MECHANISM FOR CRATER DEBRIS ESCAPE FROM PLANETARY-SIZED BODIES.
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The crystallization ages of certain achondrites give reason to believe that they may have originally formed on a large body such as Mars (1). If true, then some method must be postulated for projecting them off the Martian surface at more than escape velocity (5.01 km/sec; additional velocity may or may not have been required to overcome atmospheric resistance depending upon how much material was projected at the same time and the postulated density of the Martian atmosphere when projection occurred).

Both comets and meteoroids from the asteroid belt may be expected to encounter Mars at velocities high enough to ejection material with greater than Martian escape velocity (2). Ejection during a hypervelocity impact involves the material being shocked to high compressive stress levels and then being released back to near zero stress while undergoing acceleration to nearly twice the local particle velocity behind the initial shock wave. This release velocity is determined uniquely by the shock stress level through Hugoniot analysis. Mineralogic observations of typical shergottite meteorites indicate they were shocked to stress levels near 30 GPa (300 kilobars) corresponding to a maximum ejection velocity of approximately 3.2 km/sec, well below Martian escape velocity. A shock stress level of approximately 57 GPa (570 kilobars) is required to produce escape. But this is sufficient to cause incipient melting in the basaltic materials after they return to low stress levels through entropy trapping, which in turn reduces macro-strength of the rock to the point of disintegration. At least three special processes can be postulated to provide ejection velocity for material escape from Mars.

1. Material could receive a horizontal velocity component in addition to the shock release component during a primary impact event when the incoming meteoroid strikes the surface at near-tangential incidence.
2. Buried ice or bound water could be shock-vaporized during a primary meteoric impact with the resulting vapor explosion producing the required launch velocity.
3. Near-surface material shocked to 30 GPa or less could become entrained with material shocked to higher stresses through turbulent mixing processes.

An argument against the first process is that the material would still be expected to exhibit pronounced shock effects, which is particularly difficult to reconcile with the lack of evidence for strong shock in nakhlites and chassignite. The second process requires substantial regolith thickness, but the lack of brecciation in the samples indicate they arise from undisturbed bedrock. It also requires the presence of suitable amounts of ice or hydrated minerals.
The most likely mechanism may be the third, wherein a small fraction of the mass mobilised is converted to a hypervelocity stream of grain-sized particles. Such "jets" have been observed in both experimental (3,4) and computational (5,6) investigations of energetic cratering processes. Other, more consolidated material will suffer drag acceleration by this "jet", accompanied by extreme erosion. Calculations indicate a 10 meter block which has been shock-accelerated to 3 km/s could achieve escape velocity by additional acceleration over a time period of a few seconds, with unsupported compressive stresses remaining below one kbar, adequately below the intrinsic strength of most rocks. Larger blocks would require longer, milder acceleration profiles to be driven to escape without undergoing compressive fracture.

Surface erosion would cause significant mass loss, but slight heating. Evidence for this course of events may be difficult to find. Cosmic ray exposure ages of these achondrites are all 10 Mybp or less (1), much more recent than the putative launch date of 170 Mybp, as determined from the resetting of the Rb-Sr isochron in Shergotty (7). The meteorites collected are therefore apparently interior fragments of one or more blocks which initially escaped. Original surfaces scoured during acceleration are no longer present. A similar mechanism would be operative on the moon, and in this case the short time scale for capture by the earth should preclude extensive breakup, but surface obliteration by formation of fusion crust during atmospheric entry will destroy most if not all of the eroded surface. Some material on the moon may record erosive "jet" action, but presumably would be rare.

REFERENCES

5. Ullrich et al. (1977). ibid., p. 959-982