CATASTROPHIC DISRUPTION OF HYDRATED TARGETS: IMPLICATIONS FOR THE HYDRATED ASTEROIDS AND FOR THE PRODUCTION OF INTERPLANETARY DUST PARTICLES. G. J. Flynn[1], and D. D. Durda[2], [1]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh, NY 12901 (george.flynn@plattsburgh.edu), [2]Southwest Research Institute, 1050 Walnut St., Suite 400, Boulder, CO, 80302.

Introduction: The outer half of the main-belt is dominated by asteroids that are classified as C-, P-, or D-type, based on their reflection spectra. These low-albedo asteroids are believed to be the parent bodies of the carbonaceous chondrite meteorites. A significant fraction of the carbonaceous chondrite meteorites are hydrated, and some of the C-, P-, and D-type asteroids show evidence for hydration in their reflection spectra. Thus, a significant fraction of the targets for cratering and collisional disruption in the outer half of the main-belt are likely to be hydrated bodies. Nonetheless, most disruption experiments on natural rock targets have concentrated on anhydrous rocks, such as basalts.

Tomeoka et al. [1] impacted a small target of the hydrated carbonaceous meteorite Murchison and compared the results to the disruption of Allende, an anhydrous carbonaceous meteorite. They found that Murchison disrupted far more easily than anhydrous meteorite targets, and suggested that the hydrated asteroids might contribute far more dust to the Zodiacal Cloud than would be expected based on their abundance in the main belt.

We have begun a series of impact experiments on hydrated targets – both terrestrial rocks and meteorites – to compare their response to disruption with the results we have previously reported on anhydrous terrestrial basalt [2] and anhydrous meteorite [3] targets.

Samples and Techniques: For comparison with the anhydrous, basaltic targets we previously disrupted, we prepared targets of "greenstone," a basaltic rock in which the olivine and peridotite that made up the fresh rock have been metamorphosed by high pressure and warm fluids into green minerals including epidote, actinolite, or chlorite.

The greenstone we used appeared to be moderately fractured, which may effect its response to collisions. However, we note that most meteorites, including the hydrated carbonaceous meteorites, exhibit significant porosity [4], and that the most common type of porosity in meteorites is cracks. Thus, the pre-existing fractures in our greenstone targets may make it an appropriate analog material.

We impacted three "greenstone" targets, weighing 83 grams, 229 grams, and 492 grams, which spanned the range of anhydrous basalt target masses we had previously disrupted. In each case, the projectile was a 1/8-inch diameter Al sphere fired at ~5 km/sec using the NASA Ames Vertical Gun Range (AVGR). The details of each shot are summarized in Table 1.

Disruption Results: The extent of the destruction in a collision is frequently characterized by the ratio of the mass of the largest fragment produced in the collision (M_{LR}) to the mass of the target (M_T). This parameter, M_{LR}/M_T, is 1 for a perfect rebound in which the target emerges unaltered. An M_{LR}/M_T value of 0.5 is generally taken as the boundary between cratering events and catastrophic disruption [5], with M_{LR}/M_T ranging from 0.5 to 1 for cratering events, and $M_{LR}/M_T < 0.5$ for catastrophic disruption.

Each of the three greenstone targets suffered a catastrophic disruption, with the mass of the largest fragment being less than 50% of the target mass (see Table 1). One of our previous shots into an anhydrous, porphyritic olivine basalt (Shot 011016) almost exactly mimicked the impact conditions experienced by one of the greenstone targets (Shot 030805). The mass of the olivine basalt target was 231 grams compared to 229 grams for the greenstone target. Both targets were struck by 1/8-inch diameter Al projectiles. The projectile speed was 4.55 km/sec for the olivine basalt target and ~4.9 km/sec for the greenstone target. Thus, the kinetic energy of the projectile was approximately 20% higher for the greenstone target. The greenstone target was much more severely disrupted than the olivine basalt target. The largest fragment from the olivine basalt disruption was 141 grams, and the collision was not quite catastrophic, since the mass of the largest fragment was ~0.6 times the mass of the target. The greenstone disruption was super-catastrophic, with the largest fragment having a mass only ~0.03 that of the target. The factor of 20 difference in the mass of the largest fragment cannot be explained the ~20% difference in kinetic energy of the projectile.

We recovered all of the debris from the disruptions of both the greenstone target (Shot 030805) and the anhydrous olivine basalt target (Shot 011016) from the floor of the AVGR. While we have not yet determined the size-frequency distribution of the debris from the greenstone target, a visual comparison of the debris indicates that most of the mass from the disruption of the anhydrous olivine basalt is in rock fragments while the majority of the mass from the disruption of the greenstone target is in fine material and dust. This result is consistent with

Table 1: Disruption Conditions and Results

Shot #	Target	Mass of Target (M_T)	Projectile Type	Projectile Mass	Projectile Speed	Mass of Largest Fragment (M_{LR})	M_{LR}/M_T
030802	greenstone	83 g	1/8-in Al	0.0455 g	4.42-5.35 km/s	2.2 g	0.025
030805	greenstone	229 g	1/8-in Al	0.0453 g	4.86-4.93 km/s	7.1 g	0.03
030810	greenstone	492 g	1/8-in Al	0.0452 g	3.93-3.95 km/s.	227 g	0.46
011006	anhyd. basalt	231 g	1/8-in Al		4.55 km/s	141 g	0.61

the observations of Tomeoka et al. [1] that hydrated targets produce more dust-size fragments than anhydrous targets under the same impact conditions.

Q^*_D Value: Plots of M_{LR}/M_T versus the "specific impact energy" (i.e., the impact kinetic energy per unit target mass) generally show a power-law trend in laboratory impact experiments on many terrestrial materials. The energy required disrupt the target material such that the largest fragment has 50% of the mass of the target (a parameter called Q^*_D) can be derived from the slope of this power-law (as discussed by Fujiwara et al. [5]).

A plot of M_{LR}/M_T versus the specific impact energy for the disruption of the 3 greenstone targets as well as the results from our previous hypervelocity impacts into 10 anhydrous meteorite targets previously reported in Flynn and Durda [3] are shown in Figure 1. A least-squares fit to the meteorite data yields a value of 1419 J/kg for the threshold collisional specific energy (Q^*_D) for the anhydrous meteorites while the fit to the greenstone data yields a value of only 567 J/kg.

These preliminary results indicate that at the size scale of ~200 gram targets employed in this study, disruption of the greenstone targets requires significantly less specific energy than is required to disrupt the anhydrous meteorites.

In comparison, Fujiwara et al. [5] report a value for Q^*_D of ~700 to 800 J/kg for laboratory experiments on glass, basalt, and granodiorite. This value is not significantly different from the ~567 J/kg we measured for the greenstone targets. However, we note that our greenstone targets were moderately fractured, and that Love et al. [6] have demonstrated that it requires more specific energy to disrupt porous targets than compact targets. This result can be understood by noting that if the target is porous some of the kinetic energy of the impactor is dissipated by compressing the target, and this energy is unavailable to disrupt the target. Thus, it is likely that Q^*_D for an unfractured sample of the greenstone would be significantly lower than the value measured for glass, basalt, and granodiorite.

Conclusions: Our preliminary data suggest that the disruption of hydrated targets requires less specific energy than the disruption of anhydrous targets. In addition, it appears that the disruption of hydrated targets results in the production of a significantly higher mass of dust-size particles than we obtained from an anhydrous target disrupted under similar conditions, consistent with the results of Tomeoka et al. [1].

Further experiments on hydrated targets, including disruption experiments on hydrated meteorites, are required to develop an understanding of the response of hydrated asteroids to collisions and to assess the rate of dust production from these asteroids

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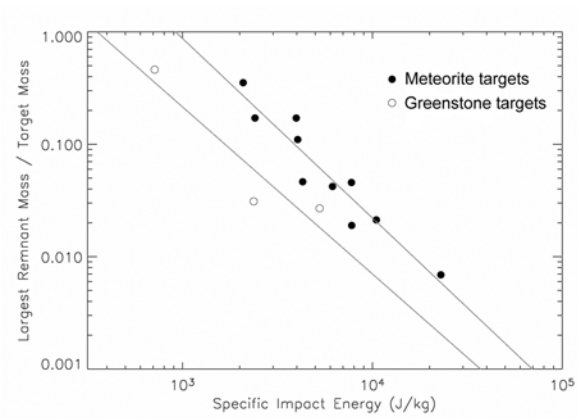

Figure 1: The ratio of the largest fragment mass to the target mass versus the specific impact energy is plotted for 10 anhydrous chondritic meteorites [from 3] and the 3 greenstone samples disrupted in this work. The greenstone data is plotted as open circles while the meteorite data is plotted as filled circles.