THE ORIGIN OF THE SHAPES OF LUNAR GLOBULES

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Abstract. This paper considers three hypotheses for the origin of the shapes of the regular elongated prolate and dumbbell-shaped lunar glass globules. These are the break-up of a jet, the vibration-freezing hypothesis and the rotational hypothesis. It is concluded that there are many results favouring the latter hypothesis so that its validity now appears conclusive. Applications of the hypothesis as a tool in lunar science are briefly discussed.

Soon after the return of lunar rock, it was suggested that the shapes of the regular dumbbell and oblate glassy objects and lunar rock were a consequence of the angular momentum they possess whilst cooling in free flight above the lunar surface (Bastin and French, 1970). Subsequent papers, Pugh (1972), Bastin and Volborth (1974), Cloud et al. (1970), Fulchignoni et al. (1971), gave evidence in favour of this view. An alternative proposal imagined that the regular elongated shapes result from the partial breakup of a jet of liquid glass (Tolanksy, 1971; Isard, 1971; Scarlett and Buxton, 1974). More recently Chernyak and Nussinov (1976) proposed that the shapes were caused by the sudden freezing of a vibrating droplet.

I believe there are many reasons for supposing the rotational hypothesis to be the only tenable one. Several of these reasons have not before been published and the subject has not been reviewed. The discussion is of some importance since, if the rotational hypothesis were proven, it would provide a valuable means of investigating the details of meteorite impact explosions. Furthermore, the equilibrium shape attained by a liquid mass under the action of rotation and surface tension alone is in itself an interesting problem in classical physics. The shape acquired by a rotating mass under self-gravitation has been examined extensively. The corresponding case in which surface tension dominates and is applicable to systems of a much smaller scale, has not yet been analyzed.

Although there have been suggestions that some globules, in particular the orange spherules, were formed by endogenic processes, most investigators agree that the globules are the result of molten rock fragments produced by meteoritic impact. Proponents of all the above hypotheses also agree that the particles will in general cool and become solid in free flight in the vacuum above the Moon's surface. They agree that surface tension is important in determining the shape of globules and that the cooling time increases with globule size so that some of the more massive globules may return to the lunar surface and splash as liquids; they also agree that the larger globules which do solidify in flight are likely to be shattered on impact with the lunar surface, and that many of the globules may subsequently be pitted or broken by meteoritic impact.

I do not know of any argument which substantially favours the jet- or the...
vibrating-droplet hypothesis for globule formation, but I now list arguments which argue strongly either against these hypotheses or in favour of the rotational hypothesis.

(1) The suggestion by Chernyak and Nussinov that dumbbells are formed by the sudden freezing in a particular position of a vibrating droplet does not bear quantitative analysis. The period of oscillation of a particle of linear dimensions 100 μm is about 10^{-4} s. During the whole of an oscillation it will only cool by between 10^{-2} K and 10^{-4} K. Although the viscosity of glasses vary rapidly with temperature (three orders of magnitude for 100 K) it is quite impossible that there can be any appreciable change in viscosity throughout a complete vibrational period, let alone during a small fraction of the period. Calculations for droplets throughout the micron to millimetre scale of size show similar results.

The criticism by Chernyak and Nussinov that rotating particles must show evidence of Coriolis forces is false. Those particles formed with a low maximum temperature doubtless do show these effects. However, if the temperature is sufficiently high for the internal motions to damp out, the particle will, before solidification, rotate as a rigid body and Coriolis force will have no effect.

(2) The shapes of globules are not consistent with the jet model. Figure 1 shows that, in the case of dumbbell-shaped drops formed in a liquid jet, the curvature at the ends of the dumbbell (i.e., the extremities of the long axis) is low, whereas, in the actual lunar globules (see Figure 2), the curvature at these extremities is clearly larger than that elsewhere on the globule surface.

(3) There seems little or no evidence for supposing that immediately after the explosion the liquified rock emanates in jets, i.e., in cylinders whose axis is parallel to the direction of motion. There is considerable literature on the subject of jetting in hypervelocity explosions (Walsh et al., 1953; Guest and Greeley, 1977). The error made by the proponents of the jet hypothesis for dumbbell formation seems semantically based. It hinges on the use of the word 'jet'. In studies of hypervelocity explosions it is clear that