

THE IMPACT OF METEORS¹

By John D. Boon

Energy changes that occur when a meteor strikes the surface of the earth or the moon, are difficult to determine. The velocity of meteors is so much greater than that of molar masses with which we are familiar, such as projectiles of high powered rifles, that there is little basis for comparison. The kinetic energy of a meteor may be two or three thousand times as great as that of an equal mass shot from a high powered gun, hence it is possible that all present experimental data are misleading. The greatest kinetic energy concentrations known are of submolecular bodies, such as are being used so successfully in the disruption of atoms. Next in order of energy concentration, one would think, is that of suns and planets moving with great speed. Neither the submolecular nor the large astronomical bodies offer an opportunity for experimental studies of the energy changes that occur when meteors strike the surface of the earth or the moon. However, it is generally believed that the kinetic energy is largely changed into heat.

Fairchild² has suggested that in the case of Meteor Crater, in Arizona, the energy was dissipated as follows:

- (1) Crushing of the rocks beneath the locus of impact.
- (2) Shattering of the rocks laterally, with expulsion of the rock strata surrounding the impact area.
- (3) Vibratory motion that shivered the sand grains of the Coconino sandstone.
- (4) If the meteor was largely brittle material as will be claimed below, it was also shivered.
- (5) Production of great heat.

¹In this article no distinction has been made between "Meteors" and "Meteorites," the term "Meteor" is used to include all bodies that come from out in space and fall upon the surface of the earth or the moon.

²Fairchild, H. L., "Nature and Fate of the Meteor Crater Bolide", *Science*, Nov. 7, 1930, pp. 463-467.

The writer believes that in the main, Fairchild's analysis is correct not only for Meteor Crater but also for all great impacts upon the earth or the moon. However, he wishes to modify this analysis by contending, first, *the amount of energy dissipated as heat may vary widely, and is often relatively small*, and second, *as a rule a large amount of energy is transformed into vibrations that run through the earth or the moon*. The bases of these contention are three fold:

(1) The craters that have been formed by meteors (such as Meteor Crater) show little evidence of heat. Oliver³ in his book on meteors, calls attention to this fact and wonders why it is true. Nearly all articles that have been written concerning the impact of meteors assume that great heat must have been produced, and yet, in the crater mentioned above and in all other craters known to be due to meteors, there is little evidence of heat other than from frictional heat of its passage through the atmosphere. The Wabar⁴ Crater found in the sands of the Arabian Desert may be an exception to this statement. In the walls of this crater and near by, a large amount of fused quartz has been found.

(2) The contention that but little heat is produced, is based on experimental evidence. For sometime, attempts have been made to measure the heat produced by crushing granite, feldspar, basalt, and glass marbles. The results are significant. A hammer weighing 32 pounds was constructed so that it would fall two feet upon a mass of rock, the fall being repeated rapidly until a powder was produced. The total energy expended was calculated and the rise in temperature determined, assuming, for the purpose of calculation, that all the energy expended was changed into heat and applied solely to the mass of rock. In all experiments, the rise in temperature was never more than a small fraction of the calculated value. Not all the heat produced

³Oliver, Charles P., *Meteors* p. 250.

⁴Spencer, L. J., "Meteorite Craters as Topographical Features on the Earth's Surface". *Annual Report of The Smithsonian Institution* 1933, pp. 307-326.

would be found in the crushed rocks, but, if the major portion of the kinetic energy of the falling hammer was changed into heat, a much larger quantity should have been found in the crushed materials, for most of the work done is applied to the rock that is being crushed. As yet, it has been impossible to measure, with much accuracy, the temperature change that takes place when rocks are crushed to powder, since the actual change is too small. However, experiments indicate that in no case did more than ten per cent of the expended energy appear as heat, and in most cases the amount was much smaller. Soft white marble showed the greatest rise in temperature when crushed, while a large number of glass marbles revealed a change so small that it was within the error of measurement. In crushing various samples of granite the heat energy produced was in all cases less than five per cent of the total energy expended. These experiments will be continued with the hope that a more accurate method of measurement will be found. *At present it seems quite certain, from experiments that have been made, that brittle rocks suffer but little change in temperature when crushed by a falling weight.*

(3) The third basis of this contention is founded upon the laws of impacts. If a steel ball falls upon a cement floor, it will rebound to a height nearly as great as the point from which it started. This is an illustration of elastic impact, a case in which but little kinetic energy is lost and therefore but little heat produced. If a lead ball falls upon a cement floor there is no rebound. This illustrates inelastic impact, an impact in which practically all the energy expended is changed into heat. If a glass ball falls a short distance upon a cement floor, its behavior is the same as that of the steel ball. If, however, the glass is dropped from a great height so as to acquire high speed, it will shatter into fragments. The only considerable quantity of heat possible, it seems, is due to friction of the particles after they are formed. It is this surface friction that accounts for most of the rise in temperature observed when rocks are crushed in the laboratory. This also explains the formation of masses of fused quartz, when the Wabar meteor fell on the Arabian

Desert. The sand was already largely pulverized, and incapable of transmitting waves, hence great heat became necessary in the dissipation of the energy.

In all elastic bodies whether brittle or not, a considerable portion of the energy of an impact is dissipated by means of waves that run through the entire medium. It is the energy of these waves that brings about the destruction wrought by earthquakes, and at times the amount may be great.

In the case of meteor impacts upon the surface of the moon, it should be remembered that neither atmosphere nor soil protects the solid rocks; hence, all impacts, initially at least, were pulverizing and but little heat produced. However, if we take into consideration the age of the moon, and the estimate that no less than one million meteors strike it every twenty-four hours, it seems reasonable to suppose that its surface is covered to a great depth with rock flour or ash. Apparently there is not one square inch of the moon's surface that has not at some time felt the impact of a meteor with energy equal to a modern auto traveling at the rate of sixty miles per hour. In recent years the existence of a great mass of ash over the surface of the moon has been proven by a study of the character of the light that it reflects. If it were possible for a wind to blow across its face with a velocity of thirty or forty miles per hour, its topography might be greatly altered. The lightness of the ash that covers the surface of the moon offers but little protection from the meteors that continue to fall, hence destruction continues.

When a high speed rifle bullet is fired into a plate glass a round hole is produced not much larger than the bullet. The whole event occurs before strains have time to spread over a large area. Something of the same character apparently takes place when a small high speed meteor strikes the surface of the moon. It is true that the cases are not quite parallel, because of the limited thickness of the plate glass. Certainly the duration of a meteor impact is very short, with but little time for strains to spread over a large area. Perhaps they make up in depth of penetration what they lack in cross-sectional area.