THE READ planet

Geologists can read the surface of Mars like a history book. The canyons and crevices tell stories of ancient floods and windswept plains. **Elliot Sefton-Nash** asks, where did it all go wrong?

Compared to Earth, Mars is surely a desolate place. A thin carbon dioxide atmosphere gently sweeps the cold, dry and ochre surface. Seasonally-changing winds blow veils of fine dust around the planet. Snaking dunes grow, migrate and shrink. Ancient bedrock is exhumed and miniature tornadoes called 'dust devils' patrol the plains. Bleak though it seems, it is an interesting planet that was once very similar to Earth.

My work concerns one of the most discussed topics regarding Mars – water. Tracing the history of water on Mars is a goal shared by planetary scientists, biologists, chemists and astronomers the world over. This goal is driven by the association between water and the emergence of life.

The differences between Mars and Earth four billion years ago, apart from size and distance from the sun, were far less than the differences today. For example, Mars's atmosphere is currently less than one per cent as dense as the Earth's and is made almost entirely of carbon dioxide. The thin air and lack of an ozone layer mean that the surface is effectively sterilised by ultraviolet sunlight.

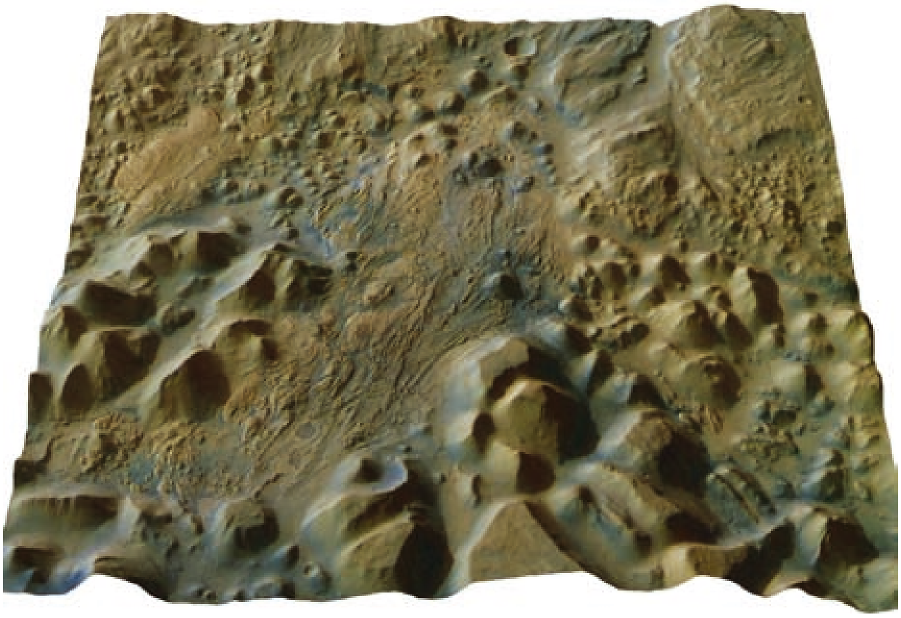
We now know that much of the water once in Mars's atmosphere was broken down by this ultraviolet light into hydrogen, which mostly escaped to space, and oxygen, which is heavier and so descended to react with the surface. It is the oxidised iron in surface minerals that gives Mars its red colour.

A thicker atmosphere would have made conditions on the surface more agreeable for liquid water, it would have kept the surface warmer by insulating it and provided a higher atmospheric pressure for water to remain stable.

Today, only near the equator or on sun-facing slopes in mid-latitudes do daytime temperatures rise above the melting point of water, but even then the low atmospheric pressure means that

Image taken by the Mars Express satellite of the Valles Marineris (Mariner Valley). The canyons are hundreds of kilometres long and several kilometres deep. Erosion features in the landscape suggest that water once flowed here, shaping these canyons after their formation.

ESA/DLR/FU Berlin-G.Neukum



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Looking down over a region of chaotic Martian terrain called Iani Chaos. Jumbled mounds, blocky mesas with kilometre-scale cliffs and fluid-carved ancient deposits dominate this landscape. The subsurface of this ancient terrain is thought to be the source of much of the water that carved the vast outflow channels. (Composite image projected onto high-resolution topography.)

East of Valles Marineris lies a network of vast water-carved channels.

any water at the surface evaporates away quickly. Water may not be stable on the surface of Mars today, but there is evidence of its past influence almost everywhere on the planet.

Valles Marineris is the largest canyon in the solar system, spanning an area more than three times that of the entire United Kingdom. It runs for roughly 4000 kilometres along Mars's equator and is thought to have been formed by rifting, the process that is forming the Afar rift in Ethiopia, currently an intense area of research for NERC-funded scientists. At the widest point, if you stood at the base of the cliffs on one side you would not see the seven-kilometre high cliffs on the other, despite their towering height. It's so wide they disappear over the horizon.

To the east of Valles Marineris lies a network of vast water-carved channels, jumbled blocky debris and steep-sided, flat-topped mesas. This is called 'chaotic' terrain and is thought to be the result of 'catastrophic outflow' – when water gushed to the surface in epic quantities, destabilising huge areas of ground and carving enormous channels.

This is the kind of terrain I am interested in. The landscape is littered with mineralogical clues as to where water once flowed. Studying chaotic terrain and its associated features represents the best chance we have of unravelling the geologic history created by a wetter Mars.

Apocalyptic floods

The massive outflows of water are thought to have been caused by a nearby magma chamber warming subsurface ice reservoirs. After the almost apocalyptic flood waters had calmed, pools may have gathered in local surface basins. If the water was salty it could have lowered its freezing point, allowing water to remain liquid on the surface at much colder temperatures.

Results from NASA's Opportunity Rover confirmed this in 2004. It discovered layered beds of salt-rich rocks, probably meaning they were covered in water at some time. These rocks were riddled with blueberry-like concretions composed of the iron oxide, haematite, which can only grow in the presence of water.

A recent theory is that the water for the outflow floods was stored at least partially in hydrated sulfate minerals in subsurface ice reservoirs or permafrost. The theory is based on the discovery of rocks on Mars that may have held a mineral called meridianiite – with a double 'i'. Crystal-shaped cavities that could have held meridianiite were discovered in rocks at Meridiani Planum, a part of the planet where water may have been liquid at the surface for long periods of time. Meridianiite is not commonly found on Earth, mainly because it is unstable. Above 2°C it melts into a slurry losing 70 per cent of its volume as water. The remaining 30 per cent forms a mineral called epsomite. If you find epsomite you've got a good indication that rapid melting has occurred some time in the past.

Looking at Mars in visible light gives few clues as to what the surface is made of, but imaging spectrometers (that take hundreds of pictures of the same area over a range of wavelengths) allow us to look at the surface over a different range of light: the infrared. This is a part of the spectrum where the light reflected from surface minerals has embedded in it a characteristic signature of what the mineral is made of. It's this kind of data that is being collected by spacecraft such as NASA's Mars Reconnaissance Orbiter or the European Space Agency's (ESA) Mars Express. The instruments on these craft let us map the abundance and extent of water-formed minerals on the surface.

Another useful thing about seeing in infrared is that you can tell how hot something is, since everything above absolute zero (-273°C) emits infrared light at a brightness dictated by its temperature. A material's resistance to the changing temperature of its surroundings is known as its thermal inertia. Using infrared images and a computer model I look at the difference between what the temperature of the surface is and what it should be according to the model, then estimate its thermal inertia. The new layer of information helps me work out if I'm looking at a deep sand dune or just a thin layer of sand covering more dense rocks.

This kind of remote sensing of Mars allows scientists to deduce which minerals formed first. By looking at the thickness of layering and the development of channels we can also take a good guess at how much water there was and for how long it was there.

We're putting together the pieces of this geological jigsaw to build a picture of what happened on Mars to make it the way it is today. But what are the implications for life? It's likely that for several billion years the surface of Mars has been inhospitable, but the optimist in me says we should be looking in the near-surface with our robotic rock-hammers for microfossils. ❖

MORE INFORMATION

Elliot Sefton-Nash is a NERC-funded PhD student (Planetary Geology) based at the Department of Earth Sciences, University of Bristol,
tel: +44 (0)117 331 5196,
email: e.sefton-nash@bristol.ac.uk or
e.sefton-nash@uclmail.net
www.elliotsefton-nash.co.nr