstrate that the methane on Mars really is varying on so short a cycle.

Various sources have been proposed to account for martian methane. On Earth it is primarily generated by methanogenic microbes. Finding these on Mars would, of course, be very exciting, but other possibilities are also intriguing. Methane can be produced by magma degassing in volcanic areas. Volcanism has not taken place on Mars for at least 10 million years (Krasnopolsky *et al.* 2004), which would seem to make this source unlikely. Finding an active hydrothermal system would be a very interesting result, but the presence of hydrothermal activity on Mars is not supported by thermal emission data. If residual hydrothermal activity persists then it is likely to be very cold compared to such systems on Earth, so would not be expected to generate as much methane (Krasnopolsky *et al.* 2004). Both of these possibilities are unlikely, but would have important implications for our understanding of Mars if they are taking place.

More likely scenarios are also being considered. Methane could be produced by ultraviolet irradiation of the martian surface, or could have been brought to Mars by meteor showers. However, whether these processes can produce methane in sufficient quantities to explain the apparent methane budget is still an open question. It is also possible that methane is being released from buried clathrates, sealed below impermeable layers of permafrost or shale (Oehler & Etiope 2017).



2 The landing site at Mawrth Vallis. The landing ellipse is shown in red, with 1000 and 2000 m contours in blue. It can be seen that the landing site sits on the high ground above the channel itself. Most of the landing ellipse is below the 2000 m elevation ceiling; however, the 2000 m contour intersects it in a few places on the extreme edges. It is unlikely that the lander will touch down in one of these locations, but this must be taken into consideration when the final site is chosen. (MOLA elevation data [Smith *et al.* 2001] over HRSC base map [Neukum *et al.* 2004]; after ExoMars Landing Site Selection Working Group 2018)

Even if it is not being produced by biological activity, or not at the present day, the presence of methane could make an environment more likely to be habitable. It can serve as an electron donor, providing energy to microbial communities. Thus a methane-rich environment could have allowed life to get started on early Mars (Schulte *et al.* 2006, Oehler & Etiope 2017, Etiope 2018).

By mapping the spatial and temporal distribution of methane on Mars with far greater precision than was previously possible, the TGO will be able to determine whether there is a pattern to methane releases. This could indicate which sources and sinks are viable, and which can be ruled out. It is hoped that these data will either provide the extraordinary evidence needed to prove a short methane cycle, or demonstrate a pattern more in keeping with the established photochemistry.

"The rover will be able to drill to a depth of 2 m, deeper than any other lander"

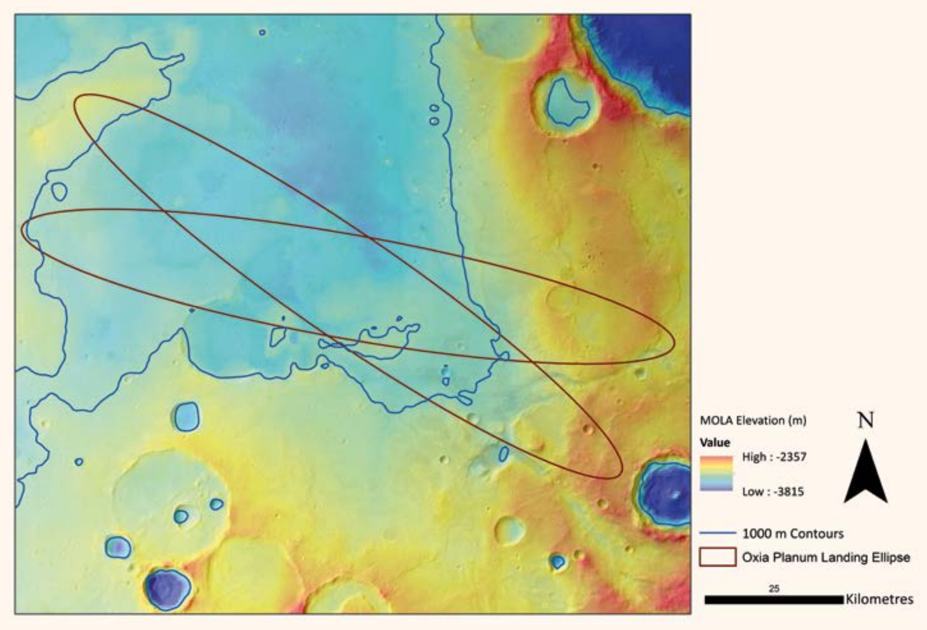
Exploring the near-subsurface

The ExoMars lander has two components: a stationary surface platform will study the martian climate for up to one terrestrial year, while a rover will drive up to 4 km from the landing site. The rover's mission is to search for organic chemicals in the near-subsurface, as well as biomarkers that could indicate the presence of past life. Key organic chemicals are an important precursor to life and so their presence on Mars would indicate that the environment could potentially be habitable.

The rover will be able to drill to a depth of 2 m, deeper than any other lander. It will also be the first probe that can both move across the surface and explore the subsurface. Excavations by the Phoenix lander in 2008 were limited in scope because it was a stationary platform, whereas ExoMars will be able to seek out the most interesting sites to drill. It carries a ground-penetrating radar system, which will be able to determine the distribution of water ice in the subsurface, as well as selecting the best locations for drilling. The drill will extract core samples, which can be fed into the rover's suite of instruments. An infrared spectrometer is mounted on the drill itself to examine the walls of the borehole.

The ability to drill into the subsurface is an important capability. The radiation and oxidation environment on the surface of Mars is hostile to both life and the geochemical traces it leaves behind (Biemann *et al.* 1977). The thin atmosphere and lack of a magnetic field mean that a lot of radiation reaches the surface, and organic matter there will quickly be broken down. The near-surface environment can also oxidize organic compounds, preventing their long-term survival. The ground provides some shielding from the radiation, so biochemical markers are more likely to be preserved at depth, where it is hoped that the oxidation environment will be less hostile.

Organic chemicals can only be preserved



3 The landing site at Oxia Planum. The landing ellipse is shown in red, 1000 m contours in blue. The entirety of this site lies below 2000 m. (MOLA elevation data [Smith *et al.* 2001] over HRSC base map [Neukum *et al.* 2004]; after ExoMars Landing Site Selection Working Group 2018)

in the subsurface if they are there to begin with. For the rover to have the best chance of finding such markers it must be sent to a site that either shows evidence of having been a habitable environment in the past, or where material generated in habitable environments would have since accumulated. The ideal site would have ancient rocks and evidence that water was present for extended periods of time. The landing sites being considered for ExoMars (ExoMars Landing Site Selection Working Group 2018) were chosen in large part because of the presence of phyllosilicate minerals. These are hydrated clays that can be formed by the aqueous alteration of basaltic rocks (Loizeau *et al.* 2007).

> **"This is the sort of environment where ancient microbes may have been present"**

Hydrated minerals (phyllosilicates and sulphates) have been detected in outcrops in various places on Mars (Poulet *et al.* 2005), in particular in the Arabia Terra region, which has been the focus of the landing site selection process. They often consist of layered exposures, found on outcrops dating from the warm, wet Noachian epoch. These deposits could have formed by several mechanisms. Altered minerals could have been deposited in a water-rich environment, or volcanic ash deposits might have been altered by protracted contact with liquid water (Loizeau *et al.* 2007). Both scenarios suggest a protracted wet period at these sites. The abundance of phyllosilicates at a site can indicate the length of time for which the area had a wet environment (Viviano & Moersch 2013).

Noachian phyllosilicates on Mars are often overlain by evaporitic salt deposits. This indicates a shift in climate from a warm, wet environment to a more arid one. This has implications for the habitability of not just these sites, but the planet as a whole during the transition between the Noachian and Hesperian epochs, at around 3.7 Ga (Molina *et al.* 2017).

Selecting a landing site

Two landing sites remain out of the four that were shortlisted in 2014: Mawrth Vallis and Oxia Planum. Both sites lie on the margin of Chryse Planitia, where the cratered highlands of the Arabia Terra meet the low-lying Northern Plains. Various ancient fluvial channels cross this region. Both sites have exposures of ancient clays. The presence of clays suggests a temperate, wet formation environment with a neutral pH. On Earth these materials are often formed in shallow marine environments. While water would likely have been more ephemeral on Mars, this is nonetheless the sort of environment where ancient microbes could have been present and where organic material would be expected to be preserved.

The rocks at both of these sites are more than 3.8 billion years old, placing their origin firmly in the Noachian epoch. However, they have been exposed more recently in geological terms. This means that they have not yet been degraded by the harsh environment at Mars's surface, where radiation and oxidation have a deleterious effect. The geology at these sites is sufficiently diverse that sites of scientific interest will be found within the range of the rover's expected mission, regardless of where within the area it lands. Both sites have pros and cons and both would provide interesting ways to address the mission's science questions.

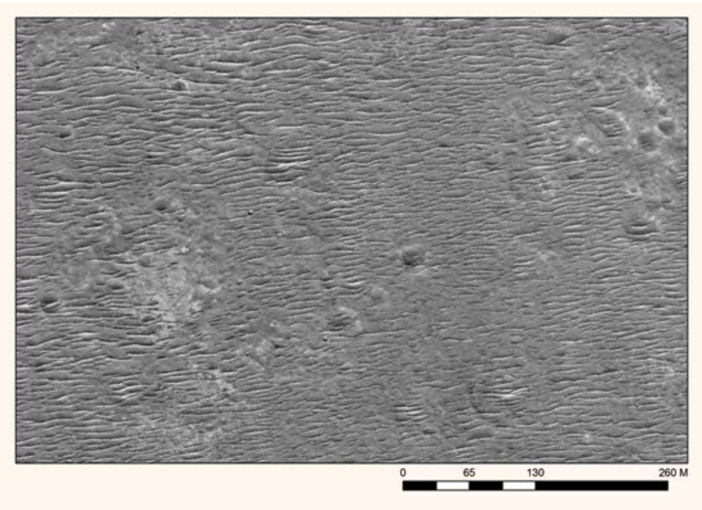
Mawrth Vallis has long been famous for its clay minerals. It contains one of the largest and most diverse exposures of phyllosilicates on the planet (Bishop & Rampe 2016) and is the site where phyllosilicates were first identified on Mars (Loizeau *et al.* 2007). Mawrth Vallis is one of the oldest martian outflow channels and has very well preserved outcrops. However, the actual landing site is going to be some distance from the channel itself, in an area that has not been as extensively studied (figure 2). The entire area has good clay coverage, and we can reliably predict that a diverse set of exposures will be available to study at this site. This makes it a popular choice.

However, the relationship between the clay exposures and the geomorphology of the site is not well constrained, particularly in the relatively unstudied area where the rover will land. A more detailed analysis is needed to determine where this material came from and what its presence at Mawrth could tell us about the past environment there. The prevailing view is that the clays represent a weathering sequence, similar to those found in basaltic soils on Earth.

Oxia Planum is less well explored, having not been studied before it was proposed as a landing site. It exhibits an abundance of iron–magnesium clays, but lacks the level of diversity found at Mawrth Vallis. It has the advantage that the geomorphology at the site is much clearer. Oxia Planum consists of a shallow basin on the edge of the low-lying Chryse Planitia (figure 3).

A sedimentary fan is present at the site and appears to form the end of a valley network. This makes the site very interesting as it means that material transported from along the full length of the channel system could potentially have been deposited at this site, providing a mechanism to concentrate biomarkers from across the area at one accessible location. This makes the Oxia Planum site a strong science target. However, the clay deposits seem to have formed in the basin first, before being overlain by the channel. They are thus not necessarily the product of the ancient fluvial system that formed the channel, unless they cover an earlier channel system that is now obscured.

The location of Oxia Planum also has implications for the controversial question of whether a northern ocean ever existed. The geomorphology at the site resembles that of an estuarine environment on Earth. If the basin opened onto a northern ocean then the sedimentary fan could be the remains of a delta, formed in a standing body of water. This means that these deposits could have formed in a shallow marine environment, which would be good for



4 This area of the Mawrth Vallis landing site is covered with closely spaced aeolian ripples. These features probably consist of loose, windblown sand; while the rover may be able to drive over small ripples, it will have to navigate around larger ones. This means that the rover could be surrounded by a maze of hard-to-traverse features. (HiRISE/NASA/JPL/Univ. Arizona)

finding evidence of life. However, looking for evidence of a northern ocean is beyond the scope of the ExoMars mission and the question is too controversial to carry a lot of weight during the landing site selection process. Nonetheless, exploration of this site might be able to provide evidence for or against it being an estuarine environment, even if it cannot prove it or rule it out.

The choice of landing site is dictated by engineering constraints as well as scientific ones (ExoMars Landing Site Selection Working Group 2018). The landing site for the ExoMars mission must be near the equator of Mars, which led to the focus on Arabia Terra. It must also be a sufficiently low-lying region that the lander can slow down with a parachute before it lands. ExoMars is designed to be able to land anywhere where the elevation is less than 2000 m. The Mawrth site is mostly below this elevation ceiling, but not by very much. This makes Oxia Planum a safer bet, since it is around a kilometre lower, providing a much larger margin for error.

It is impossible to predict where a spacecraft will land with complete accuracy, because its trajectory depends on both its precise entry angle and the amount of drag it experiences as it passes through the atmosphere. Thus a landing ellipse is plotted, covering the areas where the spacecraft could potentially land – and this entire area has to be suitable. Areas of scientific interest must also be close enough together that they will be accessible by the rover, regardless of where within the ellipse it lands.

Both these sites present different challenges for landing and traversability. Mawrth Vallis has much more topography than Oxia Planum, which is primarily a low-lying plain. This means that it will be easier for the rover to study layered exposures at Mawrth, although there are more high relief areas that could pose a hazard to landing. Slopes are not ideal for landing, and boulders larger than 35 cm across need to be avoided, because this is the clearance of the landing module.

> **“We are poised to get our first good look at the deep interior of Mars”**

Once the rover has landed and deployed, it will have to get to its science targets. Its progress could be restricted by steep slopes, boulder fields and areas covered with deep sand. Aeolian ripples are found across both sites. Oxia Planum has lots of small sand features, concentrated at one end of the landing site. If the rover lands there then it could be surrounded by kilometres of ripples, which it will then have to traverse or navigate between. Mawrth Vallis has a similar proportion of these features, but they are more evenly distributed (figure 4).

A point in favour of both sites is that they are not heavily covered with dust, which can form a thin layer over geological exposures. Even a few microns of dust can interfere with the infrared signature of the surface, obscuring its chemical composition. At the time of writing, a global dust storm is in progress on Mars. This could dramatically redistribute dust from one part of the planet to another; it will be important to see how the potential landing sites change if the storm subsides before the final decision is made.

Both sites thus have the potential to address the mission’s science questions, albeit in different ways. Mawrth Vallis is potentially the more risky of the two, but its very diverse geochemistry makes it a strong science target. Oxia Planum will hopefully be safer to land at, but the site has not been as intensively studied. It will be interesting to see which site is selected as the final destination for ExoMars.

Summary

The bulk composition of the martian atmosphere is fairly well constrained, but we are still trying to understand its minor components. Methane is of particular interest, because of its potential links to life. However, its unusually short lifetime in the martian atmosphere remains a topic of debate. The ExoMars Trace Gas Orbiter will be able to map the martian methane cycle in unprecedented detail, and should shed light on the processes by which it is released and removed.

On the ground we are about to get the capability to drill deeper into the martian subsurface than ever before. The ExoMars rover will be able to seek out areas rich in phyllosilicate clays and collect samples from depth. This will allow us to study the chemistry of the subsurface and look for evidence of past life or its precursors.

Our ability to study these samples on Mars is ever increasing, but we are also keen to develop the capability to bring them back to Earth. NASA’s next Mars rover will do just that, storing samples so that they can later be collected by a second mission.

Finally, we are poised to get our first good look at the deep interior of Mars, when the InSight lander begins its operations on the surface in late 2018. This will tell us a lot about how active Mars is and has implications for interpreting what we see at the surface.

Whether these missions resolve any of our questions about Mars remains to be seen, but it is almost certain that they will invite us to ask a host of new questions that we had never even considered before. ●

AUTHOR

Alexander Barrett is a planetary environmental scientist, specializing in cold climate geomorphology, currently associated with the School of Physical Sciences, Open University, UK.

ACKNOWLEDGMENTS

Many thanks to Peter Fawdon for maps of the ExoMars landing sites and information on their pros and cons, and Matt Balme for his support.

REFERENCES

Baker V R *et al.* 1991 *Nature* **532** 589
Biemann K *et al.* 1977 *J. Geophys. Res.* **82** 4641
Bishop J L & Rampe E B 2016 *Earth Planet. Sci. Lett.* **448** 42
Carr M H 2012 *Phil. Trans. Roy. Soc. A* **370** 213
Chevrier V F & Rivera-Valentin E G 2012 *Geophys. Res. Lett.* **39** L21202
Dundas C M *et al.* 2017 *Nat. Geosci.* **10** 903
Etiope G 2018 *Planet Space Sci.* **159** 93
ExoMars Landing Site Selection Working Group 2018 Supporting Materials for the 4th ExoMars LSS Workshop https://www.cosmos.esa.int/web/4th-exomars-lss-workshop/supporting-materials accessed 31 July 2018
Formisano V *et al.* 2005 *Science* **306** 1758
Hays L E *et al.* 2017 *Astrobiology* **17** 363
Head J W *et al.* 1999 *Science* **286** 2134
Kieffer H H *et al.* 1992 *Mars* (University of Arizona Press, Tucson)
Krasnopolsky V A *et al.* 2004 *Icarus* **172** 537
Lefèvre F & Forget F 2009 *Nature* **460** 720
Loizeau D *et al.* 2007 *J. Geophys. Res E Planets* **112** 1
McEwen A S *et al.* 2011 *Science* **333** 740
Molina A *et al.* 2017 *Icarus* **293** 27
Mumma M J *et al.* 2009 *Science* **323** 1041
Neukum G *et al.* 2004 *Mars Express: the Scientific Payload* ESA SP-1240 17
Oehler D Z & Etiope G 2017 *Astrobiology* **17** 1657
Ojha L *et al.* 2014 *Icarus* **231** 365
Poulet F *et al.* 2005 *Nature* **438** 623
Schulte M *et al.* 2006 *Astrobiology* **6** 364
Smith D E *et al.* 2001 *J. Geophys. Res. Planets* **106** 23689
Squyres S W & Kasting J F 1994 *Science* **265** 744
Summons R E *et al.* 2011 *Astrobiology* **11** 157
Viviano C E & Moersch J E 2013 *Icarus* **226** 497
Zahnle K *et al.* 2011 *Icarus* **212** 493