The Anteros Hypothesis

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Abstract

It is widely accepted that Valles Marineris is tectonic in origin, but despite almost five decades of research this remains a hypothesis and it is generally agreed that there is no other evidence for tectonic activity on Mars. Using Valles Marineris to prove a tectonic theory is therefore a circular argument. Despite the observation that most planetary surfaces have been modified principally by impact events, dismissing an impact event as an origin for Valles Marineris has been trivially easy owing to the lack of any rigorous or plausible mechanism. Here I propose a mechanism for an impact event which is consistent with observation and physical theory, and which, I claim, has far more explanatory power than a tectonic hypothesis.

Background

There have been many speculative attempts to suggest Valles Marineris (VM), was formed as a result of an impact event, all of which have been easily dismissed on very good scientific grounds. The poorly constructed hypotheses which have previously been used to justify an impact event for the formation of VM have made the task of establishing a credible impact scenario all the more difficult. For most scientists today mention of an impact hypothesis for VM is labelled under ‘crackpot’ theories. This despite the knowledge that impact events have been the predominant surface altering mechanism for all of the terrestrial planets. Most impact event scenarios for VM are variations on the theme of a large bolide hitting the surface of Mars at a very low incidence angle in a grazing orbit, then proceeding to gouge a canyon and several offshoot canyons for almost 4,000km.

This is completely hopeless as a conjecture for a number of reasons.

A large bolide impact, even at a low incidence angle will inevitably have sufficient kinetic energy to explode on impact and create a large circular crater. There is no physically plausible mechanism for a large impactor to survive an initial impact and then somehow roll across the surface of Mars to gouge out (huge) valleys.

Whilst it may be intuitively tempting to compare the scenario to pebbles skimming across a surface, the kinetic energies involved preclude such an analogy. An additional observation that completely refutes a ‘rolling impactor’ scenario, is that the VM canyons, though massive in scale, have a proportionately shallow depth in comparison to their widths. For example Ius chasma is

some 120kms wide yet has a maximum depth of 8kms. Implausibly any ‘rolling impactor’ would have to be a long cylinder rather than an irregular or spherical bolide to create such a canyon. However here I propose that there is in fact an impact scenario that is plausible and consistent both with observation and physical theory.

Moons of Mars

The present-day Moons of Mars have almost circular, prograde, equatorial plane orbits that differ markedly in their eventual outcomes. Whilst the smaller of the two Moons, Deimos, is calculated to gradually drift further away from Mars, the other Moon, Phobos, is known to be in a decaying orbit that will eventually result in an impact on Mars in some 40-50 million years.

Phobos is expected to disintegrate due to tidal forces, before it collides with Mars. Any loose rocks, dust and regolith on the surface will separate from Phobos below the Roche limit of

$$d = 1.26\, RM \cdot \left(\frac{\rho M}{\rho m}\right)^{\frac{1}{3}},$$

with RM=3389.5km the radius of Mars, ρM=3.9335 g/cm^3 the mean density of Mars, and ρm=1.887 g/cm^3 the mean density of Phobos. This results in a Roche limit of

$$d = 1.26 \cdot 3389.5\, km \cdot \left(\frac{3.9335\, g/cm^3}{31.887\, g/cm^3}\right)^{\frac{1}{3}} = 5455.6\, km$$

So Phobos will enter a Roche limit about 2059 km above the equatorial surface of Mars (taking 3396.2 km as the equatorial radius.) Therefore disintegration will start before impact. Loose rocks will collide with Phobos and unlock more material. Whether there will be a considerable solid remnant or remnants to finally cause large (tangential) impacts is difficult to predict.

The orbital speed of the fragments at the time of collision will be

$$v0 = \frac{ve}{\sqrt{2}},$$

with *ve* = 5.03 km/s the escape velocity of Mars. Phobos’ inclination of 1.093° (relative to Mars's equator) is negligible for the calculation of the impact velocity. Mars' equatorial rotation velocity is about 241.17 m/s. The impact velocity will hence be about

$$\frac{5030\, m/s}{\sqrt{2}} - 241.17\, m/s = 3316\, m/s.$$

Phobos' mass is about 1.0659 ·10^{16} kg. This results in a kinetic impact energy of

$$\frac{1}{2} m v^2 = \frac{1}{2} \cdot 1.0659 \cdot 10^{16}\, kg \cdot \left(3316\, m/s\right)^2 = 5.86 \cdot 10^{22}\, J.$$

The predicted impact of Phobos is significantly different to that of the impact of Chicxulub, the asteroid seen as the cause of the Cretaceous–Paleogene extinction event in which the dinosaurs perished. Though Phobos is larger than the estimated size of the Chicxulub impactor, it will come in at a more tangential impact angle and at the point of impact be traveling much slower at 3km/s

in contrast to the Chicxulub's estimated speed of 20km/s. The total energy of the predicted impact of Phobos will be perhaps a tenth of Chicxulub, but spread over a much wider area around the Mars equator. The above predicted scenario is fairly well understood for Phobos, but what if, in the past there was another Moon of Mars – Anteros?

Anteros

If Anteros was formed by the same process as Phobos and Deimos (possibly the result of being ejected from a previous large impact on Mars), we can speculate that it too would be in a circular, prograde, equatorial orbit. As it no longer exists it can also be safely assumed to have been in a decaying orbit. Therefore the fate of Anteros was similar to that predicted for Phobos. If Anteros created VM it would be consistent with the observations that:

VM lies very near the Martian equator.

VM is oriented parallel to the equator.

VM was formed from west to east; that is, in a direction prograde with respect to the planet's rotation.

Assuming the proposed Moon of Anteros collided with the Martian surface after a tidal disintegration, what would that impact look like?

This third Moon of Mars would start to disintegrate, depending on its composition some 2000km above the martian surface. Over time the debris field of this disintegration spreads out in a tightly focussed equatorial orbit, impacting Mars before it has the chance to form a true planetary ring. At the time of impact it is a proto ring that spreads out a quarter of the way around the planet.

The debris field of Anteros is composed of a variety of different sized fragments, with a large proportion being no bigger than gravel. In amongst the smaller particulates some large fragments may be 10s or even 100s meters in diameter. Unlike a single bolide impact the debris field will hit the surface not just as a chain of impacts but, with addition of huge amounts of smaller particles, almost like a massive shot blasting hose.

With a thin martian atmosphere the smaller particles will not initially burn up as a result of aerodynamic heating, however as they approach the surface the increasing atmospheric pressure, though low relative to Earth's, will heat the smaller particulate producing a rain of molten lava descending at more than 3km/s. This 'hose' of debris will travel across the surface of Mars producing huge gouges across the surface.

The width of these gouges or valleys will be that of the debris field in orbit, but their depth will depend on the amount and kinetic energy of the material that impacts the surface. This solves the problem of disproportionately wide valley structures relative to depth. The debris field 'hose' will travel across the surface at a speed in excess of 3km/s for almost 4000 kms, the whole impact sequence therefore lasting for some 20 minutes.

If VM resulted from such an impact, it is therefore a distribution record of a proto planetary ring formation.

Corroboration of this can be found in the topology of VM. Most of the larger depressions or chasmas (which it is proposed came about through larger fragment impacts) are situated in the central section of VM with long narrower gouges on either side. This is consistent with a tidal disintegration in orbit. This is because smaller fragments from the nearside of a disintegrating object in orbit will tend to move in a faster orbit. Correspondingly, fragments breaking off the far side of a disintegrating body will follow a slower orbit. As has been noted by others in the structure of the rings of Saturn this formation of the disintegrating orbital debris follows certain power law distribution patterns which hold universally.

Conclusion

There are only two categories of formation theories for VM. Either it was, or was not an impact event. This paper has shown that if VM did result from an impact event, not any impact event will do. For an impact hypothesis to be consistent with physical law a VM impact would have to have come about as a result of the collision of a proto planetary ring in a decaying orbit, and one that could only take place in the unique combination of circumstances that Mars presents, principally very thin atmosphere. Conceivably Mercury is the only other (Solar System) planet that a similar impact event could take place, though there is no evidence on that planet of structures similar to VM.

Further research would determine some variables which at present remain as speculations -

- the total volume of material that was carved out by the impact (this will help determine the size of the impactor)
- a distribution map of VM that will help establish whether a relevant power law of debris disintegration can be found as further evidence of an orbital disintegration
- how long a debris field can last as such before it forms a full planetary ring
- following the disintegration of (the proposed) Anteros how long before it impacted the surface of Mars

A proto ring collision or debris field impact is expected to take place with the eventual decay of the Phobos orbit. That such an event is to take place in the future suggests that it is plausible that a similar event with similar (predicted) outcomes took place in the past on Mars.