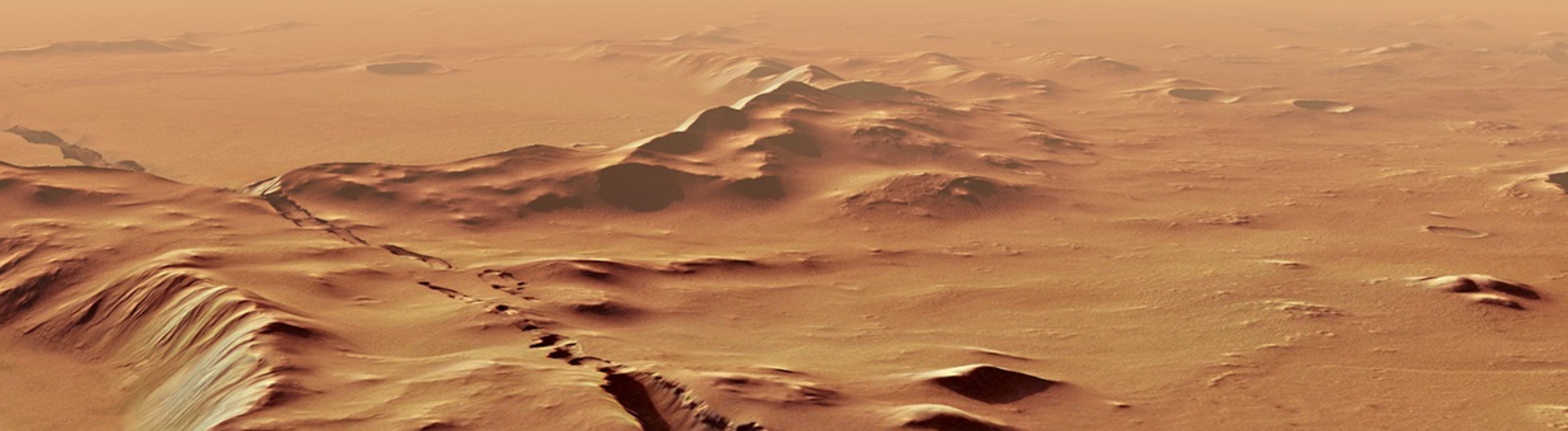
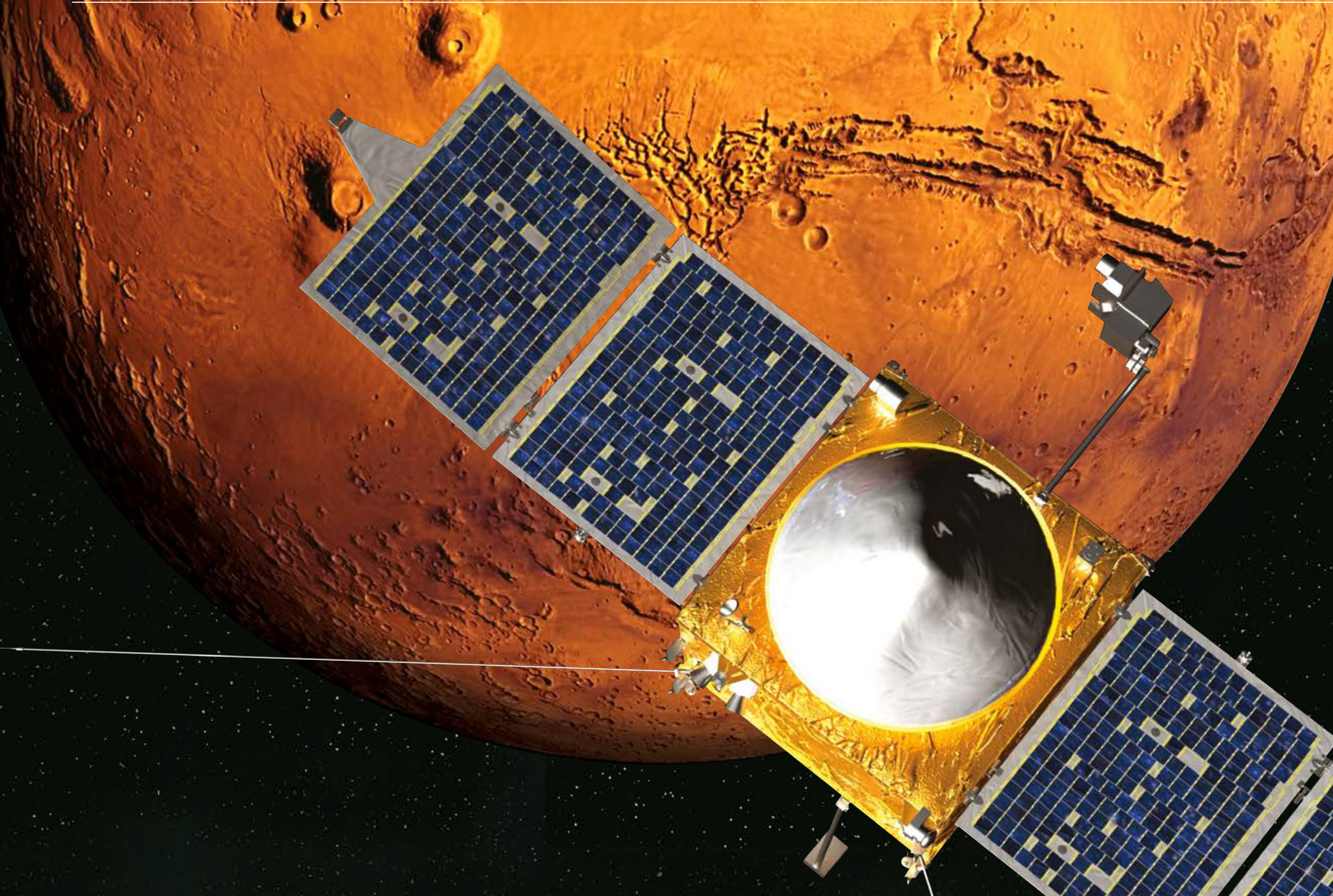
All About Space

# HOW DID MARS LOSE ITS SKY?

By Ben Biggs





# How did Mars lose its Sky?

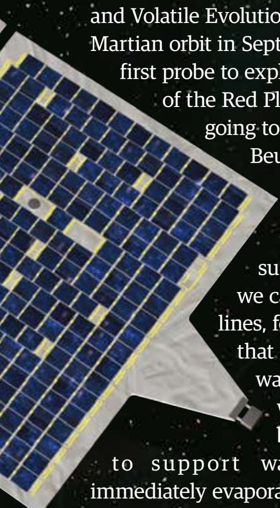
Billions of years ago, Mars had a thick atmosphere. So what happened to it? The MAVEN mission's top brass explains how they found out where it went and why

Written by Ben Biggs

Today, Mars is a very cold, very dry planet with an atmosphere 100 times thinner than Earth, composed mostly of carbon dioxide. It has some weather, with clouds and winds that speed across the surface, picking up tiny dust particles that quickly bloom into enormous dust storms. It even snows sometimes, as small crystals of frozen carbon dioxide precipitate out of the sky. But it's a barren planet devoid of any environment that could support life, and it's been like this for billions of years. However, this hasn't always been the case.

There are a number of theories that support the case for Mars once having a suitable environment for life to form, regardless of whether it did or not. Not least of all, there's the panspermia theory that Earth was seeded with the components of life by a meteorite of Martian origin. NASA's Mars Science Laboratory mission has also discovered tangible evidence for an ancient Martian environment, with liquid water flowing on its surface and a thick atmosphere. From the surface of the Red Planet, its Curiosity rover has measured the composition of Martian air as well as pieces of Martian rock that have elements of Mars' ancient atmosphere bound up in them, giving scientists a snapshot of what Mars was like several billion years ago.

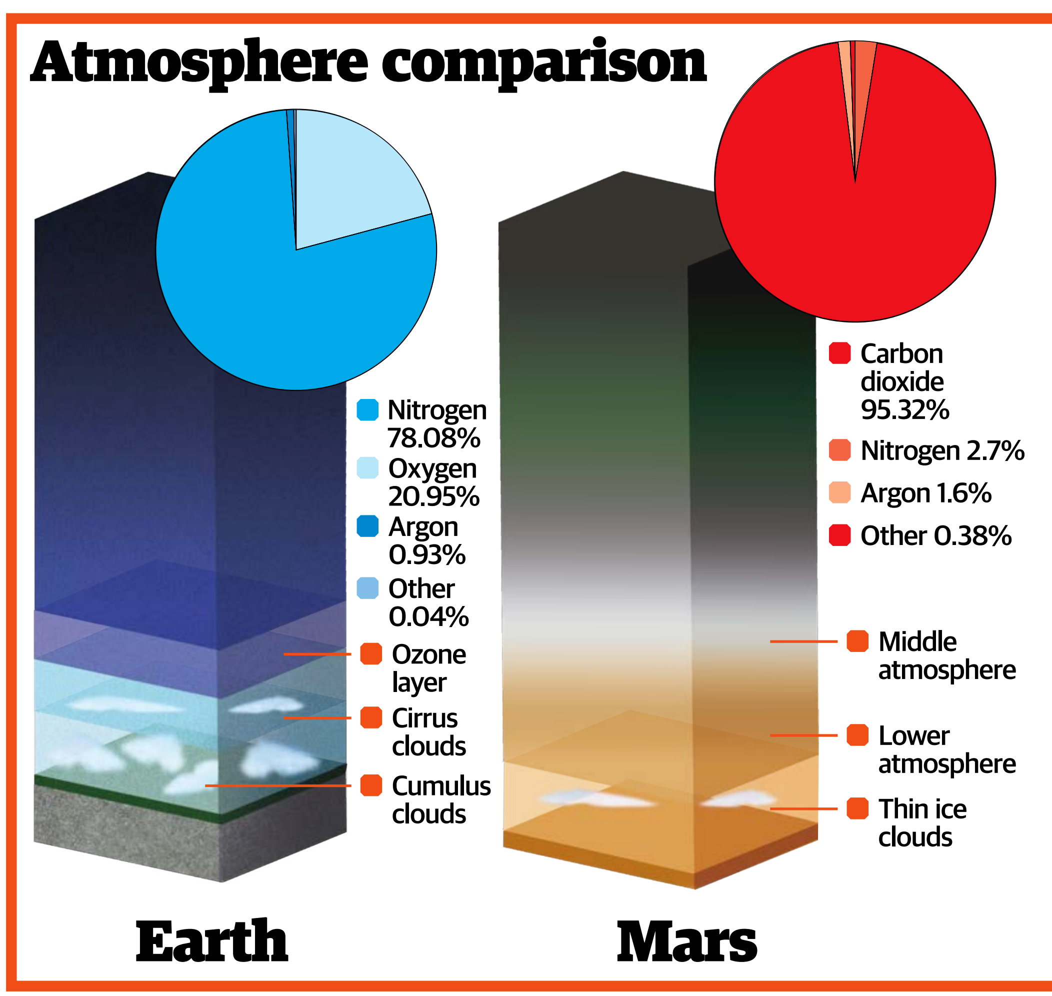
That's only half of the story, though. To get a bigger picture of what Mars was really like, NASA recently launched the MAVEN (Mars Atmosphere and Volatile EvolutioN) spacecraft to Mars, to enter Martian orbit in September 2014 and become the first probe to explore the upper atmosphere of the Red Planet. "The reason MAVEN is going to Mars," project manager Guy Beutelschies tells us, "is that the other missions before it have found that there used to be liquid water on the surface: oceans, rivers, lakes... we can see the outlines of shore lines, found rocks on the surface that only form in the presence of water. So we know there was water on the ground once, but the atmosphere's too thin to support water on the surface – it would immediately evaporate," he continues.



"The observations that drive our thinking," MAVEN's principal investigator Bruce Jakosky clarifies, "are the presence of geological features that suggest the presence of liquid water on early Mars. Because Mars is farther from the Sun than Earth is and because we think that the Sun was dimmer early in history than it is today, there must have been a thicker atmosphere early in history to make temperatures warmer. Temperatures may have been more 'Earth-like' but the atmosphere probably was made up mostly of carbon dioxide – CO2. There may have been clouds, it may have rained or snowed and the sky may even have been blue like ours, but the atmosphere would not have been breathable by humans.

"The geological features that indicate that liquid water was present occur on the ancient surfaces, and then stop relatively suddenly. We think that the change from a warmer, wetter environment to the colder, drier one that we see today must

The core structure of the MAVEN spacecraft under inspection by technicians at Lockheed Martin in 2011




The MAVEN cone, complete with protective shield, that topped its Atlas V launch vehicle

essentially complete by around 3.5 billion years ago," he adds.

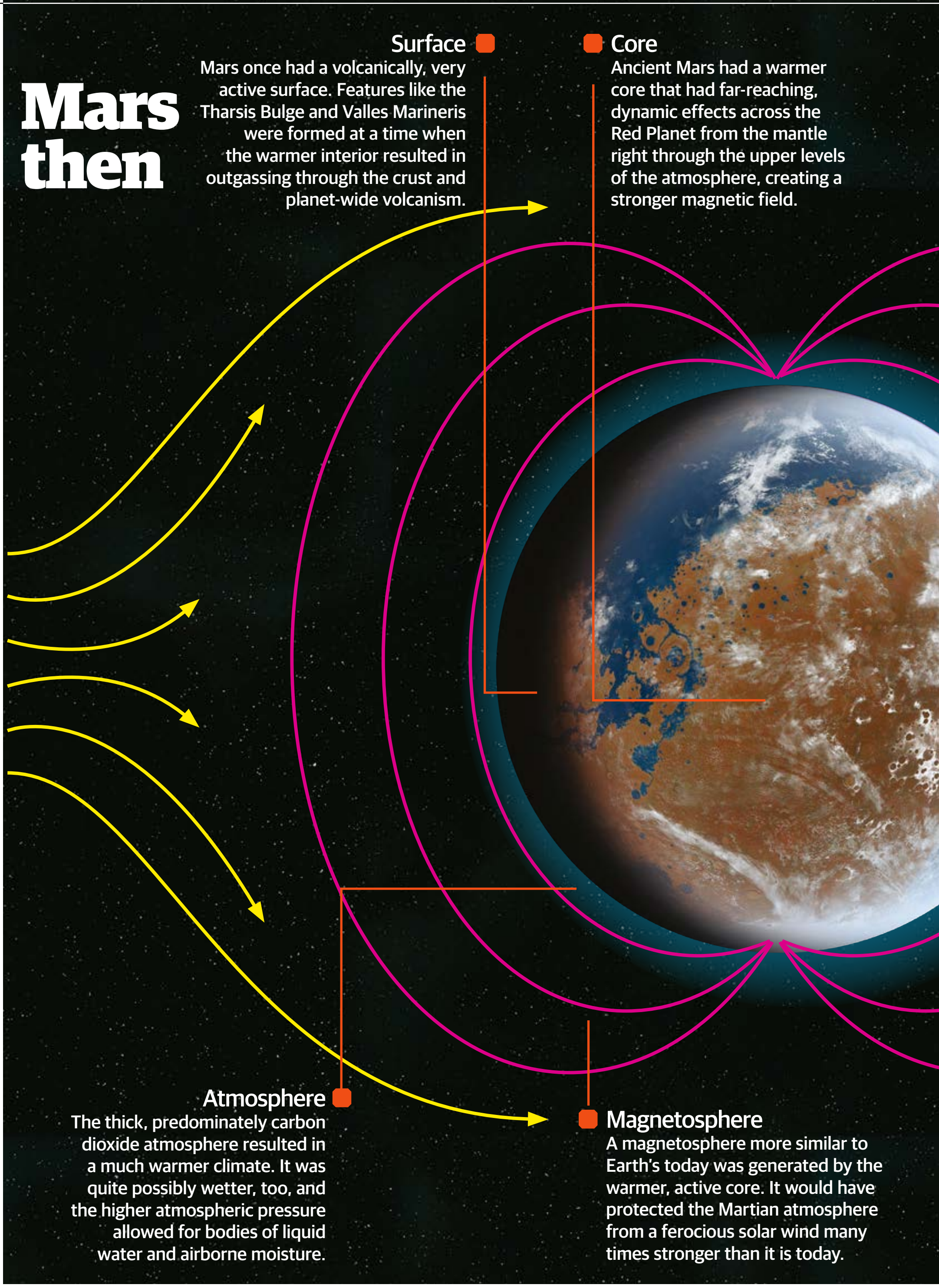
There's another mystery, the answer to which is perhaps even more interesting than the truth behind what Mars was really like aeons ago: what happened to its atmosphere? Was it swept off the planet in a cataclysmic event, or did it gradually seep away into space – and how did this happen?

Data from the Curiosity rover suggests that Mars hasn't changed very much in the last few billion years. However, for a relatively short time after its formation 4.5 billion years ago, Mars was host to rivers and liquid bodies of water that were neutral in pH and not too salty for the planet to become home for microbial life. Then, some time around 3.5 billion years ago, about the same time that simple-celled organisms were proliferating on Earth, Mars' atmosphere disappeared and subsequently, its liquid water evaporated or froze as the air pressure and mean temperature plummeted. Any life that might have existed at the time would have perished. "From a science point of view it's one of the biggest questions," Beutelschies explains. "We know there was water there but we don't know how long it was there for... so for people trying to figure out what the history of Mars was, especially if life was there, it's a pretty big and unanswered question right now. MAVEN being able to answer that question is going to help guide scientific investigation in the future."

At around the same time, the Solar System was still forming during a period known as the Late Heavy Bombardment. It was a dangerous time for all the young planets, as there were an enormous number of bolides flying around and impactors were far more frequent than they are today. According to some theories it's possible that one, or several of the great impacts evident on Mars could have created a shockwave that blasted the atmosphere off the planet and irrevocably changed the Red Planet's environment.

Some scientists believe that Mars' atmosphere never left the planet, and that most of the carbon dioxide that was once in the atmosphere became bound up in the rock of the planet. It was gradually trapped by a chemical reaction with the minerals common in Martian rock, resulting in liquid water being present on the surface as recent as 700 million years ago. That's not what MAVEN scientists believe, however. "Why do we think that the upper

## Mars then

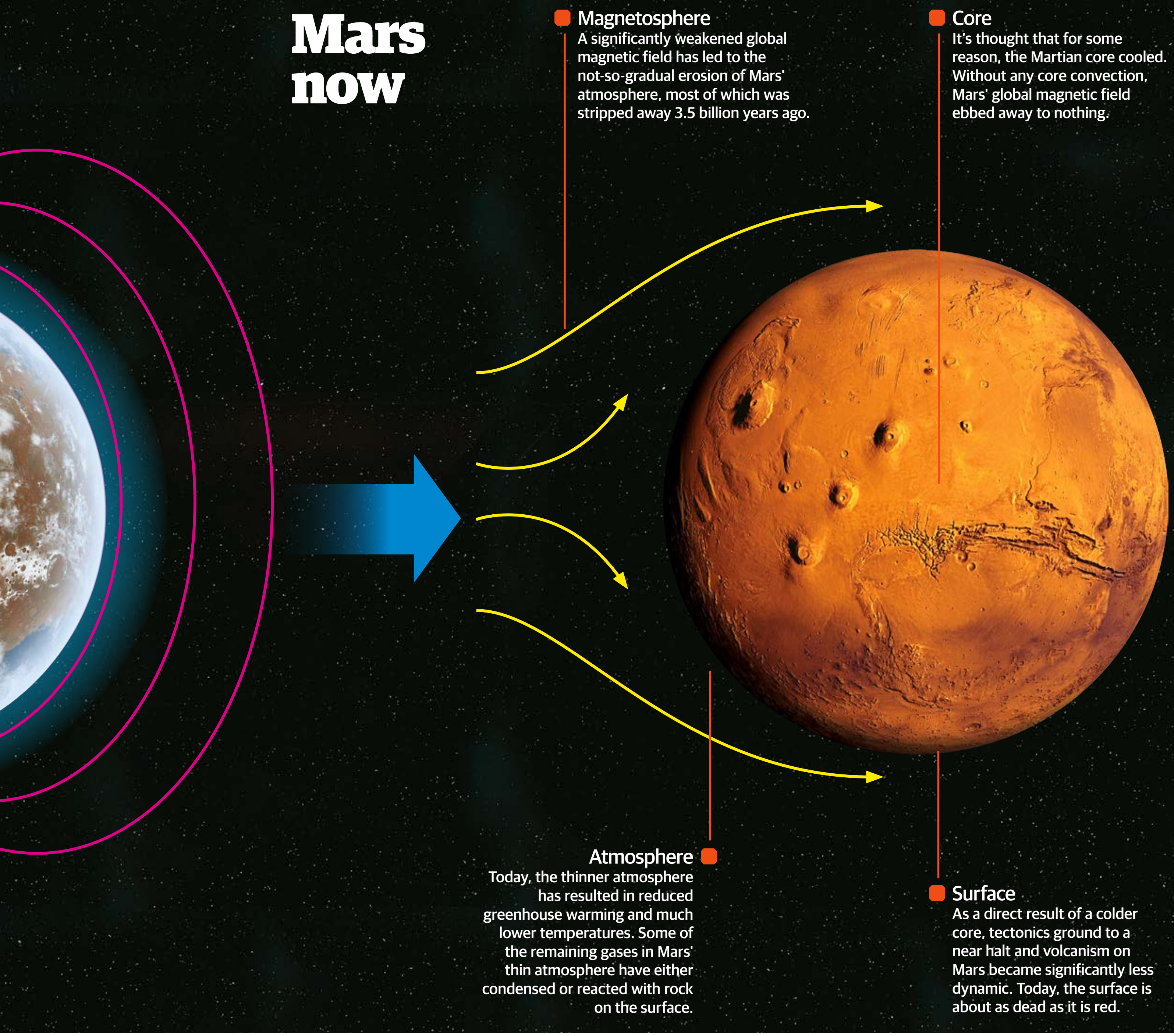



atmosphere was important for understanding this climate change?" poses Jakosky. "Two reasons: first, we see little or no evidence for a subsurface storage of the CO2 from an early thick atmosphere; there are no deposits of carbon-bearing minerals, for example, which are large enough to hold that much CO2. Second, there are measurements of isotopes in the Martian atmosphere that show enrichment of the heavier ones, a strong indication that escape to space has been an important process. If escape was important, then it occurred from the top of the atmosphere and would have involved interactions with the solar wind and other solar energetic drivers. With MAVEN, we're planning to study the top of the atmosphere and its interactions with the Sun in order to understand how escape occurs."

The theory that gained the most traction, one that the MAVEN scientists eventually proved, is that the atmosphere was very suddenly blown away by a strong wave of solar wind. The Curiosity rover has already shown that multiple isotopes of various elements, including carbon, nitrogen, oxygen and

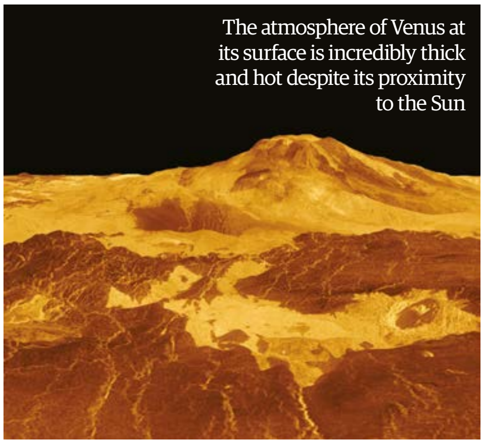
> "If escape was important, then it occurred from the top of the atmosphere"
> **Bruce Jakosky, MAVEN principal investigator**

# Mars now




## The power of solar winds

On Earth, a strong magnetosphere deflects the solar wind around our planet because the charged particles flow along its magnetic field lines, reducing its effects to zero. With Mars' almost insignificant magnetic field, however, a powerful solar wind was able to penetrate the upper levels of the atmosphere billions of years ago. This gave the particles in the atmosphere enough energy to achieve escape velocity and leak into space, leaving Mars with a much thinner atmosphere today. Little or no magnetosphere doesn't necessarily mean a thin-atmosphere planet, though. Venus, for example, not only has a weak magnetic field compared to the Earth but it's much closer to the Sun than either Mars or Earth. Given Mars' depleted atmosphere, you might assume that Venus would be devoid of any atmosphere altogether, but it's actually many times thicker than Earth's atmosphere with dense clouds and intensely hot surface temperatures of more than 462 degrees Celsius (864 degrees Fahrenheit). While the solar wind is gradually stripping the gases in the upper Venusian atmosphere, its dynamic pressure reaches a balance with the extreme pressure of the thicker lower levels, preventing much of the effect of solar wind stripping.


The atmosphere of Venus at its surface is incredibly thick and hot despite its proximity to the Sun


MAVEN launched successfully from Cape Canaveral on 18 November

argon, exist in relatively high concentrations at all levels of the atmosphere – evidence that most of Mars' atmosphere has disappeared. It's thought that a sudden weakening in Mars' magnetic field resulted in its atmosphere being eroded by a fierce solar wind. "The core is important," Jakosky says, "because that is the source for creating a global magnetic field. And the presence of a magnetic field can keep the solar wind from hitting the atmosphere and stripping it off. When the magnetic field disappeared 4 billion years ago, that allowed solar wind to strip the planet's atmosphere."

The young Sun blasted Mars with 100 times the radiation it receives now and, with relatively little in the way of magnetosphere to repel the solar wave, Mars' atmosphere was eroded away relatively quickly. Some of what was left of the atmosphere then reacted with Martian rocks or condensed and froze on the surface.

"This is one area where all [MAVEN's] instruments are playing together to try to answer the questions we're trying to solve," says Beutelschies. "We're looking at different aspects to try to understand the interaction of the solar wind with the atmosphere. What we're hoping to do is once we've taken this data, we can make an atmosphere model of Mars and use these models to go back in time. We can then see when the atmosphere would have been thick enough to support oceans and rivers and lakes on the surface of Mars, then know how long this water would have existed. Because if it's a long time, it has ramifications for people interested in answering the question of whether life could have evolved on the Red Planet."

The Mars Science Laboratory mission, if anything, raised as many questions as it has provided answers, giving MAVEN a challenging job on its year-long primary mission. But the timing of the spacecraft's launch to more or less coincide with the solar maximum was quite deliberate. With the peak of the solar cycle, the Sun is at its most active with sunspots blooming, flares erupting and dynamic solar winds interacting with the atmosphere of Mars. For the scientists on the MAVEN project, it was an opportunity to gather the greatest range of data, as the Sun won't provide an easier opportunity to study these interactions for several years – that is, until 2024.

MAVEN will by no means be able to prove or disprove whether or not life once existed on the Red Planet, but by showing us where the atmosphere went and how, Beutelschies thinks we're well on the way: "If MAVEN provides us with results that say, 'we can see that the atmosphere would have been this warm', 'this wet' or 'supporting liquid on the surface for this geologic amount of time' that will help answer some of the questions about the viability of life on Mars. Until we get that big 'dinosaur fossil', that's what will definitely help answer that question."

"We're getting at questions related to the habitability of Mars by microbes," explains Jakosky. "But the underlying question is whether there was ever life on Mars. I believe that addressing this question is the next step after MAVEN."

## The Mars Atmosphere and Volatile EvolutioN probe