It is interesting that Urey[6] and, more recently, Cameron[7] have suggested that enstatite is probably a constituent of the lunar surface.

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GEOPHYSICS

Mass of the Canyon Diablo Meteoroid

NORDYKE[1] has derived empirical scaling laws for the apparent radius R and the apparent depth D of craters produced by both chemical and nuclear explosions in desert alluvium at the Nevada Test Site. The scaling equations are $R = R_s W^{1/3.4}$ and $D = D_s W^{1/3.4}$, in which R_s and D_s are the appropriate dimensions for a 1 kt (kiloton) explosion of TNT and W is the yield in kt of the explosion in question.

If the dimensions of the Canyon Diablo meteorite crater scale in accordance with the same empirically derived equations as the dimensions of the explosion craters examined by Nordyke, then his equations can be used for calculating the energy required for production of this meteorite crater. The apparent crater for the Canyon Diablo meteorite is generally quoted as having a 4,000-ft. diameter and a 570-ft. depth[2]. The ratio of apparent radius to apparent depth is then 3·5. A value of 3·5 for the ratio of apparent radius to apparent depth occurs in Nordyke's plots close to the surface (at a scaled depth of not more than 20 ft./kt$^{1/3.4}$) and again at a scaled depth of about 200 ft./kt$^{1/3.4}$.

If the energy used in producing the Canyon Diablo crater was expended near the surface of the Earth, Nordyke's scaled apparent crater depth indicates that $W^{1/3.4} = 570/30$ kt, such that the energy necessary to produce the crater is $W = 2{\cdot}2 \times 10^4$ kt. A comparable calculation, using the apparent crater radius, gives $W^{1/3.4} = 2{,}000/110$ kt, such that $W = 1{\cdot}9 \times 10^4$ kt. Thus, if the energy which produced the Canyon Diablo meteorite crater was expended at a scaled depth less than 20 ft./kt$^{1/3.4}$, it amounted to a yield equivalent to about 20 megatons of TNT. At a yield of 20 megatons, a scaled depth of 20 ft./kt$^{1/3.4}$ is a depth of 400 ft., so, when we say that the equivalent point of detonation is at a scaled depth less than 20 ft./kt$^{1/3.4}$, we are saying that the explosion occurred somewhere between the surface and a depth of 400 ft.

At a scaled depth of 200 ft./kt$^{1/3.4}$ the equivalent yield of TNT calculated from the apparent crater dimensions is about $1{\cdot}1 \times 10^4$ kt. For a yield of 11 megatons of TNT a scaled depth of 200 ft./kt$^{1/3.4}$ is more than 3,000 ft.—a value which appears to be in excess of the depth to which the meteorite penetrated, hence will not be considered further in this communication.

Based on this information we can calculate the mass of the meteoroid that would have had to hit the Earth to release an amount of energy comparable to 20 megatons of TNT. An energy of 1 kt is[3] 10^{12} calories, or $4{\cdot}2 \times 10^{19}$ ergs, so 20 megatons is comparable to $8{\cdot}4 \times 10^{23}$ ergs. If we assume that the energy W comes solely from the kinetic energy gained from gravitational attraction, $W = 8{\cdot}4 \times 10^{23} = G\frac{mM}{r} = (6{\cdot}26 \times 10^{11})\ m$ ergs, in which $G = 6{\cdot}67 \times 10^{-8}$, the mass M of the Earth is $5{\cdot}98 \times 10^{27}$ g and the Earth's radius r is $6{\cdot}38 \times 10^8$ cm. The mass of the meteoroid is then $m = (8{\cdot}4 \times 10^{23})/(6{\cdot}26 \times 10^{11}) = 1{\cdot}34 \times 10^{12}$ g. The magnitude of this mass could have been less if the meteoroid had a measurable velocity relative to the Earth prior to its entry into the gravitational field of the Earth. Since retrograde motion of objects in solar orbit are essentially unknown, a maximum velocity of 30 km/sec for the meteoroid relative to the Earth appears to be a reasonable assumption. With a kinetic energy produced by a relative velocity of 30 km sec added to the gravitational energy, a meteoroid mass of $1{\cdot}6 \times 10^{11}$ g is needed to provide an energy of $8{\cdot}4 \times 10^{23}$ ergs at the time of contact with the surface of the Earth.

The mass found by this empirical method is intermediate between those theoretically predicted by Öpik[4] and by Bjork[5]. In general, the empirically determined mass appears to be in better agreement with Öpik's predictions. The higher mass value of $1{\cdot}34 \times 10^{12}$ g overlaps Öpik's predictions whereas the lower limit of $1{\cdot}6 \times 10^{11}$ g corresponds closely to the upper limit of Bjork's predictions.

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MINERALOGY

Pyrochlore Minerals as a Potential Source of Reactor-grade Niobium

FOR many years the chief source of niobium has been the mineral 'columbite', a member of the columbite-tantalite series (Fe, Mn) (Nb Ta)$_2$O$_6$. As the name of the series implies, niobium (columbium) and tantalum occur in varying ratios, but even at the columbite end the proportion of tantalum is still appreciable, the ratio of niobium to tantalum being generally of the order of only 6 : 1.

An important application of niobium is in nuclear power production, where what is known as 'nuclear-grade' niobium must contain less than 0·15 per cent by weight of tantalum (0·05 per cent in the United States). This requirement is based partly on physical properties and partly on the nuclear characteristics of the metal. In the production of pure niobium metal an essential step, therefore, is the careful separation of niobium and tantalum. In current industrial practice this is achieved by liquid/liquid extraction from an aqueous acid solution, using hexone (methylisobutylketone)[1].

Attention has been increasingly directed during the last decade to another source of niobium, 'pyrochlore', essentially a calcium niobate (Na, Ca)$_2$ Nb$_2$ O$_6$ (OH, F, O). Significant sources of this mineral have been discovered in several countries, but so far most of these are still the subject of intensive mineral processing research. Like columbite, pyrochlore is a member of an isomorphous, although not necessarily continuous, series, the end-members of which are pyrochlore and microlite. There is, however, an important distinction between the two series, columbite–tantalite and pyrochlore–microlite, in the way they occur in Nature. While the commonly occurring columbites always contain appreciable concentrations of tantalum, most analyses of the pyrochlore-microlite series, on the other hand, are close to one end or the other, so far as the niobium and tantalum contents are concerned[2]. This finding, supported by extensive data published recently[3], appeared to us to be of special significance, because of the prospect that high-purity niobium might be produced in future from a suitable pyrochlore source, without the expensive niobium-tantalum liquid–liquid separation step.

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