PRESSURE VERSUS DRAG EFFECTS ON CRATER SIZE

R. M. Schmidt, Boeing Defense and Space Group, M/S 87-60, Seattle WA 98124

The topic of atmospheric effects on crater formation is very complex because it includes not only pressure effects on excavation, but also drag effects on ejecta placement. Experiments have to be designed very carefully to allow isolation of the two phenomena. Historically, numerous investigators (Johnson *et al.*, 1969; Herr, 1971; Schultz and Gault, 1979; Holsapple, 1980; and Schultz, 1992) have shown an influence of atmospheric pressure. However none have identified the scaling that correctly isolates pressure from drag effects. On-going work (Housen and Schmidt, 1990; Housen,*et al.*, 1992; and Schmidt *et al., 1992)* in explosive cratering has produced scaling paradigms for deeply buried explosive charges where drag effects are negligible. Here it was found that increased pressure caused significant induced strength effects that impeded crater excavation. The effect is more pronounced with increasing burial depth and less pronounced with increased yield.

In the case of impact cratering, equivalent burst depth tends to be small, and atmospheric effects are expected to be primarily drag induced. Figure 1 is a plot of gravity scaled cratering efficiency versus atmospheric pressure, divided by lithostatic pressure for one impactor radius, for Flintshot sand with relatively large grain size, on the order of 500μ. Here we calculate negligible drag effect and attribute the decrease in cratering efficiency to pressure domination. However note the pressure exponent is quite small, on the order of 0.040 with a standard deviation of 0.007. The value for the gravity exponent alpha from this same regression is 0.49. Also shown are three tangent-below explosion data points which also agree with the weak pressure dependence seen for impact.

The data points denoted by the letter "s" are from Schultz (1992). These are variable pressure impacts fired into his S1 sand (no. 140-200). Note the strong departure from the regression based upon the Flintshot data points. This is suspected to be strength or cohesion domination, since he used five different gases with various densities to demonstrate absence of drag effects. To confirm this supposition, two impacts were made into a comparable sand, F-140. One at 1G that can be seen right in with the Schultz data as expected (see shaded "star" symbol). The second was launched at 500G to eliminate strength and as can be seen lies right on the regression curve to the gravity data. Small-scale 1G experiments are almost always fraught with undesired strength effects.

Since firing projectiles into a high pressure atmosphere is difficult, if not impossible, shallow buried explosive experiments were designed to explore the pressure-drag regime applicable to impact cratering. These experiments incorporated a pressure/vacuum chamber mounted on a centrifuge that allows independent variations in gravity and pressure. Drag was varied by using different sand grain sizes and different gases as suggested by Schultz (1992). This allowed experiments to be conducted at fixed scaled drag or at fixed scaled pressure. The tests have to be conducted at high gravity to eliminate or minimize material strength effects. Figure 2 is a contour plot of crater size versus scaled drag and scaled pressure. As can be seen crater size diminishes in the direction of the upper right hand of the plot. Reading the symbol, this contour is on the order of a 1km impactor on Venus with a block size of 1 meter. This trend agrees with observations by Phillips *et al.* (1990) reporting no craters smaller than 3 km dia.

Herr, R. W. (1971) Effects of atmospheric-lithostatic pressure ratio on explosive craters, *NASA TR-R-366*.
Holsapple, K. A. (1980) Equivalent depth of burst for impact cratering, *Proc. LPSC 11th*, 2379-2401.
Holsapple K. A. and Schmidt R. M. (1987) Coupling parameters in cratering mechanics, *J. Geophys. Res.* **92**(B7), 6350.
Housen, K.R. and R.M. Schmidt, (1990)Atm pressure effects on craters from deeply buried explosives, *EOS*, **71**, 6, 258.
Housen, K. R *et al.*, (1992) D. O. B. scaling and critical depth of burst for cratering, *DNA-TR-92-24*.
Johnson, S. W. *et al.*, (1969) Gravity and atm pressure effects on crater formation in sand, *J. Geophys. Res.*, **74**, 4838.
Phillips, R. J. *et al.*, (1991) Impact craters on Venus: Initial analysis from Magellan, Science, 252, No. 5003, 288.
Schmidt, R. M *.et al.*, (1992) Pressure/strength effects in cratering. *EOS*, **73**, 43, 324.
Schmidt, R. M. (1992) Experiments to investigate atmospheric effects on crater size, *Lunar Planet. Sci. XXIII*, 1221-1222.
Schultz, P. H. and D.E. Gault (1979) Atmospheric effects on Martian ejecta emplacement, *J. Geophys. Res.*, **84**, 7669.
Schultz, P. H. (1992) Atmospheric effects on cratering efficiency, *J. Geophys. Res.*, **97**, E1 975-1005.

 PRESSURE VERSUS DRAG EFFECTS ON CRATER SIZE: Schmidt, R. M., Boeing Co.

Fig. 1. Regression to Ottawa Flintshot data to get pressure effects

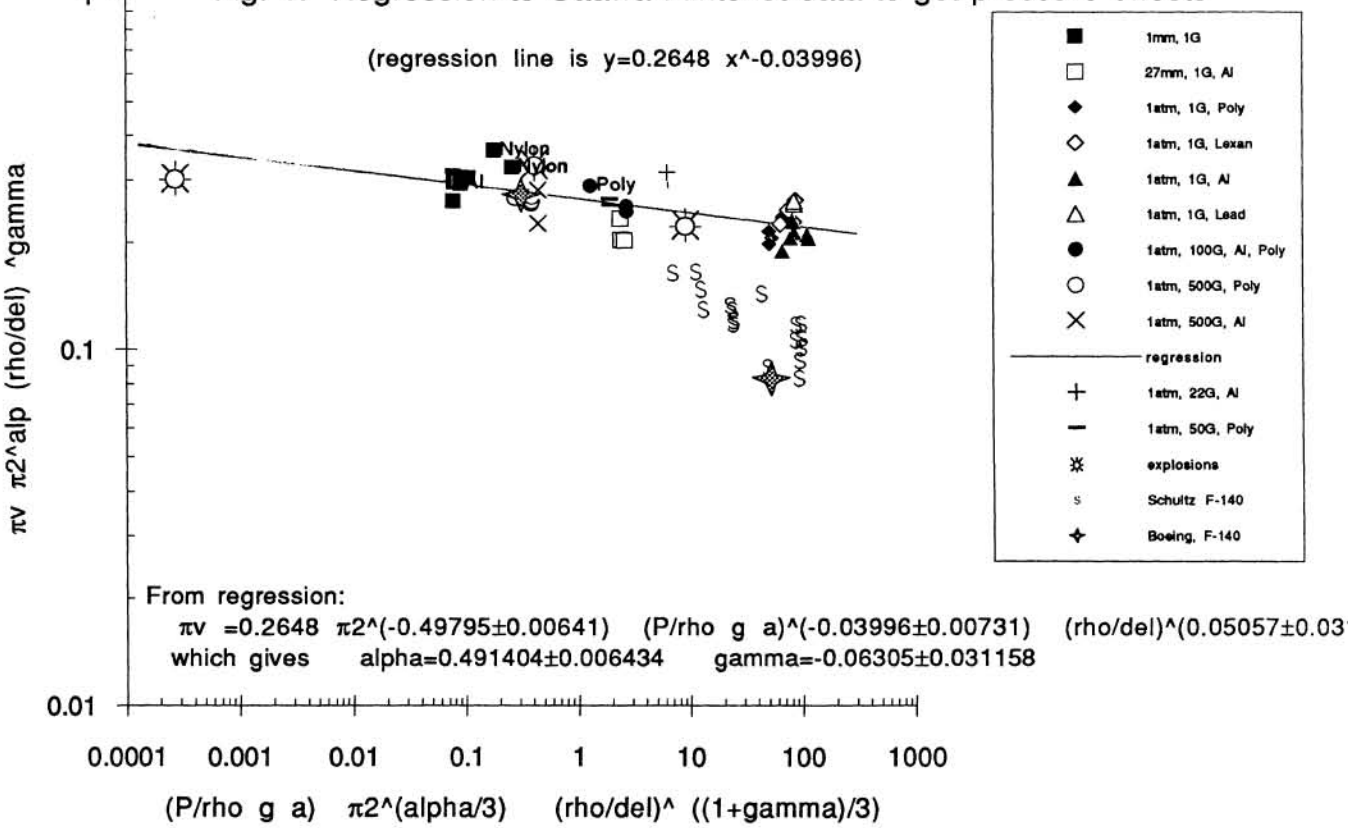

Fig. 2. Plot showing contours of constant scaled crater size