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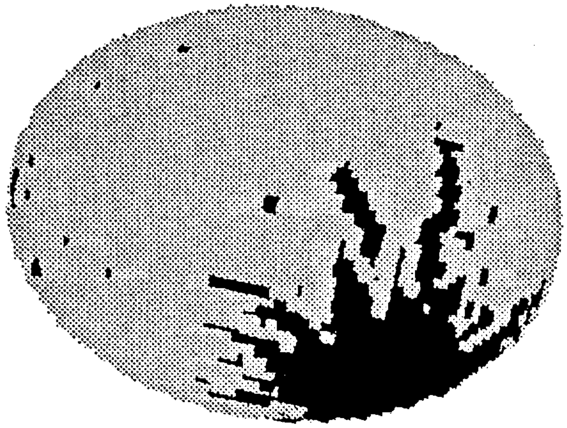
N94- 35400

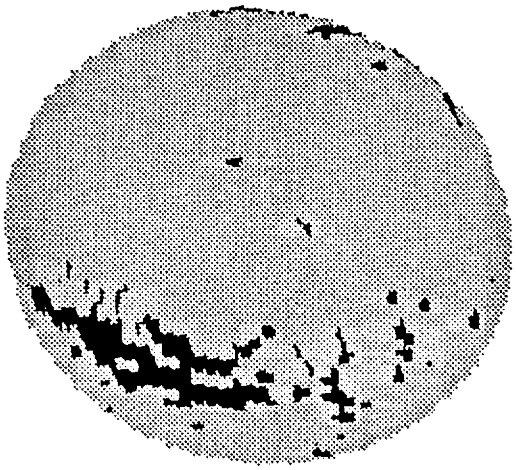
p. 2

THE SURFACE AND INTERIOR OF PHOBOS: E. Asphaug, NASA Ames Research Center 245-3, Moffett Field CA 94035, and W. Benz, Steward Observatory, University of Arizona, Tucson AZ 85721

The impact crater Stickney dominates one hemisphere of the Martian moon Phobos; its diameter (11 km) is about half the size of the body (19 × 22 × 27 km). Besides demarking a threshold between cratering and catastrophic disruption, this impact reveals a great deal about the target's interior. Because Phobos has an unusually low density yet exhibits no direct evidence for volatiles such as water ice, it has been supposed that it sequesters volatiles in the deep interior, or that it is made of some exotic substance, or that it is a loosely-aggregated rubble-pile. The network of fracture grooves created by the Stickney impact constrain which, if any, of these models accord with observation.

We first model Phobos as a homogeneous elastic ellipsoid using the smooth particle hydrocode SPH3D with fracture (Benz and Asphaug, *Icarus*, in press), which is the first hydrocode capable of resolving the dynamical growth of explicit cracks. We use the fracture constants and equation of state for laboratory basalt, substituting a density of 1.95 g/cm^3. A 6 km/s impactor is introduced with the appropriate trajectory (normal incidence at the current center of Stickney) and a size determined by gravity crater scaling[1]. The outcome of this impact is shown in Figs. 1a and 1b, which are surface plots of the damaged ellipsoid 12 seconds after impact, viewed from two sides. Dark regions are fully-damaged computational cells (i.e., cracks) and lighter regions are intact rock. By this time fracture is complete, but the crater bowl has only just begun to develop, with flow velocities of a few m/s.





The fracture grooves antipodal to the crater (1b) do not appear until the final stages of the calculation, when reflected impact stresses come to focus. The fracture orientation is sensitive to the impact locus. Phobos shows a more complex fracture pattern than our simulation, with a general trend correlated with the axis of greatest tidal stress. Nonetheless we feel we have captured the major features of the event.

The damaged region is not quite as large as the predicted size of the final crater, suggesting that strength may indeed play some role in this impact. To test this hypothesis we tried a larger impactor (strength-scaled) to see what would happen. None of the body survived fragmentation, a large fraction escaped, and what remained was transformed into something quite different from the present Phobos. Hence, although the crater does not form purely in the gravity regime, gravity scaling is far closer to the truth than strength scaling. This study confirms the earlier work of Asphaug and Melosh[2] — who used a significantly different numerical method and fracture model, in axial symmetry — that the impact took place essentially in the gravity regime, with a correspondingly slow cratering flow and a retention of crater ejecta. It is worth noting that the crater flow fields predicted by both numerical models are in very good agreement with analytical crater scaling in the gravity regime[3].

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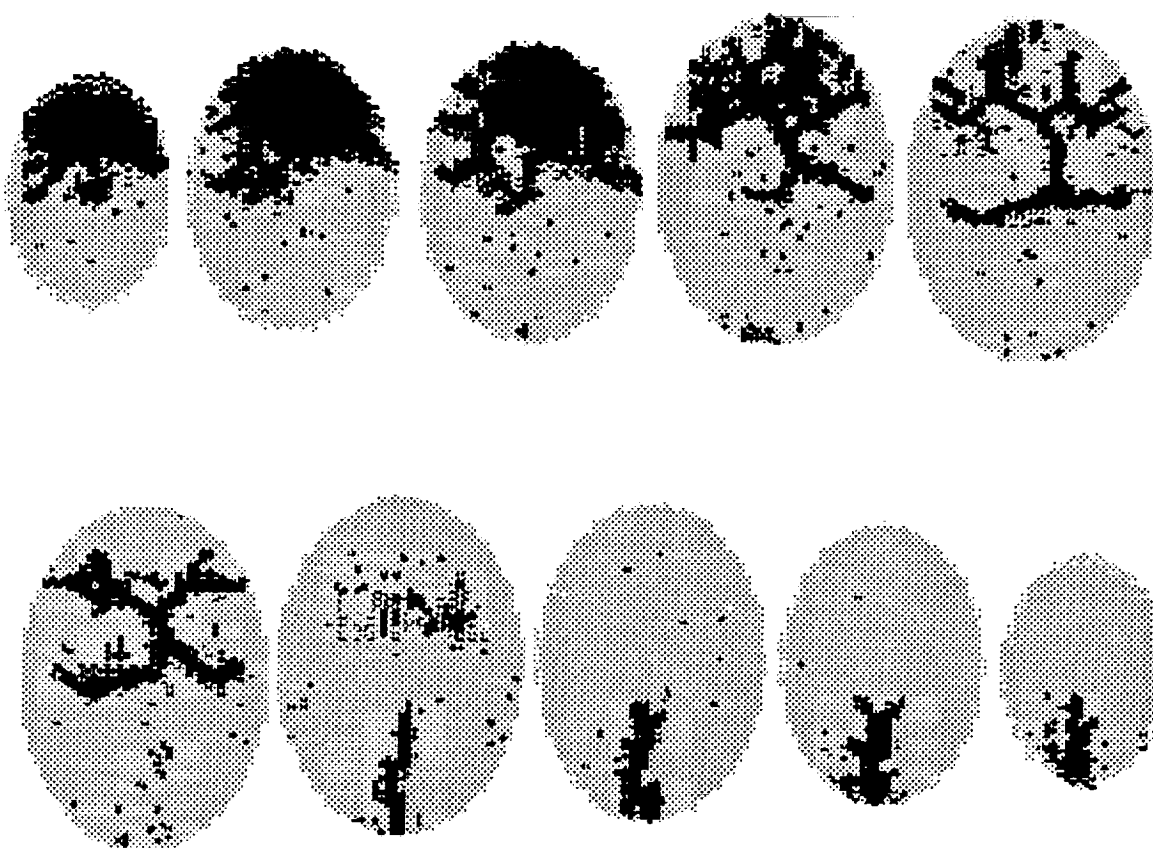
The fracture grooves in Fig. 1 extend deep into the interior, as shown in Fig. 2 below. This series of figures is a slice through the final target, again with damaged regions (cracks) shaded darkest. The slices are 1 km thick, beginning near the crater (i.e., near the bottom front of Fig. 1a) and proceeding into the least-damaged hemisphere, where one can see the antipodal fracture groove. The grooves of Phobos are not mere surface features, but extend deep into the body. Although fractures permeate Phobos, they do not disconnect it (except the near-crater zone), and hence our final target retains a significant fraction of its original strength.



We finally modeled Phobos as an ellipsoid of rock-like density ($2.7\,g/cm^3$) with a random distribution of small "holes" removed to simulate a heterogeneous interior, so that the bulk density was $1.95\,g/cm^3$. The result was dramatically different. Instead of forming the highly organized pattern of fractures seen in Fig. 1 (and on Phobos itself), the impact produced a crater and not much else. In heterogeneous targets (such as rubble-piles) the impact stresses scatter rapidly and are evidently unable to lead to coherent rupture. Hence, the existence of fracture grooves on Phobos, especially those far from the crater (Fig. 1b), leads us to conclude that the target is homogeneous, at least down to a scale smaller than the width of the grooves themselves, i.e. tens of meters. And this, in turn, places a rigorous constraint on the evolution and composition of this ever-mysterious small body.

REFERENCES: [1] Holsapple and Schmidt, *JGR* **92**, pp. 6350-6376, 1987. [2] Asphaug and Melosh, *Icarus* **101**, pp. 144-164, 1993. [3] Housen, Schmidt and Holsapple, *JGR* **88**, pp. 2485-2499, 1983.