LABORATORY SIMULATIONS OF LARGE-SCALE VORTEX FLOWS GENERATED AT IMPACTS ON VENUS AND ON EARTH. V.I.Artem'ev, V.A.Rybakov, S.A.Medveduk, and B.A.Ivanov. Institute for Dynamics of Geospheres, Russian Academy of Sciences, Leninsky prosp., 38-6, Moscow, 117979.

The analysis of the Magellan Mission data suggests that ejecta emplacement and crater formation on Venus are closely related to the atmospheric effects. The formation of the parabolic impact crater related features is supposed to be determined to the injection of small particles to the upper atmosphere and their transport by E-W zonal winds. We propose here another model of ejecta long distant transportation: the escape of ejecta particles to high altitudes can be performed by large-scale atmospheric vortex flows.

Collisions of large meteoroids with planets having dense atmospheres (Venus and Earth) are accompanying by substantial atmospheric disturbances. The impact-generated atmospheric flows with vertical size exceeding the scale height of the atmosphere may be responsible for global propagation of solid ejecta and dust.

In [1] a model for the formation of the parabolic impact crater related features is developed based on the injection of small particles to the upper atmosphere. The vorticity generation at impacts on Venus has been attributed to the interaction of atmospheric blast waves with radiatively heated surface (the thermal layer effect) [2], and to the atmospheric disturbances by the outward moving ejecta [3]. In [4,5] it was emphasized that a disturbance of the atmosphere by falling meteoroid *before* the impact (*i.e.* a formation of the wake of shock-heated gas downstream of the meteoroid) promotes the escape of the ejecta to the upper layers of the Venusian atmosphere; in experiments [6] the near-surface vortex flow has been generated by detonation of an oblique line charge burst simulated the atmospheric wake.

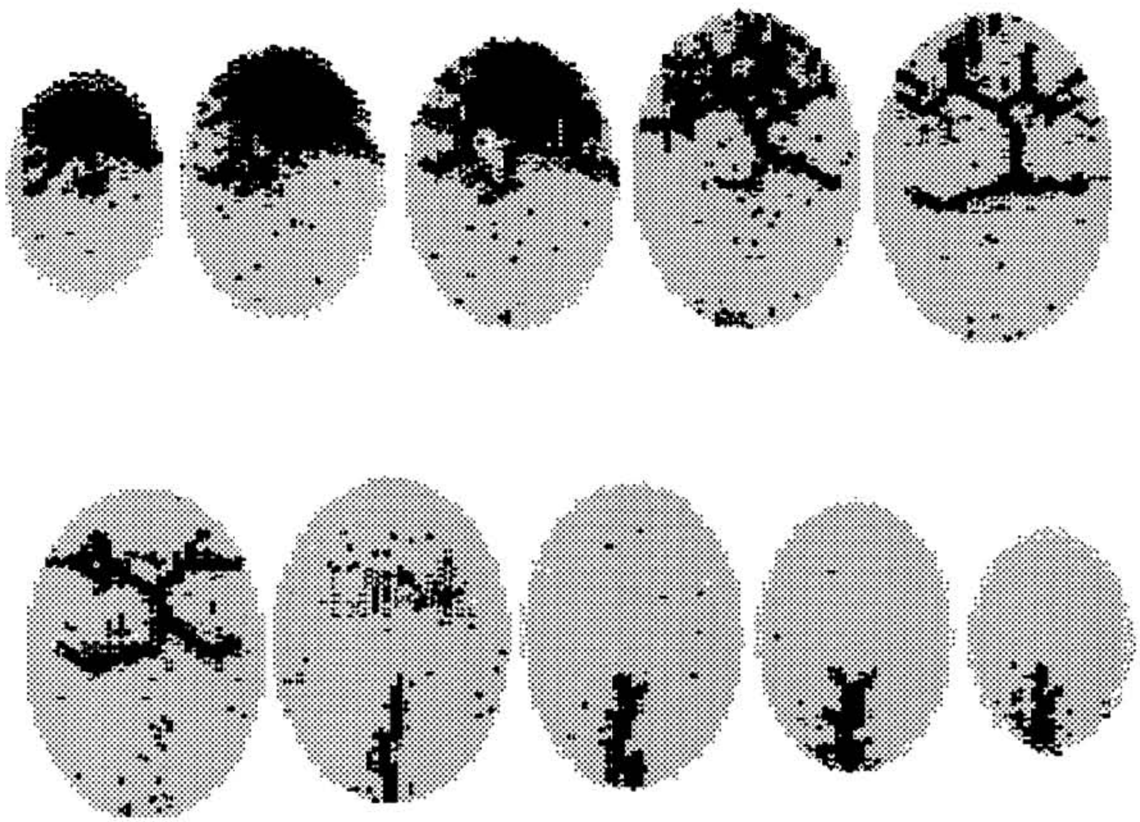
In general, the baroclinity of the gasdynamic flow ($\nabla 1/\rho \times \nabla p \neq 0$, where ρ and p are density and pressure) is responsible for vorticity generation. A complex time-spatial character of energy release during atmospheric flight and at impact of the meteoroid - the inhomogeneity of the atmosphere, the presence of heated channels and layers, crossing shock fronts *etc.* - results in such a baroclinity and hence in vorticity generation. In our experiments we make an effort to simulate the vortex flows resulting from the interactions of impact-generated air blast wave and wake.

The spherical shock wave is produced on action of a focused laser radiation onto a surface. The energy of the laser driven blast is $\mathcal{E} \approx 10$ J. The atmospheric wake is simulated by electrical explosion of a thin wire. On modeling of the impact on the Earth the atmospheric pressure and density in laboratory are the same as in real atmosphere. In this case the energy $\mathcal{E}$ corresponds to the energy of impact-generated air blast E as follows: $\mathcal{E}=(l/\mathrm{L})^3 \cdot \mathrm{E}$, where l and L are the linear scales in laboratory and in atmosphere. The explosion energy for 100 m-stony asteroid falling with velocity ~15 km/s is about $\mathrm{E} \approx 10^{24}$ erg. In this case L=10 km in atmosphere corresponds to $l \approx 5$ cm in laboratory. The energy expended for formation of the atmospheric wake can be estimated in the case considered as $\mathrm{E}_a \approx 2\rho_a \mathrm{H}/(\rho_m \mathrm{D}) \cdot \mathrm{E} \approx 0.1 \cdot \mathrm{E}$, where H≈L=10 km is the scale height of the Earth's atmosphere, and D=100 m is the asteroid's diameter. Thus the energy of electrical explosion simulating the wake must be $\mathcal{E}_a/l \approx 0.1 \cdot \mathcal{E}/l = 0.2$ J/cm.

Fig.1 represents the results of the laboratory simulation of the impact on the Earth: the shadowgraphs of the flow generated on blast-wake interaction at the consecutive points of time. The "experimental" time τ corresponds to the "real" time t as $\tau = l/\mathrm{L} \cdot t \approx 5 \cdot 10^{-6} \cdot t$. In Fig.1a one can see the expanding wake just before the impact, two next pictures illustrate the

THE SURFACE AND INTERIOR OF PHOBOS: E. Asphaug and W. Benz

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.