HYDROCODE SIMULATION OF EXPLOSIVE DISRUPTION: EXTERNAL PRESSURE AND GRAVITY; E.V. Ryan (PSI/U. of Arizona), E. Asphaug and H.J. Melosh (U. of Arizona)

The dynamic fragmentation of rock has been studied through the use of a numerical model (continuum damage hydrocode) of stress wave propagation and interaction (1). This model has successfully reproduced the observed fragment mass distributions of laboratory impact experiments (2). Recently, Housen and Schmidt (3) have conducted explosive disruption (as opposed to projectile impact) experiments at elevated pressures, which provide an additional opportunity to verify hydrocode predictions for fragmentation outcomes. By applying appropriate overpressures to small targets, Housen and Schmidt (3) have attempted to match the volume-averaged lithostatic stress of large, gravity-dominated bodies. However, their experiments cannot replicate the gradient of the lithostatic stress field, as the laboratory target is under a uniform stress equal to the applied external pressure. Therefore, these experiments do not account for the lithostatic strengthening of the interior of large bodies. Since our numerical model is not subject to the same constraints faced by experimentors (i.e., limitations in target size), it can simulate large-scale fracture events. The hydrocode is used here to establish a relationship between constant overpressure and lithostatic stress.

First, the equivalence between impact and explosive disruption events was determined. It has been suggested (3) that impact and explosive tests produce similar results if the burial depth of the charge below the target surface is in the range of 1 to 2 charge radii. The best correspondence achieved using the hydrocode occurred when the charge was buried at least 2 charge radii below the surface. Basalt was used as the target material, and the same specific energy (energy per target mass) was delivered to the target for both a projectile, impacting at 1 km/s, and a buried explosive charge. Table 1 summarizes the initial conditions and fragmentation outcome, and Figure 1 shows the final pressure and damage contours for each case. The fragment mass distributions were nearly identical. However, when the burial depth of the charge was decreased 1 charge radii, the mass of the largest fragment increased, and a spall plate appeared just above the charge at the target surface.

Having established the appropriate burial depth for the explosive charge, the basalt target was subjected to an external pressure (80 MPa) half the value of its compressive strength (160 MPa). The specific energy etc., was the same as used in the projectile and zero-pressure events. The fragmentation outcome under pressure was markedly different. The largest fragment mass contained 89% of the target mass, as opposed to the 48% observed for the explosion event without an applied pressure (see Table 1 and Figure 1). The large crater that resulted from the overpressure is in qualitative agreement with the results of Housen and Schmidt (3), who used weak basalt fly-ash as a target material under pressures near and above its compressive strength. The necessary material properties for modeling fly-ash with the hydrocode will be determined and a direct comparison between hydrocode simulation and experiment will be made.

Housen and Schmidt (4) develop an equation that relates the overpressure to a volume-averaged gravitational stress and an equivalent body radius. A pressure of 80 MPa would correspond to a target diameter of 913 km. A body of this size containing a lithostatic stress field was exploded with the same specific energy as the uniform stress field pressure simulation, and the result is shown in Figure 1. As expected, the gravity simulation has a spall plate near its surface, due to the weaker pressure state there. The presence of the spall region reduces the largest fragment mass to 67% of the target mass, but the two outcomes roughly agree. However, the fragment mass distributions are not closely related-- the gravity disruption produces more numerous, smaller fragments. In addition, effects of target size on the specific energy needed to disrupt a body are clearly evident in these simulated events: although the same energy per mass was delivered to the 13.5 cm diameter target as to the 913 km target, the small target was catastrophically disrupted, while the large body was merely cratered.

References. (1) Melosh, H.J., E.V. Ryan, and E. Asphaug (1992), submitted to *J. Geophys. Res.* (2) Ryan, E.V., E. Asphaug, and H.J. Melosh (1991), *LPSC XXII*, 1155-1156. (3) Housen, K.R., and R.M. Schmidt (1991), *Icarus*, **94**, 180-190. (4) Housen, K.R. *et al.* (1991), *LPSC XXII*, 593-594.

Table 1: Hydrocode Simulations

Disruption Conditions	Target[1] Mass (kg)	Target Diameter (m)	Proj. or Explosive Mass (kg)	Energy per Target Mass (J/kg)	Over-Pressure (Pa)	Largest Fragment Mass/M_T
Projectile Impact	3.37	$1.35\text{x}10^{-1}$	$5.82\text{x}10^{-3}$	$3.73\text{x}10^{3}$	0	0.41
Explosion	3.36	$1.35\text{x}10^{-1}$	$1.17\text{x}10^{-3}$	$3.66\text{x}10^{3}$	0	0.48
Explosion + Over-Pressure	3.35	$1.35\text{x}10^{-1}$	$1.17\text{x}10^{-3}$	$3.66\text{x}10^{3}$	$8\text{x}10^{7}$	0.89
Explosion + Gravity	$3.72\text{x}10^{20}$	$9.13\text{x}10^{5}$	$1.29\text{x}10^{17}$	$3.65\text{x}10^{3}$	—	0.67

[1]Target material is Fujiwara *et al.* (1977) basalt.

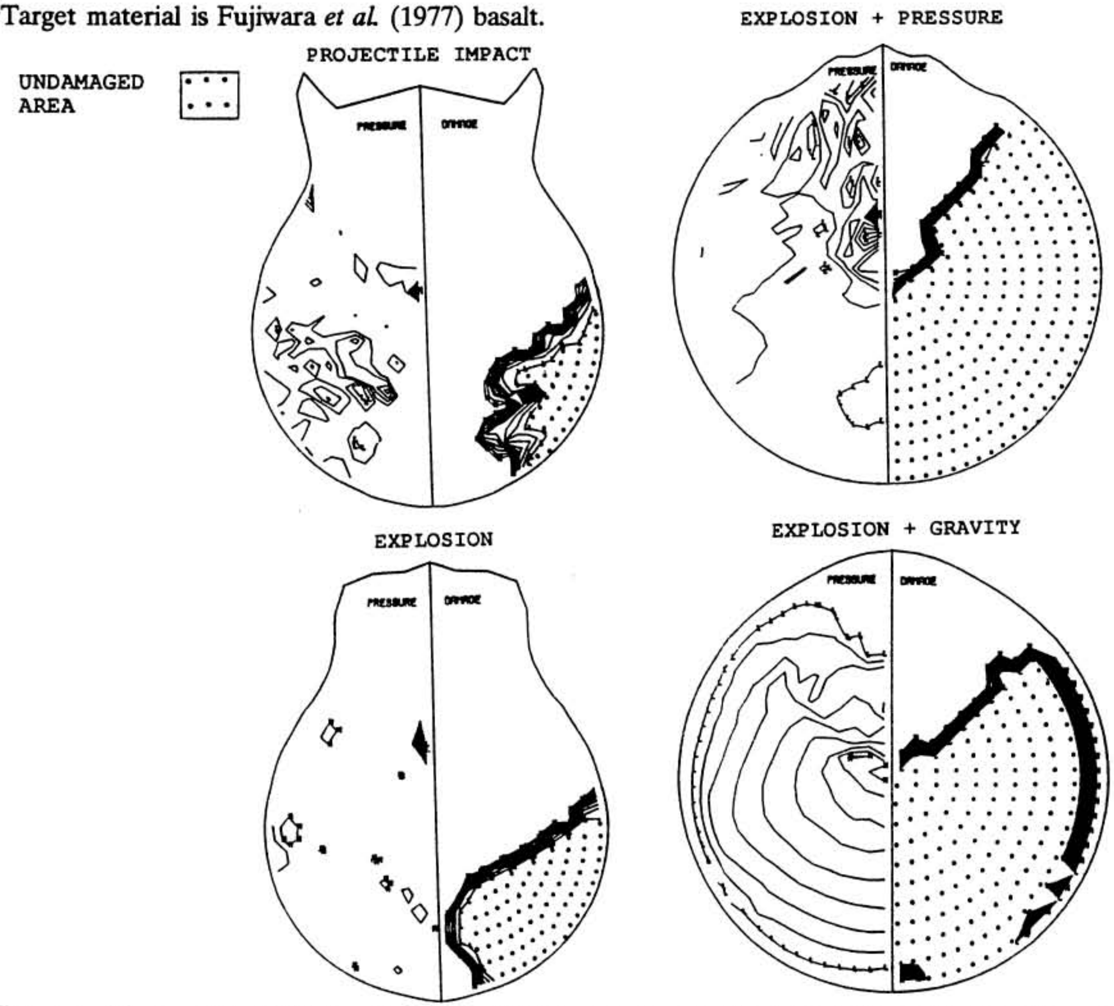

Figure 1. Final pressure (left) and damage (right) contours for the four hydrocode simulations described in the text. The undamaged area corresponds to the mass of the largest fragment in each case.