EXPERIMENTS TO INVESTIGATE ATMOSPHERIC EFFECTS ON CRATER SIZE
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The influence of atmospheric pressure on explosive cratering was first observed by Johnson et al. (1969) in experiments using aircraft to vary gravity. Also about this time, Herr (1971) used reduced atmospheric pressure in an attempt to develop scaling laws incorporating gravity effects. Subsequent applications to impact cratering were conducted by Schultz and Gault (1979), Holsapple (1980), Schultz (1982) and Schultz (1988). For practical reasons, pressure was reduced from atmospheric in all of these experiments. Recently Housen and Schmidt (1989) conducted experiments for deeply-buried explosions onboard a geotechnical centrifuge employing a pressure chamber. The ability to independently vary pressure and gravity provides a unique capability to study the relative effects in impact crater formation. This technique is now being applied by using near surface explosions to simulate impact events.

Increased atmospheric pressure is expected to augment the lithostatic overburden which retards the crater formation. Furthermore, the range of the ejecta is reduced due to the increased gasdynamic drag. Experiments are being conducted with various gases at different pressures to isolate these two mechanisms. Scaling laws are being developed that can be applied to explain various features of the crater population observed from the Magellan data for the Venusian surface (Phillips et al., 1991). Dimensional analysis and the assumption of a coupling parameter (Holsapple and Schmidt, 1987) are used to derive a basic form for a scaling law given below in Eq. 1. The crater radius is written as a function of the coupling parameter \( aU^H \), employing the impactor size and velocity, \( a \) and \( U \), and the gravitational acceleration, \( g \). The first term on the right includes the pressure, \( P \) and the target density, \( \rho \).

The drag term includes the atmospheric density and ejecta particle density given by \( \rho_a \) and \( \rho_p \). \( C_D \) is the appropriate drag coefficient which depends on average particle shape and the flow regime and \( \Delta \) is a length scale characterizing the particle size scale distribution for the ejecta. The result is stated here as:

\[
\frac{R}{a} \left( \frac{a}{U^2} \right)^{0.17} = K \left[ \frac{P}{\rho g R} \right]^{0.16} \left[ \frac{C_D \rho_a R}{\Delta \rho_p} \right]^{0.11}.
\]  
(1)

As a starting point, the function \( F \) is simply assumed to be a product of powers of the pressure group with exponent \( H \) and the drag group with exponent \( D \) as follows:

\[
\frac{R}{a} \left( \frac{a}{U^2} \right)^{0.17} = \left[ \frac{P}{\rho g R} \right]^{H} \left[ \frac{C_D \rho_a R}{\Delta \rho_p} \right]^{D}.
\]  
(2)

A multiple regression to the results of five preliminary experiments shown below gives values of -0.16 for \( H \) and -0.11 for \( D \) and a value of 1.74 for the constant \( K \) and \( \mu \) is 0.4 for dry sand. Hence:

\[
\frac{R}{a} \left( \frac{a}{U^2} \right)^{0.17} = 1.74 \left[ \frac{P}{\rho g R} \right]^{0.16} \left[ \frac{C_D \rho_a R}{\Delta \rho_p} \right]^{0.11}.
\]  
(3)

The ratio of crater size, \( R \), to particle size, \( \Delta \), provides the basis for similarity tests at fixed values of the pressure term. Experiments like these and others to better define the function, \( F \), are currently underway. Presently the chamber has a working pressure of 20 atm, but an effort is underway to increase this to 35 atm, which will provide a \( CO_2 \) density of 64.8 gm/liter at room temperature matching that for Venus (735 K, 90 atm).

The explosive charge is comprised of a 0.46 gm cylinder of Deta-sheet with a 0.03-gm micro detonator buried at \( d/a = 0.88 \), where \( a \) is the equivalent spherical radius of the charge (0.43 cm). The specific energy of this device is 4.25E10 ergs/gm and the density is 1.45 gm/cc.

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Being a cylinder, the charge was placed on its side in a tangent below configuration thus facilitating precise placement from shot to shot. This is also considered to be a reasonable burial depth for simulation of impact cratering as discussed by Holsapple (1980). The legend for the individual shots is coded in the shot number label for each set of crater dimensions. The gas used is either CO₂, helium, or air. For the labels where the pressure is shown as 20+1 atm, the chamber was not evacuated prior to pressurization and 1 atm of air is mixed in with the pressurization gas. Lastly the grain size of the Ottawa sand is denoted by FOF for Ottawa F-140 with mean grain size of 100µ and FS for Ottawa Flintshot with mean grain size of 500µ. The target density is 1.6 gm/cc for FOF and 1.8 for FS. A shot was conducted in vacuum using FS; the resulting crater dimensions were very close to those for the 1 atm air shot number 974.

<table>
<thead>
<tr>
<th>Shot</th>
<th>Gas</th>
<th>Pressure</th>
<th>FOF</th>
<th>Mean Grain Size</th>
<th>FS</th>
<th>Mean Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>994</td>
<td>He</td>
<td>20+1 atm</td>
<td>FOF</td>
<td>1.540e+1 3.102e+0 9.310e-1 2.533e+1 4.186e+0 1.192e+0 1.966e+0 1.016e+1 2.618e-1</td>
<td>FS</td>
<td>2.002e+1 3.470e+0 9.310e-1 3.335e+1 4.766e+0 1.125e+0 2.733e+1 1.102e+1 2.855e-1</td>
</tr>
<tr>
<td>991</td>
<td>CO₂</td>
<td>20+1 atm</td>
<td>FOF</td>
<td>9.822e+0 2.845e+0 7.915e-1 1.883e+1 3.597e+0 1.057e+0 1.189e+1 6.831e+0 2.612e-1</td>
<td>FS</td>
<td>9.835e+0 2.846e+0 7.968e-1 1.864e+1 3.697e+0 1.057e+0 1.189e+1 6.831e+0 2.612e-1</td>
</tr>
<tr>
<td>995</td>
<td>CO₂</td>
<td>21 atm</td>
<td>FOF</td>
<td>3.295e+0 2.336e+0 4.795e-1 9.622e+0 7.185e-1 2.103e+1 8.982e+0 2.400e-1</td>
<td>FS</td>
<td>3.399e+0 2.336e+0 4.795e-1 9.622e+0 7.185e-1 2.103e+1 8.982e+0 2.400e-1</td>
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