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A Russian Doll Diamond in the Making

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Since 1995 four diamonds have been described, Fritsch (2021), Sibley (2023), consisting of an inner diamond that moves more of less freely in a larger encasing diamond. An example is shown in Figure 1. Because of this arrangement these crystals have been called Matryoshka diamonds after the Russian toy doll. The diamonds vary in size from three to seven millimetres in longest dimension and weigh between 0.33 and 1.09 cts. Two are typical macles, including the inner diamond, a third is an octahedron within an octahedron, the fourth an octahedron in a sawn diamond. The shapes of the diamonds indicate that the sides of the cavities are aligned parallel to octahedral planes. In the four described examples the outer diamond has access to the inner cavity via a diamond fissure or one or two tunnel openings.

Figure 1: The two images show movement of the inner diamond in a cavity. The pale green specimen was recovered from the Nyurba mine in Siberia. The diamond weighs 0.62 ct and measures 4.8 × 4.9 × 2.8 mm. Sample courtesy of Alrosa; photos by Nathan D. Renfro, © GIA.

Apart from a complicated diamond growth mechanism, Pavlushin and Konogorova (2023), the present view for the origin of such diamonds involves either gas escape from a cavity or the dissolution of an internal layer of impurity. With the present set of four diamonds, the nature of the gas is undefined, but the impurity is considered to be either a crystallised carbonate-silicate melt or the presence of opaque fibrous diamond. Access to the impurity layer is afforded via dissolution of either crystal dislocations within the outer diamond or fracturing and breaking that part of the diamond. These processes take place whilst the diamond is in a magma.

If we assume the cause of the cavity is the removal of impure diamond in octahedral planes, focus shifts to the likely agent that causes that dissolution and how it gets to the impure layer. The liquid component of kimberlite or lamproite magmas, which bring diamonds to Earth's surface, is unlikely to be responsible, because that liquid does not generally have aggressive chemistry towards diamond. An exsolved C-O-H fluid component on the other hand might remove the impurity under the high-pressure conditions within the magma.

Access to the impurity via crystal dislocations from the surface is improbable. Dislocations are typically recognised on a diamond surface by the presence of a trigon or tetragon, both being the product of a mild etch at this point of weakness. They may display different sub millimetre etch patterns around the dislocation point but penetration into the diamond is measured in microns. Access is more likely through fracture and removal of part of the outer diamond. For example, images of the nature and size of the opening from the outside to the cavity in the so-called 'beating heart diamond', Sibley (2023), is better explained as outward fracturing rather than a process of drilling inwards.

Of the two proposed solid impurities, the crystallised carbonate-silicate melt is not further defined, but if that melt equates to the crystallised high-density carbonatitic and/or silicic fluid impurities described by Weiss et al. (2009), then the impurity consists of a dense array of particles of approximately two microns in size separated by diamond. These arrays, if they have a shape within diamond, are invariably associated with cube and not octahedral planes, two prime examples being impurities taking the shape of a picture frame which parallels the outside of a cube diamond, or the internal petal pattern in octahedral diamonds, the impurity only being in the [100] directions. Thus, micro-inclusions are not likely to be involved in cavity creation. On the other hand, fibrous diamonds are associated with octahedral growth and therefore could be the impurity.

Fibrous diamonds, although impure, still principally consist of diamond and thus it is unlikely that this impure layer is sufficiently different from the outer diamond to exert any serious pressure differential to fracture the outer diamond. Such a breakage is further constrained by an environmental pressure during mantle storage which is measured in gigapascals. Nevertheless, assuming the fluid has ingress to this impurity through a broken outer diamond, and dissolution occurs, the fluid is not restrained by the newly formed cavity as there are one or more fracture openings. As an unsupported void is most unlikely at a pressure of up to 4 GPa (40 kbars), the cavity is likely to collapse or be subsequently filled by magma. Thus, although cavity formation by C-O-H fluid penetration is considered a remote possibility this mechanism would at best not result in an empty cavity.

A more likely explanation for Matryoshka diamonds is shown by the diamond in Figure 2 from the Orapa mine in Botswana. Across the broken surface the central octahedral diamond which exhibits no resorption appears to be encased by a layer of garnet, followed by further diamond growth in which there is another unconnected garnet piece. In this case, the front of the diamond shown in Figure 2 has been chipped off, likely during diamond recovery and processing. Figure 3 shows two X-ray computed tomography images which confirm the garnet shape. The garnet shell is a slightly asymmetric octahedron reflecting the shape of the inner diamond and in addition, the inner diamond has three garnet inclusions. Also note that the larger unevenness of the inner and outer surfaces of the shell represent the surface characteristics of the outer surface of the inner diamond and that of the enclosing diamond. The fine moiré-like patterns, however, are artefacts of the X-ray computed tomography.

From the above evidence a new hypothesis is proposed for the so-called Matryoshka diamonds. They initially form as shown in Figure 2, although the mineral envelope may not always be garnet. They are brought to Earth's surface and reside in kimberlite or lamproite or may be weathered out into an alluvial deposit. Either in the cooling kimberlite or in alluvium or during the recovery process, the internal mantle mineral causes fractures which partially break the outer diamond shell, giving access to the mineral inside. All diamonds recovered from primary or secondary sources of a major mining company go through a rigorous acidization process before valuation prior to sale. During this process, any mineral envelope would be dissolved and washing procedures would remove any remaining debris leaving a cavity in which the inner diamond is free to move within its parent. The presence of some barite found in the channels between the inner and outer diamond in the Russian specimen, Litvin (2023), is likely the result of imperfect acidization or washing.

In the present case the surface of the garnet appears to be pristine there being no evidence of acidization. This observation would suggest that whilst the diamond went through the acidization process, it broke during the very final vigorous washing stage of diamond recovery.

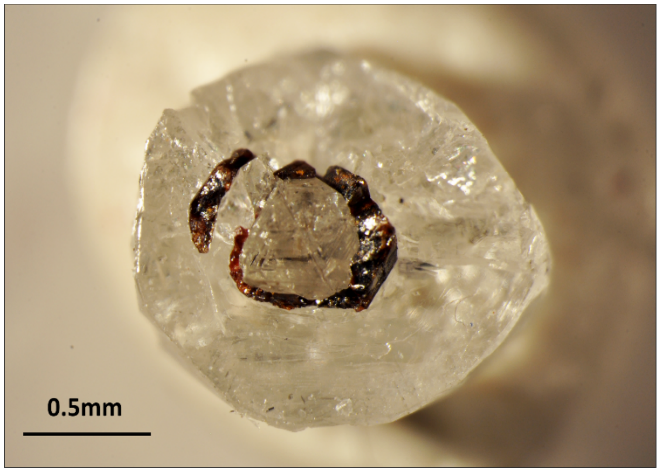

Figure 2: A diamond from the Orapa mine in Botswana. The inner unresorbed octahedra is surrounded by a layer of octahedral garnet followed by further diamond growth.

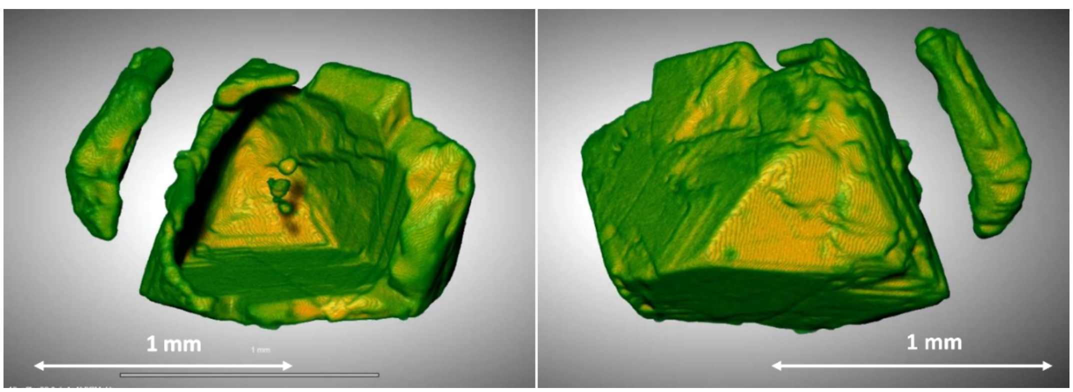

Figure 3: Two X-ray computed tomography images of the garnet inclusion; the first approximates the position of the image in Figure 2, the other is 180 degrees from that image. See text for further details.

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