INCOMPATABILITY OF THE IVANOV AND SHOEMAKER CRATER EJECTION MODELS

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Ivanov (1) has proposed a crater formation model which includes an inverse cubic distance dependence for the initial ejection velocities of fragments during crater excavation. He has made some correlations with laboratory experiments, but it is of interest to apply the model to a large lunar crater. We compare Ivanov's ballistic ejection conditions with those of Shoemaker (2).

Based on theoretical arguments descriptive of a point-impact on the surface of an incompressible fluid, Ivanov expects the target material to be ejected at the surface with speed V, according to the relation

$$V = V_R(R/r_o)^3 \qquad (1)$$

where r_o is distance from impact center, R is the transient crater radius, and V_R is the ejection speed at $r_o = R$. From material strength considerations he obtains values between 0.02 and 0.05 km s^{-1} for V_R if the target is solid rock. Assuming R = 30.5 km and applying ballistic equations for various ejection angles, measured with respect to the target surface, we have calculated the range from Equation (1) and plotted the results in the Figures. The family of curves shown as solid lines results by choosing three values of V_R spanning Ivanov's prediction for solid rock (0.02, 0.03, and 0.05 km s^{-1}).

The Shoemaker ballistic model (2) is based on observations of the positions of 975 secondary craters around Copernicus. For the fragments causing those secondary craters, he derives simultaneous values of ejection speed, ejection angle, and ejection position with respect to impact center. Oberbeck (3) has discussed the Shoemaker model in detail and points out that the model is implausible for a small amount of mass directly under impact center and that the angular range (6 to 22 degrees) may be too large (4); however, he (3) notes that the major results of the Shoemaker model are in good accord with numerous other data. For example, studies of herringbone patterns (5) agree with the Shoemaker model in the specification of an angular range between 14 and 22 degrees as being responsible for the secondary craters. Also, Oberbeck (3) shows that, by incorporating a crater formation rate scaled up from laboratory experiments, the Shoemaker model for individual particle trajectories yields a conical ejecta plume shape similar to lab experiments. It may thus be seen that there is considerable observational support for major aspects of the Shoemaker model (2) of ballistic ejection from Copernicus. To compare directly with Ivanov's Equation (1), one may derive from the Shoemaker model the following relation between ejection velocity V and ejection position r_0:

$$V = 15.57\, r_0^{-1.33} \qquad (2)$$

Comparing Equations (1) and (2), a major incompatability of the two models is revealed by the extreme difference between the r_0^{-3} and $r_0^{-1.33}$ factors. This discrepancy is clearly illustrated in the Figures, wherein we have shown curves of ejecta range both in terms of ejection angle (Figure 1) or ejection position (Figure 2), with the Shoemaker model given as the dotted curve. The horizontal dotted line distinguishes different regions of deposition: Shoemaker's input data did not include the continuous rim deposits, so that the curves should only be compared in their descriptions of the secondary craters. It is seen that about the only way the Ivanov model could yield the proper distribution of secondaries is to make V_R continuously variable, which does not seem to have any obvious justification. That is, instead of changing the "constant" V_R into a variable, one may wish to examine the possibility that the r_0^{-3} dependence represents an unreasonably high velocity gradient.

While the Shoemaker model has defects and is probably not a unique solution to the problem, it nevertheless does properly describe the observed secondary crater distribution around Copernicus. In its present formulation, Ivanov's model does not seem to offer a reasonable alternative description, at least for such a large crater.

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REFERENCES

(1) Ivanov B. A. (1976) Proc. Lunar Sci. Conf. 7th, p. 2947-2965.

(2) Shoemaker E. M. (1962) Interpretation of lunar craters, in Physics and Astronomy of the Moon (Z. Kopal, Ed.) 538 pp., Academic Press, N. Y., p. 283-359.

(3) Oberbeck V. R. (1975) Rev. Geophys. Space Phys. 13, 337-362.

(4) Oberbeck V. R. (1971) J. Geophys. Res. 76, 5732-5749.

(5) Oberbeck V. R. and Morrison R. H. (1974) Moon 9, 415-455.

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