HEATING DURING ASTEROIDAL COLLISIONS. A. G. W. Cameron and W. Benz, Harvard-Smithsonian Center for Astrophysics, and J. T. Wasson, UCLA.

We are exploring the heat deposition within the rock interiors of asteroidal bodies during collisions, using our three-dimensional smooth particle hydrodynamics (SPH) code, described in connection with our investigations of the Giant Impact theory of Moon formation (1,2,3), modified so that the smoothing lengths of the particles in the code have been made variable.

The code, originally designed to simulate hyper-velocity collisions, does not yet include proper treatment of material strength, elastic-plastic behavior and material failure. In high-speed collisions most of the heating occurs in strong shocks which are treated in the code by a classical artificial viscosity term. This produces heat deposition whenever two particles are in a relative state of compression, whether the motion is supersonic or slightly subsonic. For subsonic collisions, the case here, all the omitted physics mentioned above should ideally be included. In the equations of state which we use, solid materials are under tension below the normal equilibrium density. This tension takes the form of negative pressures and can lead to some unphysical results. Material expelled from the site of the collision, which would normally be subject to tensile failure, tends to hang together in the form of thin filaments. Furthermore, perhaps more importantly, negative pressures imply that heating can occur during expansion (this effect is particularly apparent for particle 4912 plotted on the next page). Although such a heating can occur in nature, it will be limited by the fact that the material will simply break if too much work is exerted on it. The temperatures found in our simulations that do not allow these fractures to occur can thus be overestimated.

As an initial problem we have considered collisions between asteroids of 200 and 300 km radii with relative velocities at infinity of 5 km/sec. The mass of these asteroids is sufficiently small so that this velocity is increased only a few percent during the collision. The collision parameter (aim point) is varied; so far we have looked at central impacts and impacts with aim points half-way out along the radius of the larger body. The initial temperature throughout both asteroids was set at 400 K. At this temperature the sound speed in our rock material, dunite, is 6.5 km/sec, making our collisions slightly subsonic. We placed 3000 particles in the larger asteroid and 2000 particles in the smaller one.

On the following page we show some results for an oblique collision. Particle 3904 is in the smaller body near the point of impact, and particle 4912 is in the smaller body nearly opposite the point of impact. Each graph shows the time history of the temperature and density in the vicinity of the test particles through the period in which the smaller body is completely destroyed and is being dispersed.

Particle 3904 has been shock heated to a temperature above 4000 K immediately following the onset of the collision. The temperature has stayed high and is still increasing throughout the period of the run. The density underwent a strong compression followed by a rarefaction, on which has been superimposed a variety of oscillations. It may be seen that each time the density takes an upturn, the temperature takes another small increase. It should be remembered that at these high temperatures the particles are combinations of liquids and vapor, but our hydrocode does not allow a separation of the vapor from the liquid during the run. In reality the vapor would migrate and recondense, as required to explain the refractory-depleted metal observed in H chondrites by (4).

Particle 4912 has been heated much more slowly to a peak temperature slightly over 900 K. The density underwent a series of oscillations, but of relatively small amplitude. The side of the smaller body away from the contact point of the collision becomes a little underdense, consistent with the behavior of this particle.

This behavior resembles what happens to a bowl of jelly after it has been dropped on the floor (without shattering). All kinds of quivering and oscillating takes place as compressional waves race back and forth through it. In our runs the small asteroid is totally dispersed and so also is most of the larger asteroid. From the range of conditions shown in our time histories, it appears that a single collision such as the one we have described could be responsible for producing much small debris with a correspondingly large range of mineral processing and in many cases straight vapor recondensation. We need to do many numerical experiments to explore the parameters and to verify the heat deposition assumptions in our code. Nevertheless, what has traditionally been described as shock heating in meteoritic material may often be due to subsonic warming.

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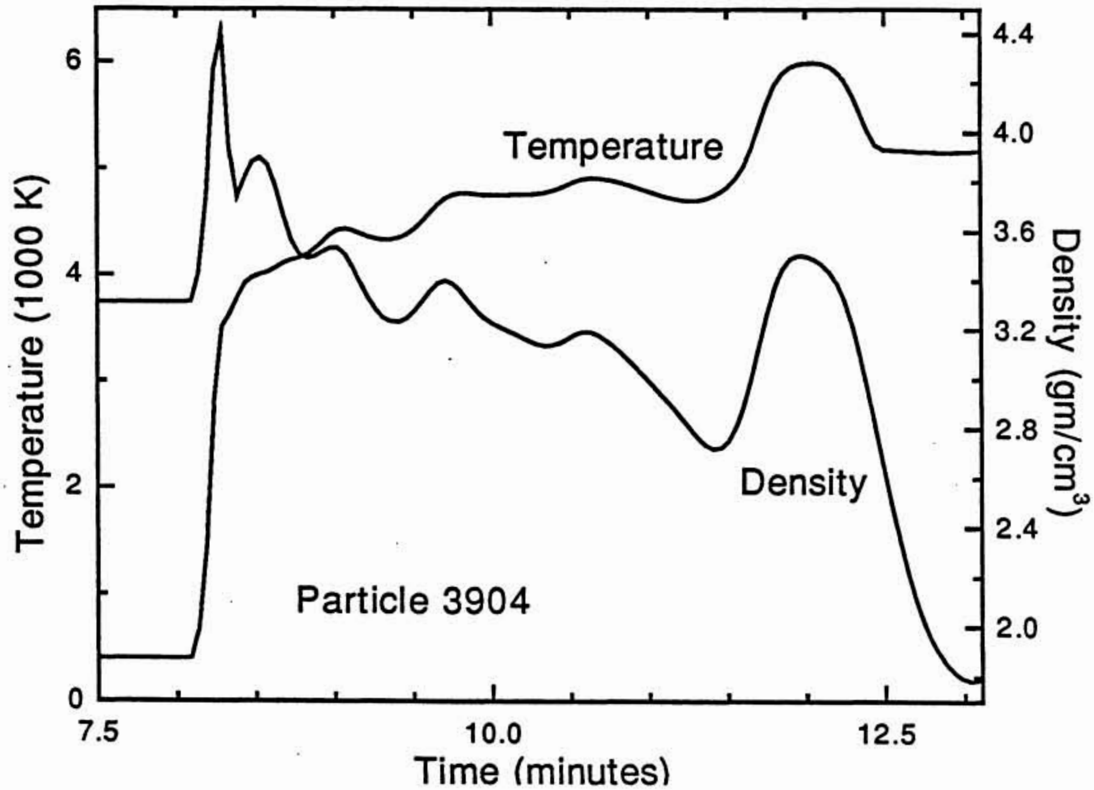

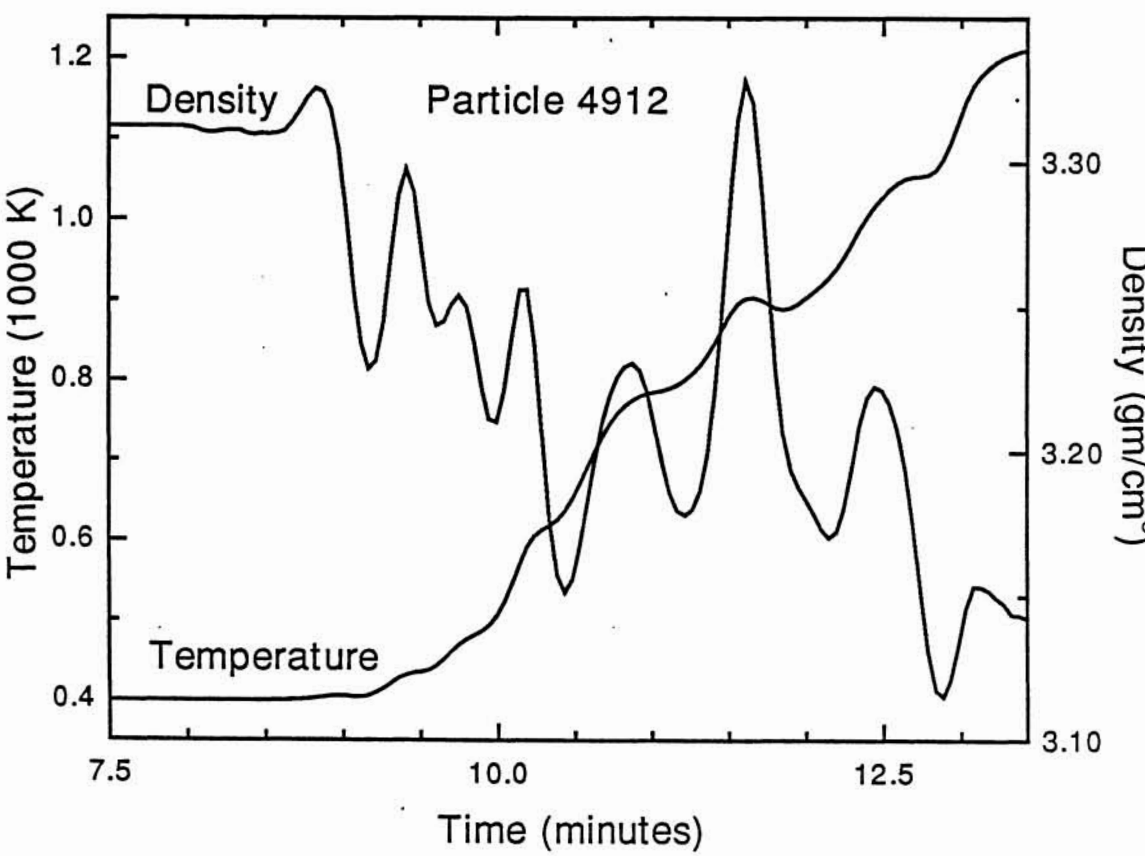

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