The research at the University of California was supported by the U.S. Air Force, Aeronautical Systems Division, through contract *AF* 33(615)-1140.

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GEOPHYSICS

Munro Jets and the Origin of Tektites

THE theory of Spencer[1] that tektites splashed out of terrestrial craters met with support from Cohen[2], Gentner and Zähringer[3] and others, but also with objections, summarized by O'Keefe[4]. The main objection was that the air resistance of bodies as small as tektites on their upward flight is too large to allow them to escape from the crater at the velocities (2–8 km/sec) required for their observed ranges. Vand[5,6] proposed a detailed mechanism of a tektite jet formation through an implosion of a conical cavity lined with molten glass which is formed immediately after impact, and showed that a jet of tektites can survive the upward atmospheric journey if of sufficient total mass; that is, if it originated in a crater more than some 4 km in diameter. The escape is further facilitated by the low density of the hot train left after the passage of the meteorite. The high-velocity jet overtakes the general debris and keeps tektites from crystalline contamination. If moldavites are from the 24 km diameter Ries Kessel crater in Germany, the tektite jet from an initial conical cavity 4 km deep and 1 km in diameter would be a cylinder about 5 km long and 40 m in diameter, moving initially at 2·36 km/sec and carrying some 10^{10} kg glass with it. The original of the required cone wall implosion velocity of about 0·15 km/sec was not well understood, as such a phenomenon had not then been observed in laboratory cratering experiments, and gravity collapse could only account for part of the velocity.

However, the work of Watson and Gibson[7] on jets formed from imploding bubbles seems adequately to elucidate the operating mechanism. Photographs are given of beautiful Munro jets formed when hemispherical cavities on the surface of a liquid are collapsed by a shock-wave travelling from below. Shock strength of some 10 kbar produces 1·9 km/sec Munro jets from cavities in water.

After a meteoritic impact, a travelling shock-wave can be reflected upwards from underlying denser rock strata. Reflexion and refraction of shock-waves are complicated phenomena. For acoustic waves of small amplitude, travelling from medium 1 to medium 2, the ratio P_r/P_i of reflected to incident pressure is given by

$$P_r/P_i = (m - 1)/(m + 1)$$

where $m = d_2c_2/d_1c_1$ and d_1, d_2, c_1, c_2 are the densities and sound velocities in medium 1 and 2. For shock-waves of large amplitude, much higher pressures can build up, so that the above expression is a lower limit. The boundary does not need to be sharp.

Typical boundaries which may be encountered under terrestrial conditions at smaller depths are those of granite (d = 2·65, c = 5·5 km/sec) over diorite (d = 2·9, c = 6·5 km/sec) or at depths of some 40 km (Mohorovičić discontinuity) of diorite over dunite (d = 3·4, c = 7·75 km/sec). We find for P_r/P_i for the above two cases 0·12 and 0·16 respectively.

Assuming that Ries Kessel was formed by an iron meteorite 1 km in diameter travelling at 15 km/sec and having kinetic energy equivalent to 10^5 megaton TNT, we find by analogy with nuclear explosions that a 100 kbar shock would be found at 2·5 km from the blast centre. According to Shoemaker[8], the blast centre occurs at 4 to 5 meteorite lengths after ground penetration. Assuming that the meteorite arrived at an angle 30° from horizontal, as required by the range of moldavites, the centre of explosion would be at 2 km depth and therefore a downward travelling 100 kbar shock would be found at 4·5 km depth. If at this depth there happened to be a discontinuity reflecting about 15 per cent of pressure, an upward travelling 15 kbar wave would form, which would attenuate to 10 kbar when reaching the cavity.

The implosion velocity which occurs on the arrival of the reflected wave is a spalling effect due to its reflexion at the free cavity interface. The implosion velocity at the free interface is then twice the instantaneous particle velocity, which is given by $v = P_s/c\ d$, where c and d are the velocity of propagation of the longitudinal wave and density at shock pressure P_s. Substituting for glass d = 2·5, c = 5 km/sec, P_s = 10 kbar, we obtain v = 75 m/sec or the implosion velocity $2v$ = 0·15 km/sec, which is just the required value for the cavity collapse to generate a backsplash jet of the required velocity.

We may further speculate that the general inward motion of other crater materials caused by the passage of waves reflected from below will also be responsible for the formation of a central peak in some craters, if underlain by denser strata at favourable depth. In fact, the central peak of Steinheim basin may have been formed through reflexion at the underlying limestone-granite boundary, and the peaks of certain other large craters through reflexion from Mohorovičić discontinuity. Similar interpretation of central peaks of lunar craters might help in mapping such discontinuities under the lunar surface.

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GEOLOGY

Origin of Silcretes of Central Australia

RECENTLY, Stephens[1] has suggested that the widespread silcretes of Central Australia can be explained by a sequence of three events: (1) mobilization of silica by lateritic weathering in the area of the present watershed of eastern and northern Queensland; (2) deposition of the silica after south-western transportation in streams and rivers for considerable distance (up to 900 miles) on a wide, gently sloping surface underlain by a large array of rocks; (3) erosive break-up of the silcrete sheet so formed due to rejuvenation, to leave caps on mesas and extensive stony pavements.