ASTEROID ENTRY INTO VENUSIAN ATMOSPHERE: PRESSURE AND DENSITY FIELDS.

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There is considerable evidence[5-8,10-12,14,15] that an ambient atmosphere has an influence on crater formation. The effect is reasonably well quantified for explosive cratering at various depths of burst.[6,7,10] However, for impact cratering there is an additional synergistic effect of the impactor traveling through the atmosphere prior to hitting the surface. This creates a strong shock flow field setting up transient pressure and density variations across the surface. There have been a number of experiments to isolate different aspects of the impact cratering process; in particular, impact at reduced pressure[14,15] and explosive simulation at increased pressure.[11,12] What has not been shown is how size and velocity effects can be scaled to full size applications of interest such as the Venusian crater record. Namely, does the transient crater lip lead or lag the dynamic pressure increase? What is the overpressure and density at the ejecta plume leading the excavation? Is there some time scale after which the remaining variation can be approximated by a constant pressure and density; and if so, are they higher or lesser than the initial undisturbed values?

Recent work[1,9] examines the atmospheric response to a 10km diameter asteroid travelling at 20km/s impacting on Venus. These calculations were made with PHyST, a computational fluid dynamics computer code utilizing techniques developed and validated for the calculation of nuclear airblast and dust/ice clouds.[2,3] Another application of interest using this code was the SL-9 Jovian atmospheric entry calculation[4] in which a scheme for impactor breakup was implemented.

The present study is to investigate the variation of impactor size at fixed velocity on the gas dynamic flow field. As in the 10km case above, the 1km diameter calculation was started with the leading edge of the impactor located at 40km above the Venusian surface and with U = 20km/s. No provision for body deformation or breakup during atmospheric passage was implemented for the present series of calculations. This is not a significant limitation for an investigation of the phasing of the pressure/density field with the kinematics of crater formation. While conventional wisdom indicates that a 1km body would most likely breakup, a 3 or 4km body probably would not and the scaling results can be interpolated or redone if interesting effects are found. What is more important is to vary impactor size over an appreciable range to exercise any effect of the finite height of the atmosphere. For the 10km body the calculated velocity at impact was 19.5 km/s compared to 15.7km/s for the 1km body. Transit times through the atmosphere were 2.01 and 2.16 seconds respectively. Peak pressure on the leading edge of the impactor ramped up to 125 kbar for the large one and 75 kbar for the small one.

To examine the time scale relative to crater excavation time, spatial distribution of pressure and density are shown on the following page for times corresponding to the same extent of crater excavation given as fixed values of R/Rfinal. The heavy curve below the x-axis in each snapshot is the transient crater profile for negligible atmosphere.[13] As can be seen, when the transient crater radius is 23% of the final value, the large impactor (heavy line) creates a many thousandfold overpressure compared with a factor of about 80 for the smaller one (light line). For each, the region of overpressure extends out to the edge of the evolving crater. Note, however, that the density has already begun to fall below ambient for the smaller body, whereas it is an order magnitude larger than ambient for the larger one. As the transient crater approaches the half radius position, the shock wave has begun to pull out in front of the crater and the pressure is about equal for both; but, still an order of magnitude above ambient. Here the shock is further ahead for the smaller one. For the major part of the volume excavation, beyond 0.59 radius (approx. 75%), the pressure is nearing ambient and the density is an order of magnitude below ambient. Also note, due to gravity, final radius/impactor radius for the small one is at an r/a of 7.8 compared to 5.3 for the larger one. In terms of r/a, the shock due to the large impactor is always ahead of that due to the smaller one.

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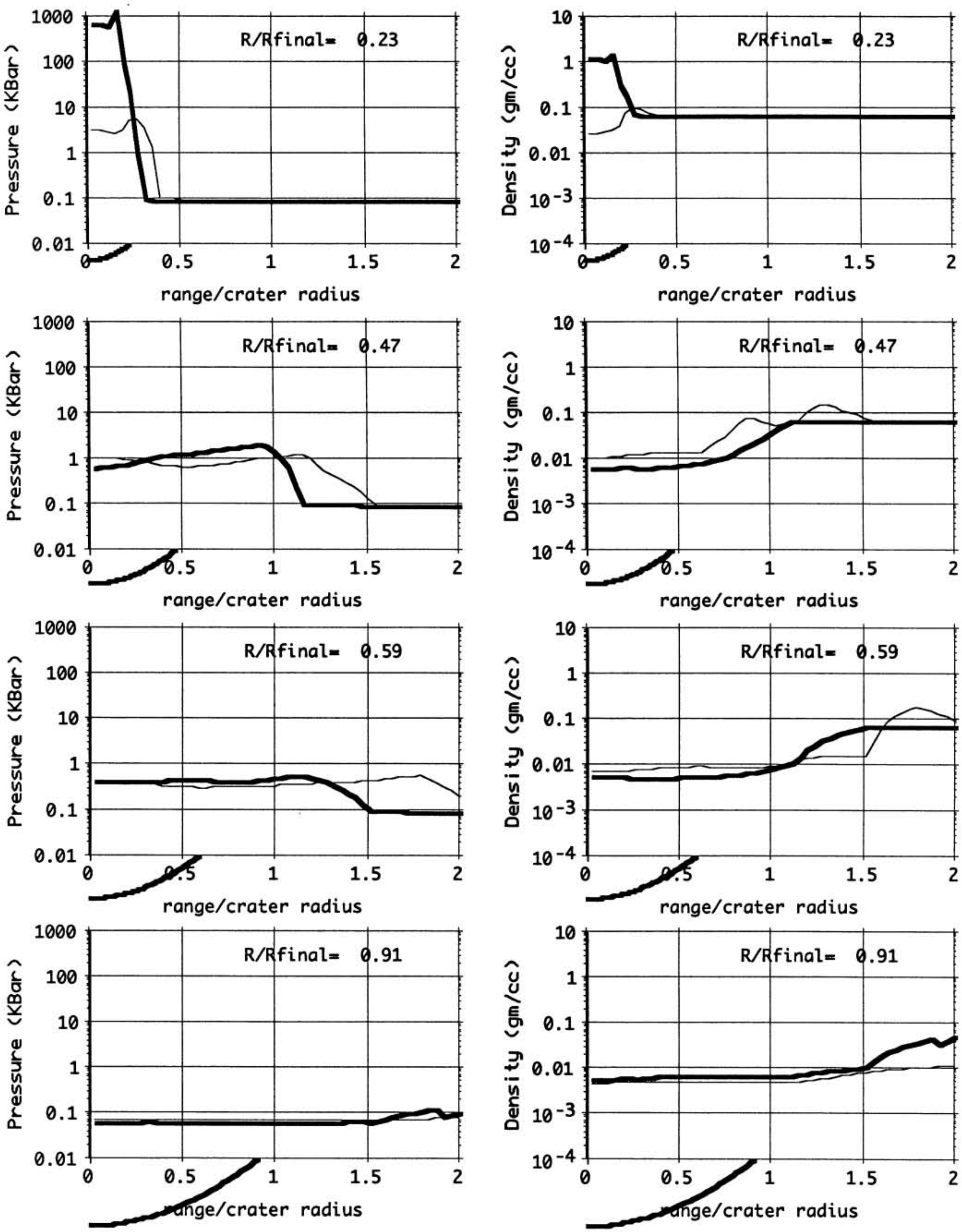
R/Rfinal= 0.23
Pressure (KBar)
Density (gm/cc)
range/crater radius
R/Rfinal= 0.47
Pressure (KBar)
Density (gm/cc)
range/crater radius
R/Rfinal= 0.59
Pressure (KBar)
Density (gm/cc)
range/crater radius
R/Rfinal= 0.91
Pressure (KBar)
Density (gm/cc)
range/crater radius