NEW EVIDENCE ON THE ORIGIN OF PHOBOS' PARALLEL GROOVES from HRSC MARS

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Introduction: Of the many previous hypotheses concerning the origin of Phobos' grooves, most authorities agree that their formation is in some way connected with the creation of Stickney crater, at nearly 10 km diameter the largest crater on Phobos [1,2,3]. The principal argument for the Stickney association has been that the grooves form a pattern that is approximately radial to Stickney [1,2]. However, such hypotheses were based on incomplete mapping of the satellite, the largest poorly-imaged area being adjacent to Stickney's western rim. Much of the unknown region has now been imaged by HRSC, and we have assembled a new groove map from this and all other available imagery. The impression of grooves radial to Stickney can be seen to be an artefact of the previous coverage. East of Stickney this idea can be sustained, but west of it the pattern is tangential to the crater. The satellite-wide groove pattern can be seen to be centred not at Stickney, but at the leading apex of Phobos in its orbit (i.e. 90° long., 0° lat.). Groove orientations are quite independent of Stickney and bear no relation to it.

Groove characteristics: Grooves can be grouped into at least 12 families of different ages. By far the most complete of these families is that which dominates most of the northern hemisphere of Phobos, and forms the continuous parallel striations that cover most of fig. 1. This family has the following characteristics:

- It covers rather less than one hemisphere of Phobos
- The grooves lie along planes cutting Phobos' surface that are subparallel to each other.
- The plane passing through the centre of Phobos also passes through its leading apex.

Other groove families, although in some cases far less complete and consisting of only a few grooves or crater chains, have the same characteristics, and taken together, all groove families have two other common characteristics:

- Grooves from different families become parallel to each other only along the sub-Mars and anti-Mars meridian.
- There is a "zone of avoidance" surrounding the trailing apex of Phobos in its orbit (i.e. 270° long, 0° lat.) where all grooves fade out.

The best-preserved grooves can be seen to be composed of closely-spaced overlapping pits with raised rims, and many appear identical in morphology and overall appearance to chains of secondary impact craters. But if they are seconda-ries, they cannot have come from impacts on Phobos, as its escape velocity (and therefore its maximum secondary impact velocity) is about 3 m sec^{-1}, and although interaction with Mars' gravity field may raise this to 10 m sec^{-1} [2], this is still much too low to form craters. A much more likely source for secondary impact chains would be ejecta from impacts on Mars. The "zone of avoidance" at the back end of Phobos would then be neatly explained as the region which ejecta from Mars cannot reach because Phobos' forward motion in its orbit exceeds the ejecta velocity.
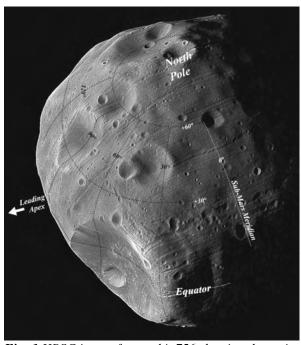

Fig. 1 HRSC image from orbit 756 showing the major groove family covering the northern hemisphere. Stickney is the large crater lower left.

On this hypothesis, each groove family originates from a single impact on Mars, and is composed of radial (effectively parallel at the distance of Phobos) coalesced crater chains. The velocity and direction of arrival of ejecta are obtained from e, the avoidance angle (defined as the minimum angle between Phobos' trailing apex and the point where the groove family fades out near the back end of Phobos) and d, the groove planes' inclination to the orbital plane of Phobos. From these data, it is possible to compute the path of ejecta from Mars impacts using an eighth order Gauss-Jackson numerical integration, with a spherical approximation to the Martian gravity field.

In laboratory experiments, much of the ejecta from a hyper-velocity impact is launched at an elevation angle of about 45° from the horizontal [4]. If we restrict the launch angle at Mars to 45°, then the latitude of the launch crater on Mars can be derived. Since Mars is rotating, there is no solution for longitude. Using this method, fig. 2b shows the predicted orientations of chains of secondary craters from 6 separate impacts on Mars, which matches the groove map shown in fig. 2a. The close fit indicates that Phobos must have been in orbit around Mars, with the same captured rotation and orientation as today, since at least the time of groove formation.

References: [1] Thomas P. et al. (1979) *JGR, 84, B14,* 8457–8477. [2] Thomas P. (1998) *Icarus., 131,* 78-106. [3] Horváth A. & Bérczi Sz. (2003) *LPS XXXIV,* Abstract #1131. [4] Anderson J.L.B. et al. (2004) Meteoritics & Planetary Science *39,* 303-320.

| 180° | 150 | 120° | 90° | 60° | 30° | 0° | 330° | 300° | 270° | 240° | 210° | 180° |

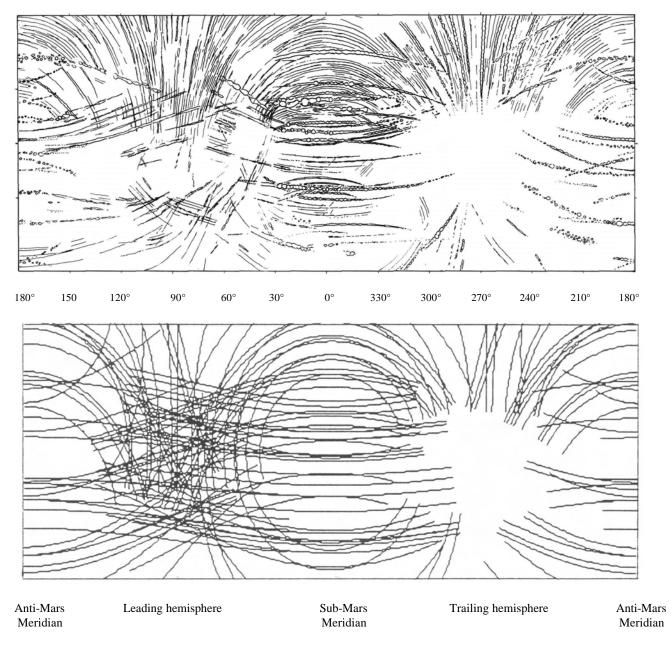| Anti-Mars Meridian | Leading hemisphere | Sub-Mars Meridian | Trailing hemisphere | Anti-Mars Meridian |

Fig 2a (top) Sketch map of the grooves of Phobos from HRSC, MOC & Viking images.
Fig. 2b (bottom): Model of secondary crater chain orientations from impacts on Mars