METEORITE IMPACT IN THE OCEAN. R. A. Strelitz, Lunar and Planetary Institute, 3303 NASA Rd. 1, Houston, TX 77058.

Large meteoroids that have struck the land portions of the Earth have left large craters. However, only about one meteoroid in five will fall on land. The remainder fall at sea and, save in exceptional cases, will not leave a permanent crater. There are two possible ways such impacts may have more than a transient effect and leave evidence in the geologic record. First, the transient crater is a deformation of the ocean surface which will cause large amplitude ocean waves similar to those generated by sea bottom earthquakes. Such tsunamis could cause large scale flooding and create poorly sorted, thin and widespread debris layers. Second, the impact will generate a large shock wave in the ocean which might cause shattering of the thinner oceanic crust and hence local venting of magmas. Only the former problem is considered at this time.

The solution is obtained in stages; at each step, the procedure consists of making an analogy to a similar land based phenomena and applying it to an oceanic impact.

1. The first stage is to calculate the depth to which the meteoroid will penetrate before the shockwave in the impacting body reaches the trailing edge. This depth is found by making simple and simplistic shock wave calculations for an iron body, ignoring edge effects and using data for the compressibility of both target and meteorite at high pressures. This is an over-estimate of the penetration depth. Shock pressures are about 1/3 that of a similar impact into a sandstone target (1), but the penetration depth is twice that of a sandstone target.

2. Using this depth as the starting point for a calculation of the depth of the transient crater, one can apply any one of a number of energy-depth-diameter relationships (2), one can determine the size of the transient cavity as a function of meteoroid mass and velocity. In fact, the relationships cited above may not be applicable to oceanic impacts for which the crater is expected to be flatter (Schultz, personal communication), but the order of magnitude should be approximately correct. Another assumption is introduced here - that the cavity forms instantaneously. The validity of this is at best questionable, but it serves to set an upper bound on the waves generated.

3. Given the shape (Fig. 1) and size of the transient cavity, one can easily determine the nature of the waves generated by the return of the water surface to an equilibrium configuration. The approximation used here is that of the shallow water wave theory, suitable for situations in which the water depth is less than the wavelength. This part of the analysis is exactly the same as the techniques used to determine wave structure for earthquakes and explosions at sea.

Waveheight dies off as $1/r$, with $1/r^{\frac{1}{2}}$ due to the effects of the spreading out of the wave and the rest due to the dispersive nature of the waves. The ocean bottom is assumed to be uniform in depth and featureless; topography of the sea floor will lead to local magnification and attenuation, but these effects may be neglected in the problem at hand.

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4. The most difficult problem is how to calculate the waveheight in the near shore region - the run up height - defined as the height of the wave as it passes the mean shore line. These calculations are highly non linear and depend very strongly on the geometry of the beach, both in terms of the shape of the shoreline and the profile of the zone between the deep ocean and the shore. For the simplest case, a linear beach with a ramp transition from deep to shallow, the solution may be approximated analytically. In no case is it possible to make any statements about breaking waves, because such calculations are more difficult yet. The results for simple cases show that the run up depends linearly on the deep water wave height and hyperbolically on the wavelength. Because the wavelength is a function of the initial source size and the amount of dispersion of the wavetrain which is in turn proportional to the distance traveled, the run up due to a 1-2 km crater is not as large as that due to a 60 km long fault with only 1 meter of vertical displacement. Further, there is a distance from shore at which the run up is maximal because of the competing effects of the attenuation of the waveheight and the dispersion of the waves.

One can define an amplification factor as the number by which the open water wave height is multiplied by the effects of the shore. This number ranges from 25 for concave slopes to several hundred for convex slopes (see Fig. 2 a,b,c).

5. If one selects a certain level of run up as a "detectability threshold", one can calculate the probability of an impact causing a tsunami whose run up exceeds that threshold. The key here is to assume a population distribution of meteoroids. Then, one can calculate the chance that a certain size body will fall within a certain range of shore. Applying the previous results, it is a comparatively easy matter to determine whether or not the detectability threshold was exceeded. Using this formalism, one can easily find the expected number of detectable impacts per million km^2 per billion years; although the numbers are small, they are not insignificant. For the largest class of craters considered (radius = 20 km) the rate of detection is essentially the flux rate, or at any distance from shore, it generates significant run up. For smaller events such as those similar to Meteor Crater in Arizona, it must land within 160 km of shore to generate greater than 10 m of run up.

Summing up the total number of events of all classes that would be detectable (using a 10 m threshold, an admittedly optimistic number) some 100 events should have been detected. For a truly catastrophic run up (100 m), the numbers are reduced by more than an order of magnitude. Now that it is clear that several such events should have occurred, it is important to consider what evidence they would leave in the geologic record.

REFERENCES:

(1) Shoemaker E. M. (1960) Report of International Geological Congress XXI Session, p. 418-434.

(2) Anselmo J. C., Rehfuss D., Kincheloe N., Michael D. and Wolfe S. (1977) (Abstract). Symposium on Cratering Mechanics, p. 12-14.

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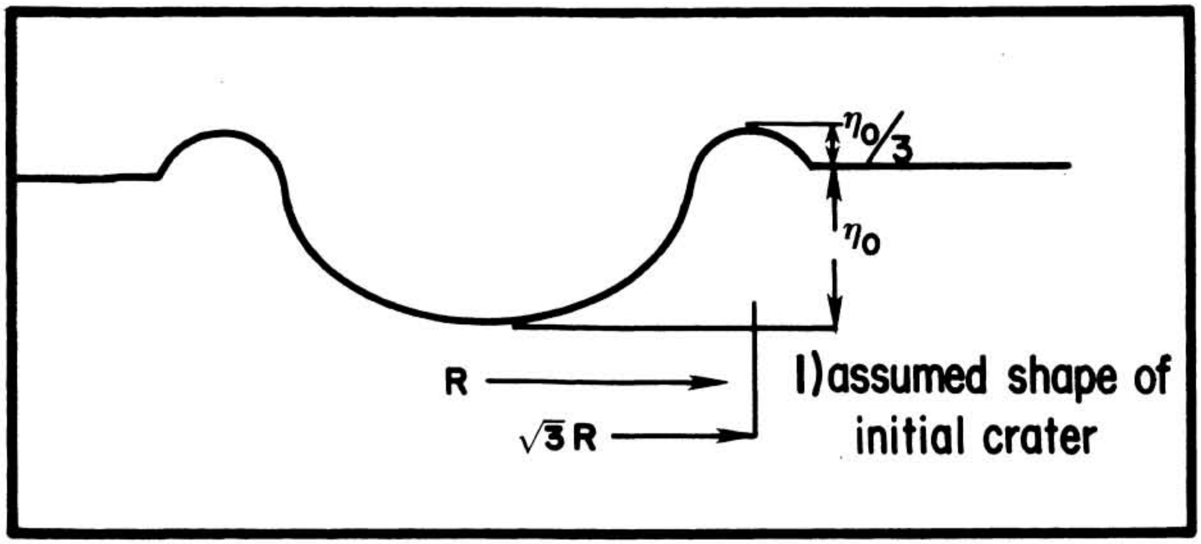
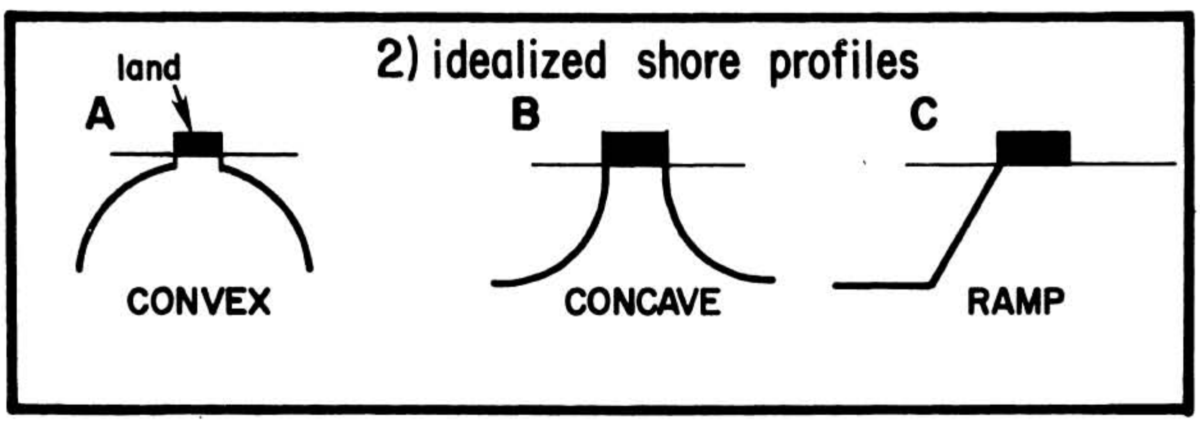
FIGURES:



1) assumed shape of initial crater



2) idealized shore profiles