Launch velocity distribution of the martian clan meteorites. J.N. Head and H.J. Melosh. Department of Planetary Sciences, University of Arizona 1629 E University Blvd. Tucson AZ 8572

Some time ago Gladman (1997) used state-of-the-art symplectic integrators to analyze the delivery of martian meteoritic material to the Earth. In that work he concluded that approximately 5% of martian ejecta arrives within 10 Ma. Part of the discussion centered on the possibility of very short delivery times, in part motivated by the prospect of the exchange of viable biologic material between planets. Ejection velocities of 5.35 - 5.9 km/sec (Mars' escape velocity is 5 km/sec) in the appropriate direction at Mars' aphelion or perihelion respectively will launch material directly into earth crossing orbits.

The velocity distribution function for ejected material is uncertain, but the fraction of material f* exceeding a speed v* greater than vesc is often expressed as f* = (vesc/v*)**p-1. Hypervelocity impact experiments by Gault et al. (1963) imply that p ~3.25. Wetherill (1984) chose a value of p=10. For this range of p, a large fraction of escaping material exceeds the 5.9 km/sec threshhold for direct injection into Earth-crossing orbits. Limiting this fraction to 10% requires p = 35, an unreasonably large value. Hence Gladman concluded that martian material is commonly ejected directly into Earth-crossing orbits. Our own work supports this conclusion. This analysis was part of Gladman's larger conclusion that martian meteorites are ejected in rather small impacts with a recurrence interval short compared to the delivery timescale. Our own work supports both these conclusions.

We have analyzed the velocity distribution data from our modeling of martian impact events. Using the SALE2D hydrocode we simulated impacts of 150 - 400 m diameter projectiles into various martian terrains at approximately 8-10 km/sec. To summarize those results, we have shown that the minimum size crater required for launch of martian ejecta is about 3 km This is much smaller than previous estimates and resolved long-standing inconsistencies in our understanding of the ejection and delivery of these meteorites to the Earth. We also showed that the ejection velocity depends on the age-dependent target composition, explaining the age-frequency distribution of the martian meteorites. In that work we concluded that small craters dominated the flux of martian material to the Earth. At this small size, the recurrence interval between ejecta-launching impacts is shorter than the delivery timescale. Hence, at any one time we are likely to sample material from Mars delivered in a steady rain--the material launched from one impact overlaps in time material from other impacts. Material from impacts large enough to alter this picture are rare enough that we are unlikely to sample it in great amounts.

ejection velocity. The distribution was analyzed in accord with the power law function given above, which was solved for p. In the three cases the calculated values for p were ~3, ~4, and ~4 respectively. The variance in p is estimated as -1 to +3, i.e., in sum the values of p implied by our model data range from 2-6. The results are noisy in that in each case a single cell calculated to have fragment sizes at or near the lower limit of acceptable martian meteorite sizes swamped the size distribution. Values of p derived from these cells (p ~9-14) were given minimal weight in the reported averages.

While a significant fraction (20-35%) of the fragments exceeded 6 km/sec, the fall off in the distribution is still rather steep. This is an artifact of the investigation into martian meteorite provenance. We were interested in determining the smallest crater required to launch material from Mars. Naturally we studied impacts, and hence velocity distributions, that were just sufficient to the task. Simulations of impacts at higher velocities will provide additional insight into this interpretation.

We reaffirm our conclusion that most martian meteorites come from relatively small events. These events are of necessity just large enough to eject candidate martian meteorite material and therefore would not be expected to launch much material at speeds greatly in excess of Mars' escape velocity. Thus it appears that the small crater sizes and the velocity distributions generated in our model is consistent with the conclusions reached by Gladman on substantially different grounds.

References:

Gault et al. (1963) NASA TND-1767.
Gladmann (1997), Icarus 130, pp. 228-246.
Wetherill (1984), Meteoritics 19, pp. 1-12.