VALIDATION OF THE RAGE HYDROCODE FOR IMPACT MODELING. C. S. Plesko[1,2], R. F. Coker[1], K. H. Wohletz[1], E. Asphaug[2], and M. L. Gittings[3], [1]Los Alamos National Laboratory, [2]University of California Santa Cruz, cplesko@pmc.ucsc.edu, [3]SAIC.

Introduction: Before a hydrocode is used to make detailed predictions about impact processes, it should be compared to the results of laboratory experiments and currently accepted model estimates. To this end, we compare results from the RAGE hydrocode against laboratory experiments and analytical crater scaling models in preparation for eventual models of impacts into the Martian and Lunar surfaces. Results to date show good correspondence to experimental data and analytical estimates of shock wave properties.

RAGE: The Los Alamos National Laboratory Hydrocode RAGE is a promising tool for the simulation of impact cratering processes. It is an Eulerian code that runs in a variety of geometries, in up to three dimensions, with a variety of equations of state. RAGE has undergone many verification and validation tests of its hydrodynamics. It has been validated against various gas dynamics experiments [1, 2], and at least one involving shocks in metal on the millimeter scale [3]. We now wish to validate it for use in modeling large-scale impact problems.

Lab-scale Impacts into Basalt: In this validation test, we compare the results of a series of gas gun impacts into basalt conducted by Nakazawa et al. [4]

Laboratory Experiments. Nakazawa et al. fired small copper flier plates into rectangular basalt plates interleaved with pressure sensors. The sensors recorded the pressure as a function of time and position within the column. Three different types of shots were done, with peak pressures near 7, 16, and 31 GPa, respectively, in order to examine pressures within the column below, at, and above the Hugoniot elastic limit.

RAGE models. We modeled 35 of Nakazawa et al.'s 38 published measurements in 20 separate model runs. The setup was modeled as a solid column of basalt with fixed tracer particles set at the specified locations of the laboratory pressure sensors. This setup yielded shock pressures comparable to Nakazawa et al.'s measurements for the initial pressure at point of impact, given available strength and equation of state data, and for shock pressure at the sensor location if the sensor was the first sensor in the column [Figure 1]. The shock wave attenuates significantly as it passes through the interfaces between successive basalt plates and pressure sensors.

It is encouraging that the model results show a sensitivity to the material boundaries. This indicates that first-order wave mechanics are correctly obeyed. The results of higher resolution models of the separate basalt plates interleaved with carbon sensors will be presented at the meeting.

Large-scale Impact Model Comparison to Analytical Estimates: A variety of analytical approximations have been developed to predict various aspects of the impact cratering process. Here we run the simple case of a 2-D, cylindrically symmetric solid 10 km diameter granite impactor striking a Mars-like basalt target at 9 km/s and normal incidence for comparison to various analytical models.

Preliminary comparisons of the expanding shock wave to analytical predictions by Chapman and McKinnon [5] and others show close correspondence of the modeled peak shock pressure to the predicted peak pressure proportional to $1/r^n$, with n~2 predicted, and n=1.75 observed in this model. [Figure 2]

Pi-scaling predictions. Pi-scaling of impact processes was developed by Housen, Schmidt, and Holsapple [6]. They use dimensional analysis and Buckingham's pi theorem to develop a set of dimensionless parameters that can be used to relate and compare the properties of very different impact scenarios. They use this and a database of impact and explosion craters with known properties to predict the outcome of a new impact event. For the impact model described above, Pi-scaling predicts a 46 km. diameter crater, with a depth of 12.5 km.

Maxwell's Z-Model predictions. The Z model [7] is a crater excavation model based on explosion crater data. In its simplest form, $y_1=K*E^{(1/3.55)}/g^{(1/6.4)}$, it predicts a radius y_1 ~ 20 km crater for the given initial conditions..

RAGE results for this impact and comparisons to more detailed predictions of both Pi-scaling and the Z-model will be presented at the meeting.

Conclusions: Validation tests for the application of the RAGE hydrocode to impact cratering processes are underway. Preliminary results are promising.

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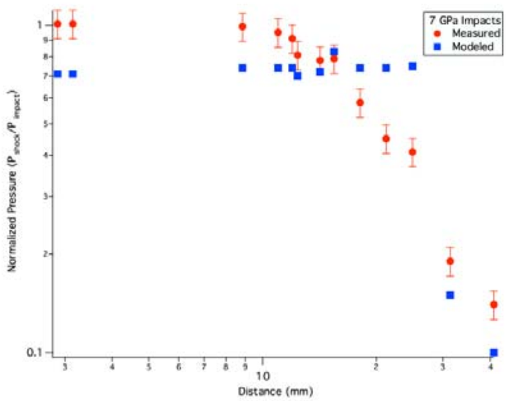

Figure 1: Normalized pressure vs. distance, laboratory measurements (red) plotted with RAGE model results [4] (blue) for the 7 GPa gas gun experiments. RAGE results show unexpected sensitivity to material boundaries, but otherwise show good agreement to laboratory results.

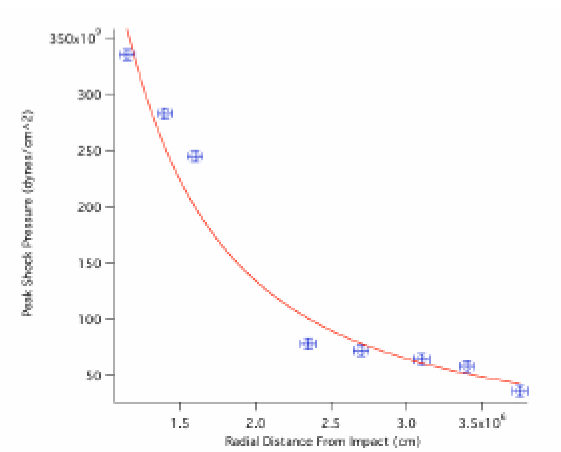

Figure 2: Pressure vs. radial distance from impact site. The RAGE model shows the $1/r^n$ (n~2) fall-off of peak pressure with distance as predicted by Chapman and McKinnon [5] and others. For this model, n=1.75.