

PLANETARY SCIENCE

Mars at the tipping point

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There's a big problem with the idea of ancient oceans on Mars: if they were contained within the 'shoreline' visible today, sea level would not have been level. Could it be that Mars has since tipped over?

Despite spectacular *in situ* chemical and geological evidence for water on the surface of ancient Mars, courtesy of NASA's Opportunity and Spirit rovers^{1,2}, the temporal persistence and the spatial extent of surface water during the planet's early years remain unclear. Early studies raised the possibility that there was once an ocean in the lowlands of Mars's northern hemisphere^{3,4} (Fig. 1), an idea based on the identification of 'palaeo-shorelines' in orbital images. Given the absence of preserved shorelines of a similar age — at least 2 billion years old — on Earth, their identification on Mars is necessarily a subjective endeavour⁵. Nevertheless, credible additional analyses do support the hypothesis^{6,7}. On page 840 of this issue, Perron *et al.*⁸ present a quantitative analysis that removes arguably the main objection to the shoreline interpretation.

This objection is that a shoreline must follow a line of constant gravitational potential: the 'geoid' on Earth, the 'areoid' on Mars. Mapped onto a topographic profile that indicates the level of fill, such an equipotential surface represents 'sea level'. Once Mars's topography and gravitational field had been accurately mapped^{9–11} in the late 1990s, it became apparent that the traces of the previously hypothesized shoreline deviated from an equipotential surface. Unless these deviations could be explained, the observed features could not plausibly have originated as the edge of an ocean. Given the extent of the mapped shorelines, which extend over thousands of kilometres, any explanation for this deviation would have to reflect a process that was global in scale.

Perron *et al.*⁸ demonstrate that the deviations

of a couple of prominent palaeo-shorelines might be explained by a phenomenon known as 'true polar wander'. This is the reorientation of a planet with respect to its spin axis, and requires a significant mass redistribution on or within a planet¹². In essence, the authors calculated how the topography of a planet deforms in response to a change in rotational potential as the planet reorients in response to a large load, and tested whether this could have been responsible for the modification of the mapped shorelines.

But why would a planet reorient itself at all? In general, a planet rotates stably around its axis of minimum inertia. The plane normal to that axis, approximately the equatorial plane, is often flattened owing to the centrifugal effect of rotation. The equatorial region of Mars has a huge excess mass associated with the vast Tharsis volcanic province (Fig. 1). Earth's largest volcano, Mauna Loa, which rises almost 10 kilometres above the Pacific Ocean floor to form a large part of the island of Hawaii, has an estimated volume of some 40,000 km³. The volume of Tharsis is about 10,000 times greater. Such a bulging waistline would be impressive enough on Earth, but is even more so on Mars, which has only an eighth of Earth's volume.

Tharsis probably formed early in martian history¹³, during the planet's Noachian era¹⁴, some 3.8 billion years or more ago. Wherever on Mars Tharsis originally formed, its massive load would have reoriented to situate itself near the equator, and so form a stable rotational configuration. Structural superposition relationships indicate that the shorelines post-date the emplacement of Tharsis, and so its formation



50 YEARS AGO

When reindeer were introduced into Scotland some ten years ago, a significant factor was that the various ground, rock and tree lichens eaten by reindeer play little part in the diet of red deer, roe deer, sheep, or other indigenous animals... In northern Scandinavia there are more than 600,000 domesticated reindeer and in the northern USSR approximately two million, valued for their meat, skins, milk and hair, and for transport. These benefits have led to imports of reindeer in Alaska, Canada and South Georgia... There were many reindeer in Scotland in prehistoric times, and these were probably hunted with red deer. Why the wild reindeer died out while the red deer remained is unknown... reindeer meat was probably more popular, and the pre-firearm techniques of the chase were not adequate to eliminate the fleetier red deer.

From *Nature* 15 June 1957.

100 YEARS AGO

The closing months of 1906 and the opening months of 1907 are likely to be long remembered by electrical engineers as a period of a remarkable recrudescence of interest in the subject of incandescent electric lamps. For many years the familiar carbon filament lamp has been the only commercial incandescent electric lamp, in spite of its threatened extinction by the invention of the Nernst lamp in 1897–1898. The feeling of uncertainty caused by this discovery was short-lived... the electrical world settled down with the conviction that the threatened revolution was not destined to be achieved. But in the meantime inventors were busy... The tungsten lamp appears to have a brilliant future before it. A lamp working at a little more than 1 watt per candle brings electric lighting almost to the level of gas for cheapness... a radical improvement has long been wanting, and there seems every reason to believe that it has at last been made.

From *Nature* 13 June 1907.

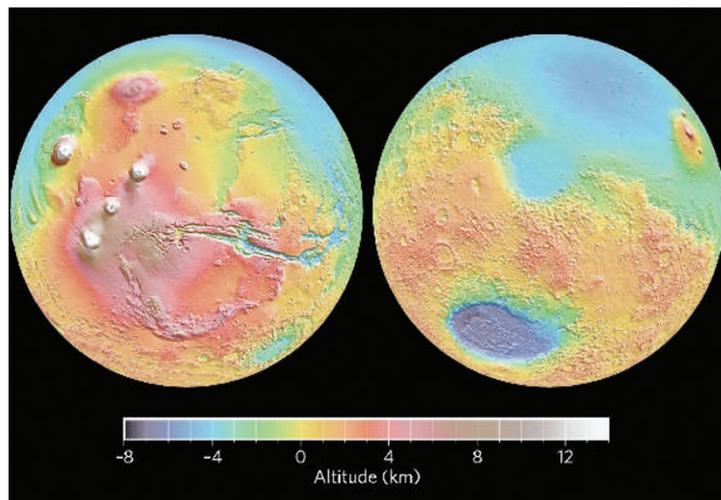


Figure 1 | Topographic maps of Mars. These maps show the Tharsis province (in red and yellow in the left-hand image), and the lowlands of the northern hemisphere (in blue in the upper parts of both images) that are the proposed site of an ancient ocean.