THE COMPOSITION OF THE MARTIAN MOONS PHOBOS AND DEIMOS IN A GIANT IMPACT SCENARIO.

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Introduction: The origin of the two martian moons, Phobos and Deimos, still remains unknown. Both moons exhibit featureless red spectra in the visible and near-infrared (VNIR) range, relating them to either D-type asteroids [1] or 'primitive' objects such as comets [2]. Their spectral characteristics along with their irregular shape and low density have long lead authors to associate them with captured asteroids (e.g. [3]).

However, the nearly-circular and nearly-coplanar orbits of the moons disagree with a capture origin. Several studies suggested that Phobos and Deimos were captured in an extended martian atmosphere due to drag forces ([4] and [5]). This atmosphere need then to be quickly removed with the right timing (when both bodies are close to the synchronous orbit at ~6 Mars radii) in order for the captured satellites to match today's observed martian system. A capture scenario seems then to be a succession of very improbable events, making it very inefficient to account for the origin of Phobos and Deimos.

Several authors recently suggested that the martian moons could have formed *in situ,* following the impact of Mars with a body roughly the size of the moon [6], as coplanar and circular orbit is a natural outcome of such a formation mechanism.

Here we investigate the bulk composition of the satellites that would form in an accretion disk around Mars and relate it to the observations of Phobos and Deimos. We aim at bringing new constraints on the formation conditions under which formed the martian moons.

Formation of Phobos and Deimos in an accretion disk around Mars. Similarly to the Moon impact scenario, a disk of debris around Mars could have originated from the impact of a large object with the protoplanet. Such an impact would explain the excessive prograde angular momentum of Mars if the impactor mass was $\sim10^{22}$ kg. Moreover, if the disk's mass was large enough, numerous moonlets could have formed within, thus explaining the elongated crater population on the surface of Mars as many bodies would have fallen back to the planet under tide effects.

Recently, the impact of Mars with a body the mass of the Moon has been modeled using SPH simulations [7]. These authors showed that, depending on impact angle and relative velocities of the two bodies, 2-4% of the impactor mass was set into orbit around Mars. This results in a disk several order of magnitude more massive than Phobos and Deimos. Unfortunately, the numerical resolution used in this study did not allow to derive precisely the thermodynamic properties of the system as only ~280 particles finally ended up in the disk out of the 3×10^5 initially used to model Mars and the impactor. Thus the thermodynamic conditions inside a circum-martian disk are poorly constrained and the same applies for its composition given that it is mainly composed of the impactor mantle (see e.g. [8]).

Methods. Given the few constraints on the properties of an accretion disk around Mars, we assumed a disk similar to the proto-lunar disk. This is a two-phase disk consisting in a melt layer concentrated at the midplane and surrounded by an atmosphere of vapourized material. In such a disk, moonlets form beyond the Roche limit where gravitational instabilities set in, allowing large clumps to emerge from the magma [9]. These clumps are already the size and mass of Phobos and Deimos and need not to accrete together in order to form larger bodies.

Based on these considerations, and given that Phobos and Deimos are not massive enough to allow the melting of rocks or an efficient differentiation, the composition of the moonlets should be that of minerals that form as the melt cools down. We used a CIPW norm calculation in order to estimate this mineralogic composition. The CIPW norm is a simple calculation based on sequences of crystallization and geochemistry calculations, it allows to infer the mineralogic composition of a rock sample from its chemical composition. Although it is not a precise crystallization sequence calculation, it accounts for the most abundant minerals and gives a good estimate of their final proportions. It is based on idealized mineralogy but it may applies well in the case of the martian disk because it supposedly cooled down slowly [10].

Results and Discussion. Considering the impactor probably formed near proto-Mars (e.g. [11]), the two bodies would have a closed composition. We then first performed our calculation on a magma with a Bulk Silicate Mars composition.

We found the most abundant minerals to be Olivine (~90 wt%) and Pyroxene (<10 wt%). In this scenario Phobos and Deimos would thus be very Olivine rich. Olivine and Pyroxene have characteristics absorption bands at 1 μm and 1 and 2 μm respectively that should be observed in the spectra of the moons. Such a composition is in disagreement with the featureless measured spectra of the satellites.

This method should be applied to different magma compositions in order to discriminate between scenarios and bring new constraints on the conditions of formation of Phobos and Deimos.

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