THE ROLE OF TARGET STRENGTH IN HIGH-SPEED EJECTA SIZE DISTRIBUTIONS. J. R. Elliott[1] and H. J. Melosh[1], [1]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, 550 Stadium Mall Drive, West Lafayette, Indiana 47907, USA, (elliot26@purdue.edu).

Introduction: Impact spallation remains the most reasonable mechanism for the launch of lunar and martian meteorites [1]. However, much is still unknown about the fragmentation and ejection process of these meteorites, particularly regarding why the majority of recovered meteorites are basaltic, yet basalt is only ~5% of the martian surface. Previous attempts to explain the martian meteorites have examined impacts into only basalt [2] or neglect material strength [3, 4].

In this study we employ a joint Eulerian-Lagrangian hydrocode to study impacts into the martian surface. We derive fragmentation parameters for dry tuff to explain the scarcity of tuff-like meteorites. We explore the effect of impactor size and velocity on material that escapes the martian system.

Methods: We use a hybrid numerical model approach that combines the Eulerian iSALE [5–7] hydrocode with the Lagrangian SALES_2 [8] as described in [9]. SALES_2 utilizes the Grady-Kipp fragmentation model [8, 10] to predict fragment sizes after tensile fracture. We caution that this method may miss some ejected material that is directly beneath the impactor. This region is difficult to resolve with a Lagrangian mesh due to extreme distortion. For this reason, our results should be viewed as a lower bound for ejected mass and fragment numbers.

Previous studies have exclusively studied impacts into competent material, such as basalt or granite [2, 3], which fails to explain the material bias in our sample collection. We have identified Weibull fragmentation parameters for dry tuff, which we use to approximate the weaker material composing most of the martian surface, using experimental data from [11]. The Weibull parameters are $m=10.8$ and $k=1.0x10^{23}$. The $ln(k)/m$ value of these parameters agree well with the Weibull parameters for weak mortar by [12], which they used to approximate dry tuff, indicating little difference in results between the two fragmentation parameter sets.

We have conducted a resolution test from 10 cells per projectile radius (CPPR) to 400 CPPR using an idealized impact scenario in which a 1 km radius basalt impactor strikes a basalt target at 12 km/s. We find that the surface velocities converge almost immediately, in stark contrast to the non-convergence demonstrated in iSALE [4]. Size-frequency distributions of ejected fragments are relatively consistent, but the total ejected mass increases with resolution. This was also found by [4]. The extra mass in higher resolution runs usually manifests as additional small fragments, but larger fragments may appear. All further runs in this study are conducted at 200 CPPR.

Impactor size: We first simulate impacts into targets of pure basalt or dry tuff at the average martian impact velocity of 12 km/s. Impactor radiuses range from 1 m – 100 km, in steps of orders of magnitude.

Figure 1 shows the cumulative fragment size distributions for material ejected faster than escape velocity. We first note the relatively consistent linear increase in fragment size with increasing impactor size. At small impactor sizes, there is initially a large difference between basalt and dry tuff fragment sizes. However, as impactor sizes increase, the difference in fragment sizes decreases. At an impactor radius of 10 km, the two material types are similar.

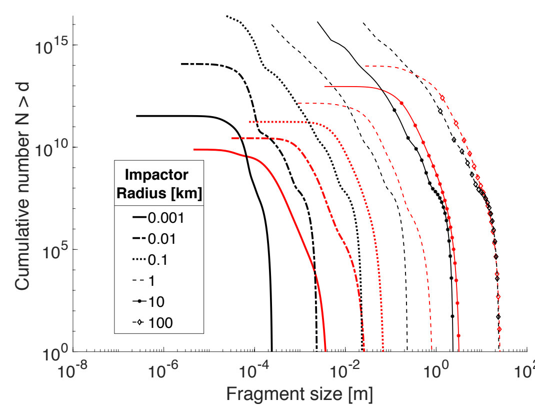

Figure 1. Cumulative fragment size distributions of material ejected at >5 km/s for varying impactor sizes and target materials. Basalt is denoted by red lines, and dry tuff by black. The line type denotes impactor radius (see legend). Impactor size generally increases from left to right across the figure.

The total amount of material ejected at >5 km/s increases proportionally with impactor volume. Impacts into dry tuff ejected roughly 25% the mass that impacts into basalt ejected. The mass of material ejected with respect to the mass of the impactor is consistent for all impacts. Impacts into basalt eject ~7.5x10^{-3} % of their mass, while impacts into dry tuff eject ~1.8x10^{-3} %. This is an order of magnitude lower than the efficiencies reported by [4], however this may be expected due to our inclusion of material strength and fragmentation.

Impact velocity: We next simulate impacts at a range of impact velocities, from 10 km/s to a maximum of 25 km/s in steps of 5 km/s. We hold the impactor radius constant at 1 km. Velocities below 10 km/s are omitted because the source region of ejected material is directly beneath the impactor at these speeds [4], a region that our Lagrangian mesh is currently incapable of simulating.

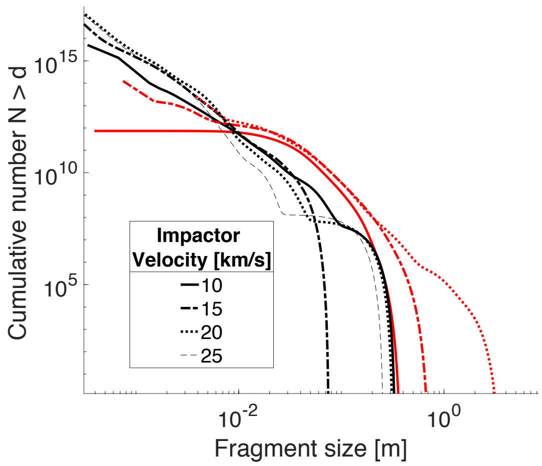

Figure 2. Cumulative fragment size distributions of material ejected at >5 km/s for varying impactor velocities and target materials. Red lines denote basalt targets, and black denote dry tuff.

Figure 2 details the cumulative size destructions of fragments ejected faster than martian escape velocity. We note that, for basalt, fragment sizes appear to increase with velocity, while dry tuff fragments decrease with velocity. The larger basalt fragments may be explained by the increasing amount of mass ejected with impactor velocity (Figure 3). There does appear to be a turnover in amount of mass ejected at around ~20 km/s. The increased mass may be explained by stronger shockwaves damaging the material, reducing its strength, and making it easier to eject. We note that the turnover point is ~10 km/s higher than found by [4], although this may again be due to our inclusion of material strength. The difference in mass ejected between basalt and dry tuff decreases as impactor velocity increases, indicating strength plays a smaller role as impact velocity increases.

Conclusions: This work has established Weibull fragment parameters for dry tuff, which show that dry tuff fragments are smaller than basalt fragments for most impactors. Thus, impacts into basalt may eject large meteorites more frequently than impacts into dry tuff. We simulated impacts over a wide range of impactor sizes and found that the amount of material ejected is constant when put in terms of impactor mass. The size difference between dry tuff and basalt fragments decreases as impactor size increases. Finally, we varied impact velocity from 10 – 25 km/s. Mass ejected increased with impact velocity up until 20 km/s.

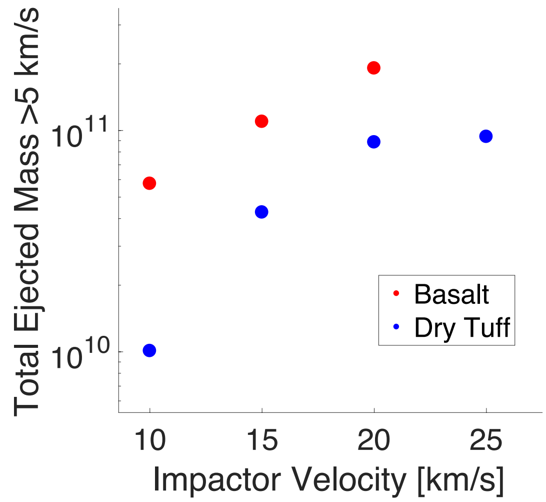

Figure 3. Total ejected mass as a function of impactor velocity.

Future work: In the future we will continue to improve the stability of SALES_2 to achieve higher CPPR and to examine the region directly beneath the impactor. Preliminary results indicate that the SFD of ejected fragments has reached convergence, but higher resolutions are needed to explain the lack of 2π irradiation in the martian meteorites. Once stability has been achieved, impacts can be simulated to later times in order to obtain a size-velocity relationship for all ejected fragments. Finally, we will investigate the influence of target heterogeneities, such as layering and imbedded boulders, on ejecta fragment SFDs.

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