uplifts as a percentage of the total uplifts observed; it is clearly a function of crater size and hence presumably energy. This pattern is repeated if one cumulates the ratio of the eccentric single peaks to the total number of single peaks; a single peak formed in a large crater is more likely to be eccentric than one formed in a small crater. Clearly, these results are inconsistent with the velocity invariance of oblique impacts. Thus one could look for an alternative mechanism, but this should be a by-product of the general uplift process.

It is usually assumed that the probability of finding a central uplift at all increases with the crater size. Although this appears true for very small ones (up to 5 miles diameter), it is no longer true for those greater than 20 miles diameter. In Table I (*b*) I have shown the cumulative distribution of peaks (of all types) as a percentage of the number of craters and find that between 20 and 100 miles diameter the production of peaks is effectively constant. The range of crater size shown probably corresponds to an increase of energy by a factor of about 100. A further breakdown of these data shows that while the total remains constant, the percentage of single peaks slowly decreases while that of multiple peaks increases. (For eccentric peaks only there appears to be a slight maximum in this ratio at about 50 miles.)

In order to explain this invariance in peak production, it is necessary to find an explosive mechanism or a property of the missile or target rocks which is independent of energy. Further data on the extent of the central uplift area are required, but wherever one is formed it would not be unreasonable to suppose that local rock variation would produce eccentric and multiple peak effects observable in the more energetic impacts. Those properties of the missile which are independent of energy include density, tensile strength and direction of impact.

I am, Gentlemen,
Yours faithfully,
D. W. Sida.

Mathematics Dept.
Carleton University,
Ottawa.

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The Orbit of Pluto

Gentlemen,—

We have integrated the orbits of the 5 outer planets over a period of 120,000 years by Cowell's method using the data of Eckert *et al.*[1], and have analysed the motion of Pluto relative to Neptune. The angle $\delta = 3l_P - 2(\lambda_N - \tilde{\omega}_P) - 180°$, oscillates with a period of about 19,670 years and an amplitude of 76°. Here l_P and $\tilde{\omega}_P$ are the mean anomaly and longitude of perihelion of Pluto and λ_N is the mean longitude of Neptune.

The kinematic characteristics of the libration can be portrayed by considering the path of Pluto relative to a frame with its origin at the Sun and rotating with Neptune. This is shown (Fig. 1) for the synodic period of about 500 years. The path is almost periodic. The loops are due to the eccentricity of the orbit of Pluto and the consequently varying speed. In the synodic period there are two passages through perihelion, one at each loop. When the angle δ is at one extremum of its libration, Neptune is fixed with respect to the path at one N. At the other extremum, it is at the other N. Over the 19,670-year period, Neptune librates from one N to the other and back. The closest approaches of Pluto to Neptune are at the loops, where the distance oscillates between 25 and 53 A.U., and near the closer aphelion where the distance is between 18 and 22 A.U. The closest approach is thus determined more by the aphelion distance from the orbit of Neptune than by the perihelion distance. It may easily be reasoned that the libration is dominated by the attraction of Neptune on Pluto in the nearer loop, resolved transverse to the Sun–Pluto line. The libration of Hyperion–Titan may be similarly explained, with 3 loops in place of 2.

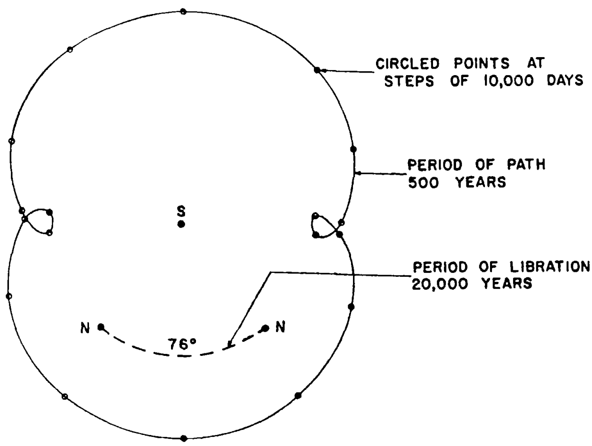

FIG. 1
Path of Pluto about SN at extrema of libration.

It thus appears that the orbit of Pluto is safe from very close approaches to Neptune and no particular instability results from the fact that the radius of perihelion of Pluto is less than the radius of the orbit of Neptune.

We are, gentlemen,

Yours faithfully,

C. J. COHEN,
E. C. HUBBARD.

U.S. Naval Weapons Laboratory,
Dahlgren, Va.,

1964 August 6.

Reference

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