

## ATMOSPHERIC EFFECT ON CRATERING ON VENUS

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Magellan data showed that some craters have wide dark halos with low radar backscattering cross sections surrounding the ejecta patterns of the craters on Venus. This is a peculiar feature of the Venusian surface. Venus has a thick atmosphere, and as a result, hypersonic impacts of bolides in the atmosphere induce shock waves which interact the surface [1,2]. The gas shocks incident on Venus surface induce regions of high pressure and high shear velocity around impact craters during and after their formation.

We developed a bow shock model to quantify the effects of hypersonic atmospheric shock on a planetary surface and calculate such quantities as maximum gas pressure, shear flow velocity, and the resulting maximum boulder size that can be saltated by the shock-wave-induced flow. The bow shock model applies two dimensional oblique shock dynamics [3] to the three-dimensional paraboloidal bow shock front interacting with an incompressible half-space surface of Venus. This model provides the surface map of the region of gas shock perturbed surface materials for normal and oblique impact as a function of the impactor radius, velocity, and the impact angle of the meteoroid. For example, in the case of impact velocity of 20km/s of the meteoroid and impact angle of 30° above the horizon, the maximum horizontal shock induced gas flow velocity and resulting maximum saltation boulder size are shown in fig.1. The calculated relation between the radius of the halo  $r_h$  to the radius of the meteoroid  $R$  is approximately  $r_h/R \simeq 17v$ , where  $v$  is the impact velocity in km/s, and the relationship between the ratio of the longest to the shortest halo and the impact angle is calculated in fig.2.

This model can be used to quantitatively predict the extent of areas affected by the saltation of particles by shock-induced blast waves which results in the change of the radar properties surrounding some of Venusian impact craters in the diameter range of <15km. The dark halos probably result from a mechanism such that the strong gas flow lofts surface materials and they are ground up and redeposited on the surface. These processes are believed to change the initial roughness, possibly forming smoother surface with fine materials. The blocky boulders that are not broken-up could be redeposited around the dark halos. These would form a rough surface in a scale of radar wave length of 12cm and that could result in the bright halo seen in e.g. the crater located at 16.5°N latitude and 334.4° longitude (fig.3).

Using the bow shock model, scaling law [4], and observing the radius of the halos and the crater diameter, we can estimate impactor radius, density, impact velocity, and impact angle, assuming that the radar properties of the surface will be only changed in the locations where the maximum saltation boulder size is greater than ~10cm. In the case of the crater of fig.3, assuming that the impact is caused by a stony meteorite of the density of 2700kg/m<sup>3</sup>, the impact velocity on the surface is estimated to be 38±8km/s and an estimated radius of the meteorite becomes 185±15m. From the ratio of the longest to the shortest halo, an impact angle from the horizon is estimated about 60±5°.

In a summary, the bow shock model can provide the quantitative estimate for the shock induced surface disturbances.

References ; [1] Phillips, R.J. *et al.* (1991) *Science* 252, 288-297. [2] Ivanov, B.A. *et al.* (1986) *J. Geophys. Res.* 91, B4, D413-430. [3] Hornung, H. (1986) *Ann. Rev. Fluid. Mech.* 18, 35-58. [4] Schmidt, R.M. and K.R. Housen (1987) *Int.J. Impact Engng.* 5, 543-560.

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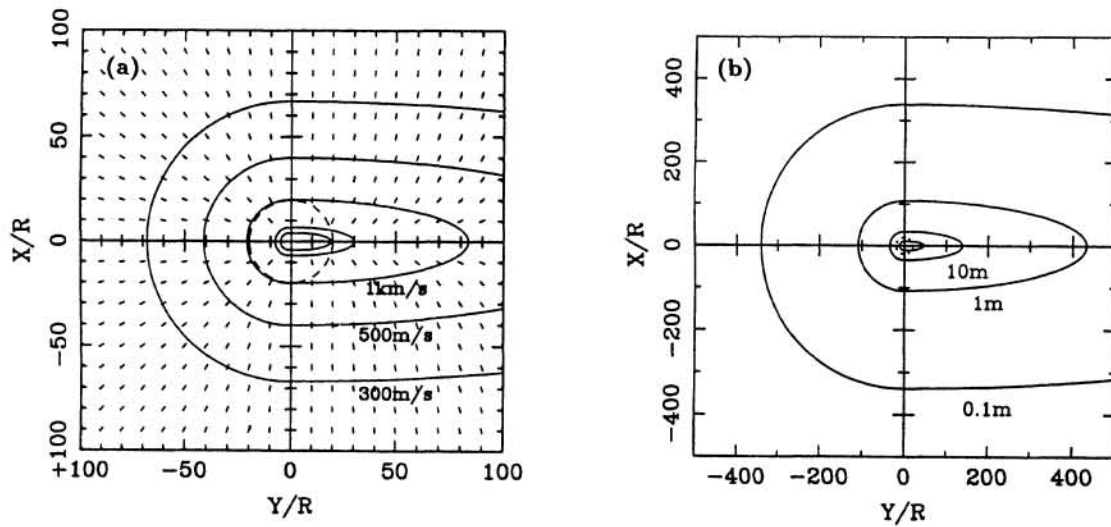


Figure 1. The coordinate is normalized by meteoroid radius  $R$ . Dotted circle represents the crater size for the impact by 1km size stony meteorite. (a) maximum horizontal gas velocity induced by the shock wave and the flow direction. (b) maximum saltation boulder size.

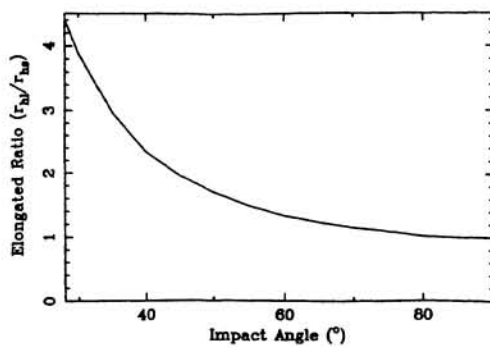


Figure 2. The relationship of the elongated ratio (the longest radius of the halo  $r_{hl}$  to the shortest radius of the halo  $r_{hs}$ ) to the impact angle.

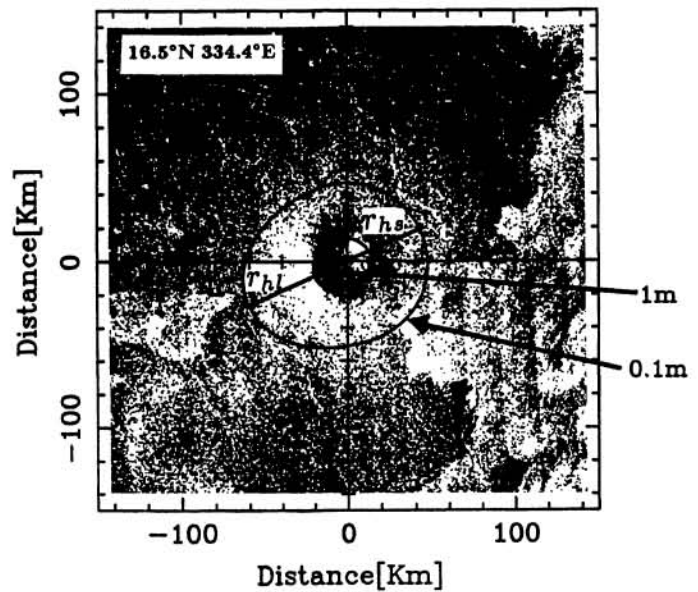


Figure 3. Contrasted image data of the crater located at 16.5°N lat. and 334.4° lon. Contours represents maximum saltation boulder size by the impact of stony meteorite of radius 185m with the impact velocity of 38km and impact angle of 60°.