THE CRYSTAL FORMS OF THE PANNA DIAMONDS

BY S. RAMASESHAN

(From the Department of Physics, Indian Institute of Science, Bangalore)

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1. *Introduction*

THE opportunity for the present study arose from the visits made by Sir C. V. Raman two years ago to the State of Panna in Central India where diamonds have been mined since very ancient times. One result of these visits was the acquisition by him of 29 diamonds in their natural state as crystals. This material has been placed at the disposal of the author for a report on the crystal form of these specimens. Not one of them exhibits the plane faces and straight edges demanded by the ordinary rules of crystallography. Nevertheless, several of them show a high degree of geometric symmetry, as also smooth lustrous faces and rounded contours which endow them with a distinctive beauty. They also show various other characteristic features which appear to merit careful study and description. It has been found convenient to adopt the usual crystallographic nomenclature in classifying the specimens, though this procedure has no strict scientific justification, even in the case of the more regularly shaped diamonds.

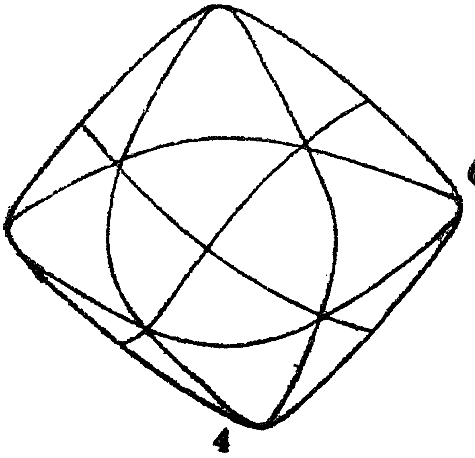

FIG. 4. Form of D9

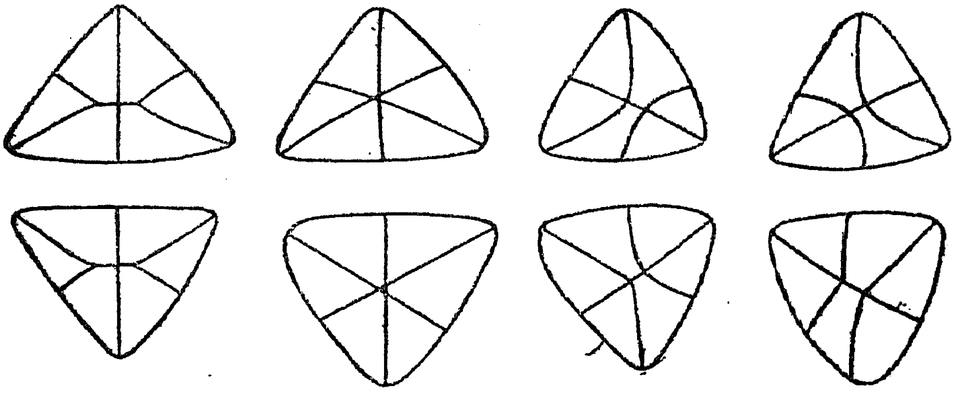

FIG. 5. The Eight Faces of D9

2. *The Hexakis-Octahedral Forms*

Three of the diamonds in the collection, namely D8, D9 and D27, approach sufficiently to the general form of the cubic system with 48 faces to justify their being compared with it. Fig. 4 represents D9 which is the most perfect of this group. The resemblance, it will be noticed, is far from being exact. The six vertices or protuberances are, no doubt, present and convey to the eye the suggestion that the crystal has an octahedral form. The edges separating the octahedral faces are however missing, these regions being smoothly rounded off. The transverse curvature along them is sufficiently great, however, especially in D8 and D9, to suggest a resemblance to the octahedral form. Sharp edges cutting across the octahedral faces and dividing them into segments are observed. Four such edges meet at each vertex of the octahedron and run across to the opposite vertex, intersecting at or near the centre of the faces. Since, however, the octahedral edges are absent, the curved surface of the crystal appears actually divided up into 24 clearly defined and approximately equilateral triangles and not into the 48 faces required for the hexakis-octahedron. It should be remarked also that the angle between the curved surfaces meeting along these edges is highly variable. It is greatest near the vertices of the octahedron and diminishes to a relatively small value midway between them. This circumstance makes the observed form tend somewhat towards the triakis-octahedron.

There are, however, certain minor irregularities. Instead of the edges meeting exactly at the centre of the octahedral faces, they may deviate slightly, or even meander, with the result that their meeting point is on one side or another of the centre. The edges in such cases do not run a continuous course from each vertex to the opposite one. It is an interesting point that in D9 even these irregularities appear symmetrically. Fig. 5 shows its eight octahedral faces, their features being qualitatively indicated and parallel faces being drawn one above the other.

D27 is the largest of the three diamonds and weighs 341 milligrams. It has a grey tinge which is probably superficial. D8, which is the next in size and weighs 279 milligrams, has a delicate greenish tinge which is particularly evident at the octahedral tips. This is a superficial tint characteristic of many of the best Panna diamonds which disappears when they are cut and polished (Sinor, 1930). D9 which weighs 226 milligrams is perfectly colourless. Both D8 and D9 have lustrous surfaces, while D27 has rather a dull appearance.

3. *The Tetrakis-Hexahedral Forms*

The six diamonds D18, D20, D21, D22, D24 and D25 may reasonably be compared with this ideal form. They are relatively small diamonds weighing 61, 56, 51, 41, 32 and 22 milligrams respectively. All of them have the common feature that the surface of the crystal appears divided up into 24 distinct areas bounded by sharply defined edges. These are, however, not plane figures but are curved surfaces, with the result that all these diamonds, at a first glance, appear like small transparent globules. These features will be evident from the photographs of D18 and D20 in Plate XXIX which are the two largest diamonds in the group. It is evident that the three diamonds described in the preceding section, and the six now under consideration, have in reality the same basic form, a solid having 24 curved faces bounded by sharply defined edges. These edges meet on the surface quite exactly at six vertices in groups of four each and more or less exactly at eight points in groups of six each. In the ideal case, therefore, the surface appears divided up into 24 triangles. The general shape of the crystal is determined by the size and shape of these triangles, as well as by the angles which they make with each other along the lines where they meet.

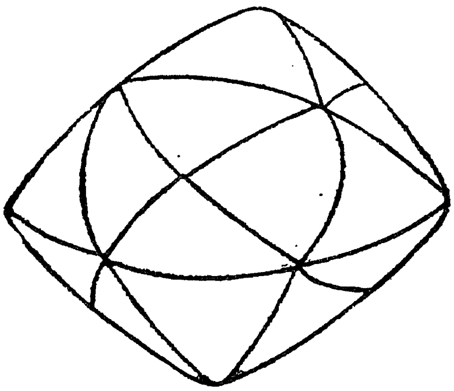

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FIG. 6. Form of D18

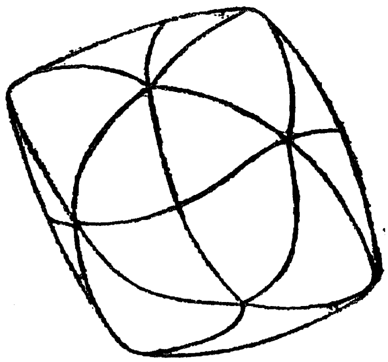

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FIG. 7. Form of D20

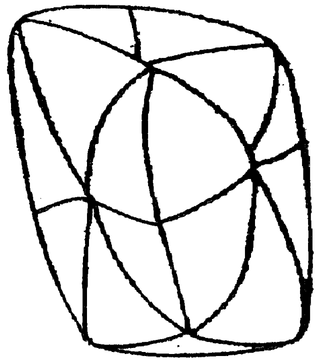

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FIG. 8. Form of D21

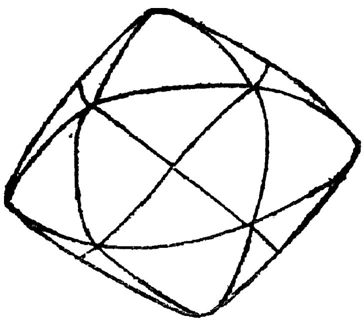

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FIG. 9. Form of D22

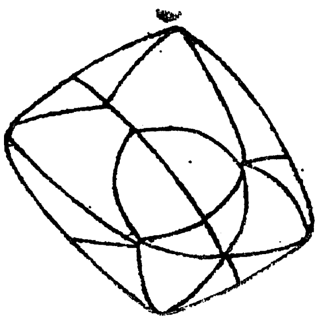

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FIG. 10. Form of D24

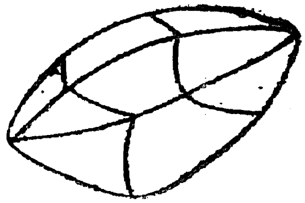

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FIG. 11. Form of D 25

Each of the six diamonds has 6 protuberances like those of the octahedron or the tetrakis-hexahedron, but they are not equally prominent in all the crystals. They are particularly conspicuous in D18 and D22 which most nearly resemble the ideal form and less conspicuous in the other four diamonds. The angle between the faces meeting along the shorter diagonal of the rhombus (Fig. 6) is much less than that between the faces which meet along one of its sides, thereby suggesting an approach to the dodecahedral form. This is a common feature in the Panna diamonds. D20 (Fig. 7) is a beautiful crystal which shows some resemblance to the octahedral form. Here again, the edges are sharp and clear. D21, D24 and D25 (Figs. 8, 10 and 11) are ellipsoidal crystals which are comparatively irregular. The faces are unequal and the edges meander so much that it would not be correct to call some of the faces triangular in shape. These irregularities are evident from the figures. D25 in some positions, presents a very flat surface which is divided into 6 faces. Such a view is portrayed in Fig. 11.

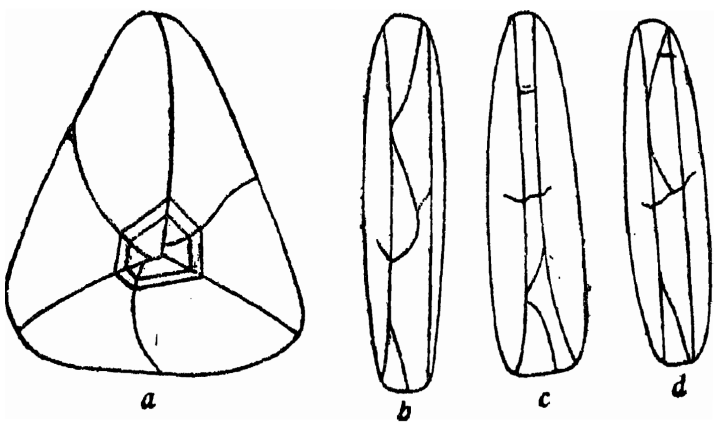

FIG. 12. Front and Edge Views of D28

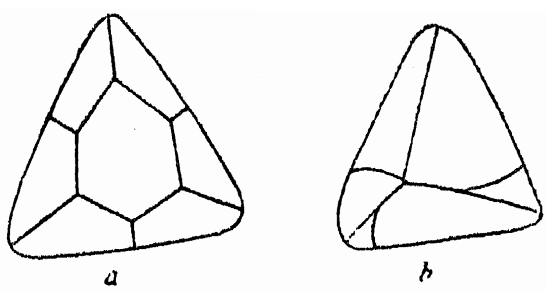

FIG. 13. Front and Rear of D29

The remaining crystals can only be classed as irregular and most of them are heavy distortions of the tetrakis-hexahedron. These diamonds can be divided into two groups, those which are colourless and transparent and those which are coloured yellow or grey. Some irregular crystals are illustrated in Fig. 2, Plate XXIX. As examples, a few of them are described below.

D3 is a colourless transparent crystal which appears highly distorted, but a close examination shows that it resembles a hexakis-octahedron whose growth has been restricted in one particular direction. The crystal can be described as a hexakis-octahedron cut by a plane which is approximately parallel to one of the octahedral faces. This intersecting plane is a natural face and it has six well-marked lines on it which divide it into six segments. The crystal exhibits practically all the characteristics of the hexakis-octahedron which have already been described. It weighs 405 mgm.

D1 and D12 (Figs. 14 and 15) are both yellow crystals which are heavy distortions of the tetrakis-hexahedral form, but nevertheless display its characteristics. The most striking feature about these diamonds is the enormous variation in the area of the faces. The crystals are flattened and the flat portions are those where six faces meet. These faces are much larger in area than the others. The edges are sharp but wavy and are distinctly seen on the surface. The faces are curved but the variation in curvature is not always continuous as in the other diamonds. Sometimes on a convex surface, a small concave depression is present.

4. *Twinned Crystals*

There are two flat triangular crystals in the collection which closely resemble the macled diamonds of the Kimberley mines and have been found by X-ray examination to be actually twins. D28 (Fig. 12) weighs 214 milligrams and D29 (Fig. 13) weighs 29·9 milligrams. The crystals appear to have 24 faces, 6 faces being found on either of the flat sides and the remaining 12 being distributed on the thin girdle which connects the two components. The line of demarcation or seam between the two components (which is a common feature of the Kimberley twins) is absent. The edge view presents distinct faces (Fig. 12 *b, c, d*). The edges on the flat side are fairly sharp ; but those on the thin sides are faint and wavy.

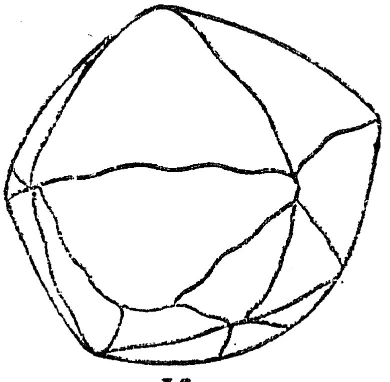

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Fig. 14. Form of D1

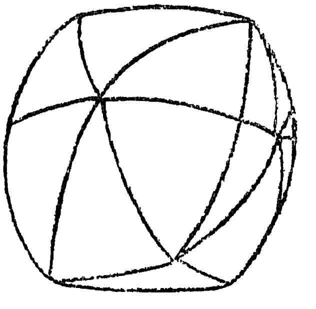

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Fig. 15. Form of D12

The two sides of D29 do not appear alike (Figs. 13 *a* and *b*). On one side there is a flat area which is full of rugged triangular pits. The faces are, as usual, curved and the curvature increases as one moves from the centre to the edge of the triangle.

5. *Surface Characters*

The surface markings of the Panna diamonds show great variety and beauty. All the diamonds examined have striations on the surface, but their nature varies from crystal to crystal. The striæ on the clear colourless diamonds are very close together and they have a kind of satiny sheen to the surface. They are so disposed on the octahedral face as to give the appearance of a spider's web. A microphotograph of such striations on D3 is given in Fig. 3 *a* in Plate XXX. The lines found on the yellowish diamonds are quite different. The surfaces reveal somewhat rough and bold striæ, each face having two or three sets of such parallel lines. The criss-crossing of these lines gives a drusy appearance to the surface. Sometimes, but not often, tiny tetrahedral pits are found at the intersections of these lines. Under fairly high magnification the lines, although absolutely straight, are found to be discontinuous (Fig. 3 *c*) in Plate XXX. Most of the striations are parallel to the intersection of the octahedral planes with the surface.

The faint milky white appearance of D20 and D3 is due to the scattering of light by the large number of pits which abound on their surface. These pits are rather peculiar in nature, being circles with the circumference sunk into the diamond, the central area being shiny. Some of the pits are incomplete circles and occasionally only semi-circular. A few such pits are also seen in Fig. 3 *a*. D29 has triangular pits on its surface, all the triangles pointing in the same direction. Microscopic examination of these pits shows that they are really tetrahedral cavities with flat sides. Some of these sides are striated. The angle between two faces of a "trigon" was measured and was found to be near about the angle between the octahedral planes. A microphotograph of the pits on D29 is given in Fig. 3 *b* in Plate XXX.

6. *Photographic Study of the Diamonds*

It is difficult to obtain a satisfactory photograph of a crystal of diamond showing the detail on its faces. The strong internal and surface reflections conspire to defeat any attempt to bring out the outlines and natural beauty of crystal form. However, in the case of small crystals, these difficulties are not insuperable. Seven out of the twelve photographs reproduced in Plate XXIX, *viz.*, the representations of D20, D18, D9, D3, D12, D4 and D10, were obtained by illuminating the diamond obliquely and avoiding any direct reflection from its surfaces entering the camera. The remaining five pictures, *viz.*, those of D27, D28, D9, D8 and D1 were obtained by photographing the diamond by its luminescence under ultra-violet irradiation. This was done by passing sunlight through a plate of Wood's glass, a cell of sodium nitrite solution being used as a complementary filter. The bright patch at the centre of the green fluorescent D1 represents an intensely blue fluorescent region.

7. *Measurements of Curvature*

It appeared to be of interest to study the curvature of the surface in some of the more regular diamonds, and to find in what respects they differed from each other. As already stated, the surface of every such diamond consists of 24 similar triangles, and it is sufficient therefore to determine the configuration of the area included within a rhombus formed by a pair of adjacent triangles of this kind. The two vertices at the ends of the longer diagonal of the rhombus are points where four edges meet, and the two other vertices are points where six edges meet on the surface of the crystal. The measurements could be made by setting the crystal on the movable stage of a microscope and focussing the latter on a series of points on the area of the rhombus and reading off the vertical and horizontal displacements.

Figs. 16 and 17 represent the results of such a study for the four diamonds D9, D20, D18 and D22, the graphs for which are numbered serially in that order.

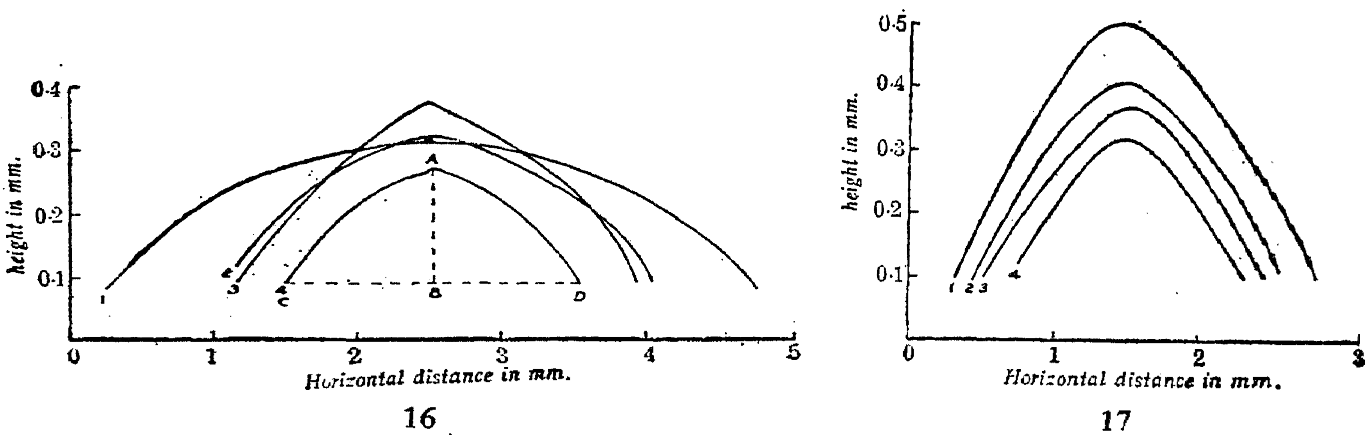
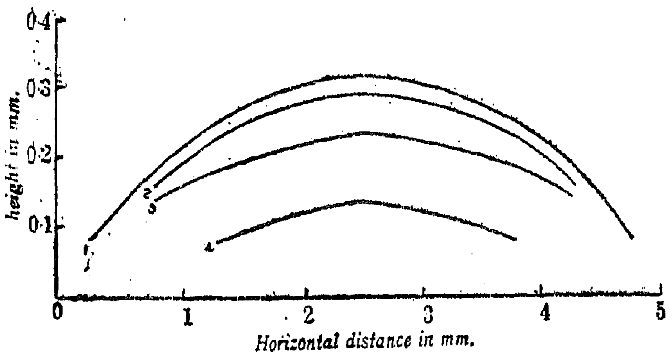


FIG. 16. Sections through the longer diagonal for D9, D20, D18 and D20
FIG. 17. Sections through the shorter diagonal for D9, D20, D18 and D22

It will be seen from the figures that the general shape of the section along the shorter diagonal is very similar for these four diamonds. On the other hand, the sections along the longer diagonal show conspicuous differences, the curve being very open in the case of the approximately octahedral diamond D9. A further idea of the configuration of the surface of this particular diamond is conveyed by Figs. 18 and 19 respectively, in which its sections by a series of planes 0·25 millimetre apart are shown. The graphs are numbered in serial order moving away from the diagonal referred to in the caption of the figures.



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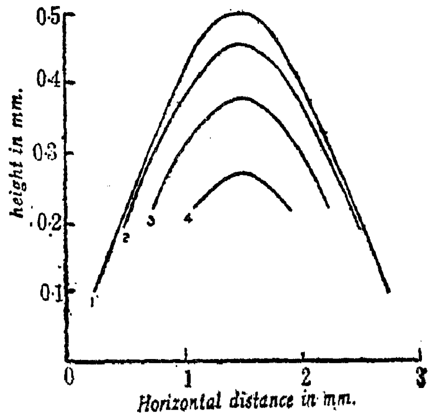

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FIG. 18. Sections of D9 by a series of planes parallel to the longer diagonal

FIG. 19. Sections of D9 by a series of planes parallel to the shorter diagonal

As we pass along the longer diagonal of the rhombus, we meet an edge or discontinuity of direction when crossing the shorter diagonal of the rhombus. This discontinuity is small, but it becomes more pronounced when we move to one side or another of the longer diagonal. This is shown by the series of graphs in Fig. 18. No such discontinuity is encountered as we move along the shorter diagonal or parallel to it, but the curvature becomes distinctly more marked as we approach the vertices of the rhombus (Fig. 19).

The angles between the tangents to the surface of the four diamonds at the ends of the longer and shorter diagonals were carefully measured. They are given in Table I together with the theoretical angles for the ideal geometric forms with which the crystals have been compared. It is clear from these figures that the crystals cannot in strictness be assigned to any particular form of the kind usually considered in geometric crystallography.

TABLE I

Crystal	Angle between ends of longer diagonals	Angle between ends of shorter diagonals
D9	152°	124° 30′
D20	144°	130°
D18	140° 30′	137° 30′
D22	140°	138° 30′
Tetrakis-hexahedron	143° 8′	180°
Octahedron	180°	109° 30′
Triakis-octahedron	180°	141°
Hexakis-octahedron	157° 30′	158° 30′
Dodecahedron	180°	180°

In conclusion, the author wishes to thank Prof. Sir C. V. Raman for his guidance throughout the course of this investigation.

8. *Summary*

The external forms and surface characters of 29 diamonds from the Panna mines in the personal collection of Sir C. V. Raman have been studied. Drawings and photographs of a selection from amongst them have been reproduced with the paper. In all the specimens examined, the surface of the crystal exhibits a set of sharply defined edges dividing up the area into 24 segments. In the best specimens, these segments have the shape of triangles, and the edges bounding them meet at points or vertices on the surface of the crystal respectively in groups of four and six. Measurements have been made of the curvatures of the surface in four of the best specimens. They show that these curvatures are highly variable both in an individual diamond and also as between different specimens.

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Sinor, K. P. .. *Diamond Mines of the Panna State*, 1930.

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