Curr. Sci. **28** 1–3 (1959)

Percussion figures in crystals

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The impact of elastic solids was the subject of investigation by the author many years ago. The earliest of his publications on the subject which appeared in the *Phys. Rev.* for December 1918 recorded the discovery that the coefficient of restitution in the impact of elastic solid spheres tends to unity as the velocity of impact diminishes and becomes small, a result which could have been anticipated from theoretical considerations. His second paper which appeared in the *Phys. Rev.* for April 1919 considered the problem of the impact of spheres on elastic plates of finite thickness but of extended area. It was shown theoretically and confirmed experimentally that the kinetic energy of the impinging sphere is transferred to the elastic plate as energy of wave motion to an extent determined by the thickness of the plate and that as a consequence, the coefficient of restitution diminishes progressively from unity for thick plates to small values for thin ones.

In the course of the studies referred to above, the remarkable effects arising from the impact of a polished sphere of steel on the surface of a thick slab of glass came under the notice of the author. They were described and illustrated in a note published in *Nature* (*London*) of the 9th October 1919. Some further studies of the same effect were later reported in the *J. Opt. Soc. Am.* for April 1926. It had long been the intention of the author to return to the subject and investigate the effect of impact of spheres on crystal slabs. Only recently, however, did this intention materialize. Studies have been made of the results of the impact of polished steel spheres of appropriately chosen size on the optically polished surfaces of quartz, calcite, barytes and felspar. The results of the study show clearly that though the size of the sphere and the velocity of the impact are important factors, the general nature of the effects observed is a characteristic property of the crystal itself and is related both to the structure of the crystal and to the orientation of the face on which the impact occurs. The importance of the subject is thereby made evident and a wide field of research is opened up. It is proposed to give here a brief account illustrated by selected photographs of the results of the research. The interested reader will find a more detailed account and many more illustrations in the paper published by the author in the *Proc. Indian Acad. Sci.* for December 1958.

2. Percussion figures in glass

It is useful to commence with a brief account of the effects observed when a polished steel sphere is dropped on the smooth surface of a thick slab of glass from an appropriate height. The most striking feature of the percussion figures observed in the glass is a fracture which is symmetrical in shape and extends inwards from a ring-shaped crack on the surface to a sharply defined limit in the interior. The fracture exhibits interference colours both in transmission and by reflection, these being complementary to each other. A remarkable feature is that the area over which the sphere and the glass come into contact during the impact exhibits no visible damage, and indeed only with difficulty can one perceive by passing the finger over the surface of the glass that the impact has had any effect at all. The ring-crack from which the internal fracture spreads inwards is however readily visible at the surface, and a critical examination by reflected light also reveals a slight elevation of the surface round the crack, as is naturally to be expected from the presence within the glass of fracture surfaces which are separated from each other. This effect is however best exhibited by placing a test plate of glass over the percussion figure and observing the interferences between the lower surface of the test plate and the upper surface of the glass slab by reflected light. Monochromatic light, e.g. that of a sodium lamp should be used for the observations. The phenomenon of which a photograph is reproduced as figure 1(*a*) is then observed. At the centre of the figure is seen the undamaged area of the surface bounded by the circular ring crack. There is then a sudden elevation of the surface which is symmetrical around the area and slopes down gradually to the original level on all sides, as is shown by the configuration of the closely spaced circular interference rings.

3. Percussion figures in quartz

The nature of the results observed with quartz is found to depend notably on the orientation of the surface on which the impact occurs. The most interesting results are those noticed when this surface is perpendicular to the optic axis of quartz. Figures 1(*b*) and 1(*c*) reproduce photographs of the percussion figure observed in this case, figure 1(*b*) representing what is observed by transmitted light and figure 1(*c*) being the interference rings observed when a test plate is laid on the slab of quartz over the percussion figure. Figure 1(*b*) exhibits the very striking fact that the fracture surface inside the quartz exhibits only trigonal symmetry and *not* hexagonal symmetry. This feature is further evident from the nature of the elevation of the surface as revealed by figure 1(*c*). There are, of course, many other features noticeable in the photographs reproduced, but it is not possible to refer to them here in detail. They will be found fully set out and illustrated in the detailed paper referred to above.

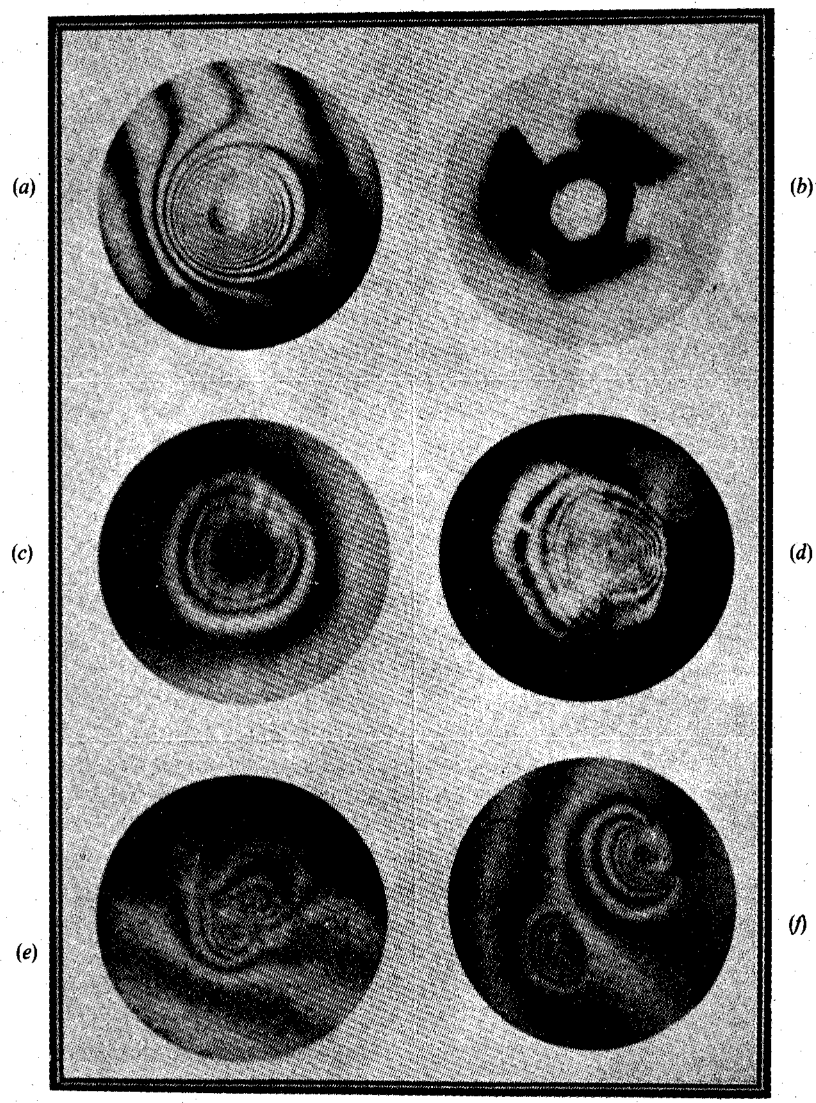

Figure 1. Percussion figures.

4. Percussion figures in calcite

Figure 1(*d*) illustrates the effect of dropping a small steel sphere on the rhombohedral face of a crystal of calcite which had been smoothed and polished to optical perfection. The photograph was taken with a test flat laid on the surface and allowed to settle down. Much the same features are also exhibited by the percussion figure itself without a test plate. An examination of the percussion figure reveals that the characteristic cleavages of calcite play an important role in determining the results of the impact. Indeed, it is observed that on either side of the area of contact between the impinging sphere and the crystal, two cleavages making an acute angle with each other develop and extend outwards from the edges of that area. These cleavages are clearly visible on the face of the crystal and they sharply limit the area within which the fracture develops and spreads inwards. Another interesting feature is the appearance of a whole series of parallel lines outside the region of contact and only on one side of it. These lines are equally inclined to the two sets of cleavages and may be explained as due to glides occurring within the crystal along the direction of a rhombohedral edge.

5. Percussion figures in other crystals

Quartz and calcite are specially suited for studies of the kind described, since it is possible to obtain fairly large specimens which are clear enough to enable the results of the impact within the crystal to be satisfactorily observed. In other cases, it is not so easy to find material of this quality which could be used for such studies. There is usually no difficulty, however, in obtaining single crystals of the desired size on which surfaces of the desired orientation can be cut, ground and polished to optical perfection. The results of the impact on the *external* surface can then be readily studied by placing a test plate on it and observing the configuration of the interference patterns seen in monochromatic light. These patterns are found to be highly characteristic of the material studied as well as of the chosen orientation of the surface. Figure 1(*e*) in the plate shows the pattern observed with barytes and figure 1(*f*) with felspar.