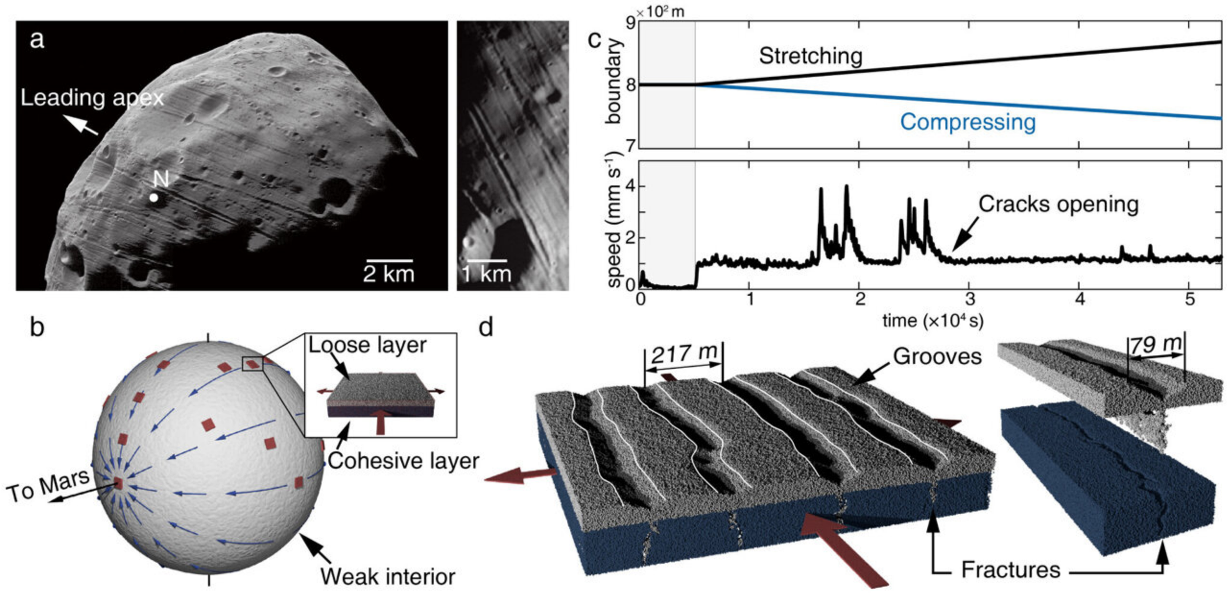
# Phobos surface striations tell a story of its rupturing interior

November 14 2022




Groove formation in response to the tidal orbital decay of Phobos. (a) Linear depressions cutting across Phobos's surface (ESA/DLR/FU Berlin). (b) Our simulated Phobos is a weak rubble pile covered by an exterior regolith that consists of a cohesive layer (blue) mantled by a shallow loose granular layer (white), as highlighted in the inset. Blue arrows indicate tidal forces exerted by Mars, and red patches represent the 23 local areas that we have simulated. Our simulations force the deformation of these patches to mimic the reshaping of Phobos as it spirals inward. (c) As the cells are stretched and compressed (top), fractures occur as indicated by abruptly accelerated regolith particles. (d) A parallel pattern of grooves and accompanying subsurface fractures develops over a regular spacing. The failure orientation is generally perpendicular to the direction of local principal tensile stress. The morphology and pattern of these extensional depressions are commensurate with some linear grooves on Phobos.

Data shown are for the patch located at 60° N and 0° E with the cohesion strength c p = 36 kPa. Credit: *The Planetary Science Journal* (2022). DOI: 10.3847/PSJ/ac8c33

Phobos, the 22-km diameter innermost moon of Mars, is a groovy body. Unlike its little brother Deimos, Phobos has developed a striking pattern of parallel linear features running across its surface. These grooves are a distinctive global feature of Phobos, not present on Deimos. How they formed has perplexed planetary geologists for over forty years, since they were first imaged in geologic detail by NASA's Viking missions.

In a new paper published in *The Planetary Science Journal*, researchers from Tsinghua University, University of Arizona, Johns Hopkins University and Beihang University have made an important step toward solving this enigma. The new study proposes that these grooves are surface expressions of underlying canyons hidden inside Phobos, which are early signs that the moon is falling apart due to increasing tidal forces from Mars.

Apart from its weird linear markings, another special thing about Phobos is its orbit, so close to Mars—only 6,000 km—that tides are causing it to spiral in at about 2 meters per 100 years. Mars is pulling it down. The rapid pace of this evolution—it is predicted to crash into Mars in about forty million years—has inspired researchers to propose that the grooves are stretch marks, torn by Mars gravity.

But so far, it has been impossible to demonstrate that such a surface-tectonic mechanism could work. The problem with the idea of stretch-marks is that it requires a somewhat stronger outer layer that gets fractured when the shape of Phobos changes underneath it. Phobos has a near-surface porosity of at least 40%, so it seems impossible to sustain networks of major crevasses in a pile of fluffy dust, even in a gravity of less than 1/1000 that of Earth.

Using the most highly detailed supercomputer simulations of the problem to date, Bin's team explored the idea that loose dust rests atop a somewhat cohesive sub-layer, a material that is also weak but has enough strength to sustain deep fissures. The loose dust then drains into those cracks.

"This is the first time to use millions of particles to explicitly model the stretching and squeezing of granular regolith experiencing tidal evolution," says Bin Cheng of Tsinghua University who led the new study. "Therefore, we can directly confront the model to observations of grooves on Phobos surface." The new models give a strong match to the observations that have been obtained so far. If correct, then extended back in time they can inform us about the early history of Mars. Extended forward, they can predict how Phobos will evolve as it spirals in.

Bin and his team represented the upper 150 m of Phobos surface as two rectangular piles consisting of 3 million grains, with the uppermost 50 m being very loose, and the deeper grains having a slight cohesion. "Sort of like a sandwich cookie," says Bin. They put these rectangular piles at various locations on Phobos, representing the potato-shaped moon as an ellipsoid. From this they calculated the biaxial strain that would be experienced by each patch, while Phobos interior deformed beneath them to the increasing tide.

The resulting structures were found to bear a startling resemblance, in size, spacing and orientation, to many of the grooves observed at mid-latitudes on Phobos, including their parallel patterns and even their pitted-to-scalloped-to-linear morphologies.

Not all grooves would be predicted to form this this way, but for those that do, the simulations provide a clear view of the process. The tidal strain, as it increases, opens up parallel, narrow fissures in the substrate. This triggers drainage of weaker material in the upper layer into the deeper fissures, leading to the formation and evolution of complex groove morphologies that can further evolve, somewhat analogous to crevasses forming on a deforming glacier, except here forming in dry dusty regolith, in microgravity, over tens of millions of years.

To form parallel grooves, the model requires a sub-layer with a cohesion of at least 1 kilopascal. "This value is similar to that of wet sand at a beach," says Bin. "It is hard to imagine a sandy canyon that is 100 m deep and only 10 m wide, but this makes sense when you think about powdery materials in extremely low gravity."

Japan's upcoming Martian Moons eXploration (MMX) mission, scheduled for launch in the mid-2020s, with a lander, rover and sample return, will shed much more light on this puzzling, and ultimately transitory moon. Scientists expect that Phobos will de-orbit in 20 to 40 million years, when tides pull it apart completely, forming a ring that could make Mars the brightest planet in Earth's sky. The new study predicts that this demise has already begun, and that its surface grooves and underlying canyons are the early signs.

"We're lucky to be around now, to see it at all," says Erik Asphaug, who participated in the analysis.

According to the new model, Phobos is a precarious place, a landscape that is being dynamically transformed through the opening and reworking of granular fissures, and the drainage of loose material into those cracks, until the entire moon eventually breaks apart.

Although definitely tragic, this creeping destruction may also present an opportunity. Caverns, a hundred or more meters deep, could provide new places to explore—mindful of how weak the walls would be—and where humans could shelter equipment and supplies from the radiation and heat and cold of space as we look for water and other resources around Mars. And the opening of fractures could be an exploration boon in another sense, producing vibrations that would enable seismology, from which a future mission could map out the global interior and learn how this strange moon formed in the first place.

**More information:** Bin Cheng et al, Numerical Simulations of Drainage Grooves in Response to Extensional Fracturing: Testing the Phobos Groove Formation Model, *The Planetary Science Journal* (2022). DOI: 10.3847/PSJ/ac8c33

Provided by Tsinghua University