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Modelling the survival of ejected martian biomarkers impacting Phobos

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Motivation and Approach

Phobos' proximity to Mars and short orbital period has led to the hypothesis that Phobos could sweep up particles ejected from large impacts on the martian surface [1]; models suggest that Phobos' regolith could include up to ~250 ppm of martian ejecta material [2,3]. Considering that Mars' surface has many "Special Regions" that could have been habitable in the past [4], it is not unreasonable to suggest that life could have developed and left behind biomarkers. An impact into one of these areas could eject material containing biologically-significant compounds and deposit it on the surface of Phobos. Therefore, an appealing possibility is that samples collected from the surface of Phobos, by missions such as JAXA's Martian Moons eXploration (MMX) [5], could contain martian biomarkers. Further investigation into the feasibility of biomarker transfer from Mars to Phobos is hence necessary before returned samples and *in situ* spacecraft data are analysed.

In order to investigate this scenario, light gas gun impact and heating experiments will be used to simulate the conditions a martian rock, containing biologically-relevant material, would undergo throughout the transport process from Mars to Phobos [6,7]. However, prior to carrying out these experiments, the biologically-relevant material must be defined. It is important that this material represents plausible molecular fingerprints of the types of organisms that might have existed in the harsh radiation conditions of Mars' near-surface for billions of years [8]. Furthermore, they must survive the shock conditions experienced during ejection by a sizeable impact capable of delivering material to reach Phobos' orbit, and the subsequent deposition onto the surface of Phobos. Biomarkers that could satisfy these criteria include amino acids, polycyclic aromatic hydrocarbons (PAHs), fatty acids and sterols [e.g. 9], some of which may be precursors of chlorinated molecules detected in the Cumberland mudstone at Gale Crater [10].

Previous impact modelling has suggested that a small proportion of near-surface martian material can be ejected at high velocities, capable of reaching Phobos from Mars, and experience shock-pressures low enough to remain solid [11]. However, simulations of martian ejecta impacting Phobos are limited to mass-less [2,3] or "hard rock" projectiles [12] that neglect the reduced shock experienced at the trailing edge of a projectile during the early stages of contact and compression [13], which could aid biomarker survival [14]. Therefore, this study uses the iSALE-2D shock-physics code [15-17] to estimate the pressure and temperature regimes within martian ejecta as it impacts Phobos' surface. This will enable constraints to be placed on conditions necessary for biomarker survival.

Model Parameters

Consistency between *in situ* [e.g. 18, 19] and remote sensing [e.g. 20] observations, and the global meteorite collection [21], indicate that Mars' global surface composition can be approximated as basaltic. Thus, it can be assumed that basalt is the most likely crustal rock composition to be ejected from Mars. However, this igneous composition is not the most likely rock type in which to find biomarkers. Sedimentary rocks, such as mudstones, indicate favourable past conditions for habitability on Mars and have an increased potential to preserve biomarkers [22]. Organics and bioessential elements have been detected within mudstones at Gale crater [e.g. 23, 24]. However, mudstones are spread sparsely over Mars' surface, so are less likely to be ejected by impacts. This work, therefore, considers both igneous and sedimentary ejecta, modelling basalt and mudstone projectiles.

For the target, the surface composition of Phobos is largely unknown, owing to the lack of direct sampling from the surface; spectral data indicate that the surface resembles D- or T-type asteroids or carbonaceous chondrites, rich in phyllosilicates [25]. Therefore, the closest match to Phobos' compositional and physical properties will be chosen for the target, with reference to Phobos regolith simulants [e.g. 26].

The simulations will be run over a range of realistic impact parameters, including impactor size (~0.01 - 10 m [27]) and impact velocity (up to 5.3 km s^{-1} [3,12]).

Implications

The results from this modelling will provide insight into the survival of martian biomarkers during deposition onto Phobos. Furthermore, the results will inform the subsequent impact and heat experimental simulations.

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