# *Inclusions in Diamond from South Africa.*

By J. R. SUTTON, M.A., ScD., F.R.S.S.A.
Director of the Observatory, Kimberley, South Africa.

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THERE are certain foreign minerals upon which the South African diamond has crystallized readily. The chief of these are garnet, ilmenite, olivine, and iron-pyrites. In addition, zircon and mica are also probable inclusions. Cognate inclusions are graphite, bort of every kind, and diamond itself of unconformable orientation.

The evidence that the above minerals occur as real inclusions, i.e. that they are of earlier (or at any rate not later) date than the enclosing diamond, is fairly strong. Thus we find garnets of every colour from orange-red to violet embedded: (1) more or less deeply in a natural crystal face of diamond; (2) in a cleavage face; and (3) completely enclosed. The last of these would be, of course, sufficient of itself to prove the case; otherwise the first two might be thought to indicate a later crystallization of garnet in convenient holes. We shall see the importance of keeping the three cases in mind when we come to consider their bearing upon the problem of the origin of broken diamonds.

The same evidence is available for olivine and the green minerals allied to it, as well as for ilmenite, graphite, and the borts. Pyrites has not yet been proved to exist in an unbroken diamond, albeit the alleged included 'gold leaf' of the text-books may be that, if it be not mica. Pyrites, however, is found embedded in lumps of bort, and in the holes in cleavage faces of diamond, two of which holes, specially examined, being of cubic outline. Diamond in diamond is curious. It is rare in most South African mines, but in Bullfontein it is so common as to give the yield of this mine its unique character for white spots, cross grain, and 'knots', all so difficult for the saw to cut. These diamond inclusions, which may be either whole crystals or fragments, often carry an intensely hard black shell.

Inclusions are sometimes found of two or more foreign minerals in conjunction. An interesting case is a Dutoitspan diamond containing an inclusion mainly of olivine, which, in its turn, enclosed a small and much-worn diamond. A specimen of ilmenite, in bort, has a brown shell suggestive of limonite: the iron of stewartite may come from this source. Garnet inclusions sometimes have kelyphite shells. Conglomerate groups composed of shapeless diamonds and other minerals are found. Occasional diamonds embedded in garnet, probably derived from some such conglomerations, are met with in which the almost black shell of the garnet simulates having been squeezed while in a plastic condition round the diamond. Incidentally it may be mentioned that a large proportion of South African diamonds appear to have originally belonged to these conglomerations. The statement that diamonds have been formed in a fluid magma, admitting of their free all-round development, is not generally true. Specimens of good geometrical symmetry do abound, especially in the Wesselton and Dutoitspan mines; nevertheless in all the mines distorted individuals, some of which have evidently been formed in tight corners, are the more common.

Inclusions invariably set up fracture or strain (or both together) in the enclosing diamond. When the latter is small it will generally be broken in pieces by the inclusion; when it is large the fracture may not reach the surface. A fracture which reaches the surface without actually breaking the diamond asunder is in most cases found to be filled with an intrusion of later crystallization, such as calcite, apophyllite, pectolite, &c.

The existence of inclusions and intrusions is well known; but they do not appear to have received adequate attention, and their significance has been ignored by theorists and experimentalists alike.

It is not easy to understand why the various known inclusions should set up a state of permanent strain within diamond. The accepted coefficient of expansion of diamond is very much smaller than that of any of its associated foreign minerals. Therefore if we assume that crystallization occurred at a fairly high temperature, not strain, but rather relief from strain should be expected to ensue from cooling. And yet it seems clear that the forces which produce the fractures are directed outwards even at the temperature of the earth's surface, and so have been able to cause the fractures to open wide enough for the admission of late intrusions. The subject needs detailed investigation. Meanwhile it may be suggested that the state of strain observed may arise in part from distortion, from instability due to the unconformable foundation of foreign mineral inclusion upon which the diamond is built. Some such explanation seems to be required in order to explain the strain set up when the inclusion is diamond of unconformable orientation, whether it be surrounded by foreign mineral or not. It may be noted here that a similar state of strain arises in local areas in the so-called composition 'plane' of macles.

It may be regarded as proved that the broken diamonds occurring in nature owe their condition for the most part to the presence of some foreign mineral in the original whole stone. The crumbling process is, in fact, beautifully exhibited by the 'hailstone' diamond, where the active agent appears to be magnesia.[1] It is doubtful if there has ever been a case of spontaneous breaking (to say nothing of bursting or exploding) of pure diamond. Diamond shells and natural diamond beads have been produced by the disappearance of former mineral inclusions.

[1] J. R. Sutton, Trans. R. Soc. South Africa, 1921, vol. 9, p. 100