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A NOTE ON SOME LARGE DIAMONDS

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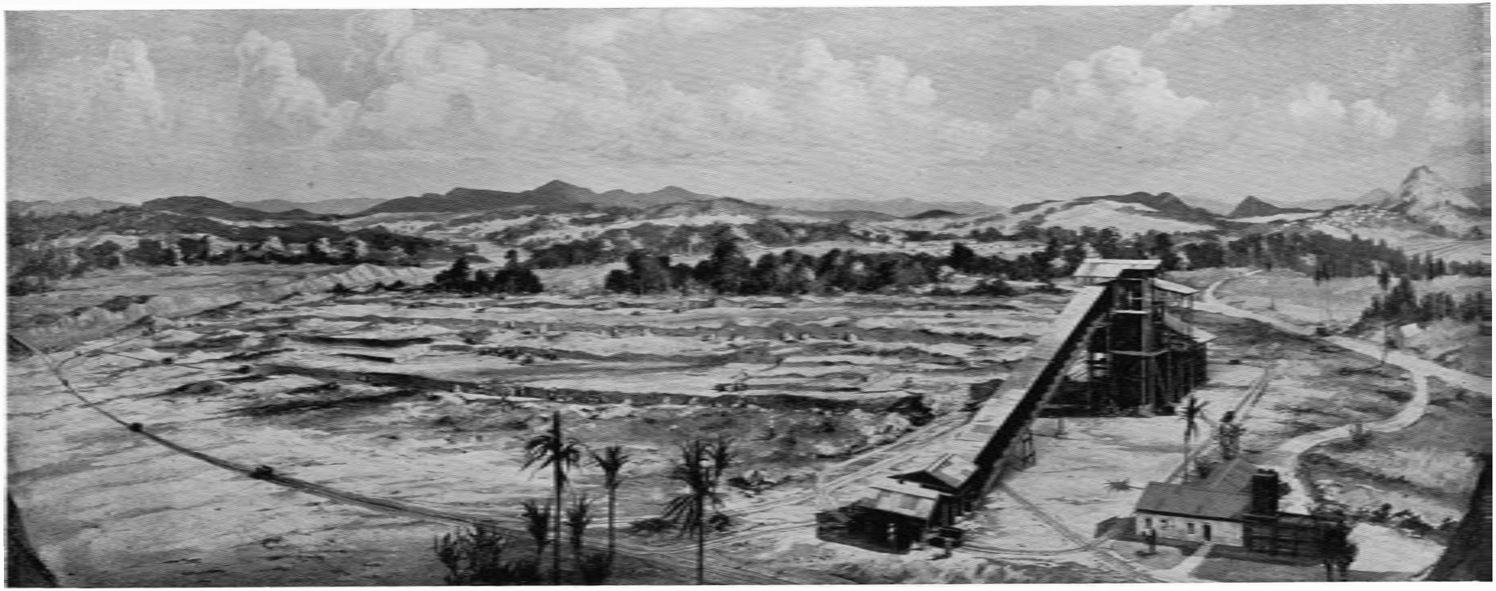
PLATE III.



Sierra Leone: General View of Alluvial Diamond Mining.
Reproduced from a Diorama in the Exhibition Galleries of the Imperial Institute.

facing page 111]

A NOTE ON SOME LARGE DIAMONDS RECENTLY RECOVERED FROM THE GRAVELS OF THE WOYIE RIVER, SIERRA LEONE

By W. T. Gordon, M.A., D.Sc., F.R.S.E.,
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The finding of three exceptionally large diamonds in Sierra Leone since March, 1943, has already been announced in this Bulletin (1943, **41,** 206, and 1945, **43,** 55). All three stones came from workings in the Woyie River gravels and were obtained in the normal course of diamond recovery at the plant operated by Sierra Leone Selection Trust, Ltd. They are by far the largest diamonds of gem quality yet found in Africa, apart from the Union; one, indeed, is probably the largest diamond ever found in any alluvial deposit. As such they are of considerable scientific interest apart from their intrinsic value.

It is a curious circumstance that all the exceptionally large diamonds found in recent years have been irregular in shape, and the three discovered in Sierra Leone during the past two years are no exceptions. All these large specimens have been single individual crystals; indeed, even if irregular in development, single individuals are common among diamonds. Crystal aggregates of diamond are, on the whole, rare, if we exclude the two important industrial varieties *carbonado* and *ballas*, the former a compact mass of small crystals and the latter with a fibrous radiating structure.

Diamonds from Sierra Leone are interesting from several points of view and notably because of the frequent occurrence, in material of good quality, of octahedra with extremely flat faces and clean-cut edges. In the lower qualities, crystals, though well formed, often have rough faces and sometimes a skin that consists of extraneous substance embedded in a diamond meshwork, each part of which is in crystallographic continuity with a central core of good quality. The skin may be thick or thin, and not infrequently appears to have the extraneous material arranged in a very regular pattern.

As with diamonds from other localities, the crystal faces are pitted. Octahedral faces have triangular or, rarely, hexagonal pits, and the triangles are equilateral in shape (Plate IV, Fig. 5). Cube faces have square pits, with their edges diagonal to the cube edges.

The octahedral faces of Sierra Leone diamonds are sometimes so smooth that pits are quite minute and difficult to detect. The writer has never seen one absolutely devoid of pits, though sometimes it required examination under quite a high-power microscope objective to be certain that such pits did occur.

But the three large stones that are the basis of the present short account are not in this category. Indeed the largest, and latest to be found, has one octahedral face with triangular pits that are larger and deeper than any previously recorded (Plate IV, Fig. 5). Some of them measure nearly 6 mm. on edge and are about 1 mm. deep. They are arranged in parallel position, as usual, and set with their sides towards the points of the ideal octahedron. The spacing of the pits is such that the areas between them assume raised, shield-shaped, triangular forms; the points of the shields and those of the pits are in ranks facing opposite directions.

The largest specimen (No. 1), found in the Woyie River gravels in January, 1945, is 770·00 carats in weight, *i.e.* 154 gm., or nearly $5\frac{1}{2}$ oz. It is rather lozenge-shaped, some 71 mm. long, 53 mm. broad, and 32 mm. thick (Plate IV, Fig. 4). These measurements are approximate as they depend on the direction in which they are made. Roughly speaking, the crystal is like a four-sided, truncated pyramid on a lozenge-shaped base, as can be seen in Figures 4 and 6.

The boundaries are mostly natural, but only one is what one might call a free crystal face, the other surfaces being either irregular or the result of cleavage. The one natural octahedral face is some 55 mm. by 25 mm. in area, and, taken in conjunction with two cleavages (one a remarkably perfect cleavage surface measuring 40 mm. by 28 mm.), serves to determine the orientation of the crystal. When placed in such a position that the cleavage directions (as indicated by fractures or the pitted face) would be parallel to the faces of an octahedron, the amount of distortion of the specimen from an ideal octahedron can be seen, and the direction of some of the main edges can be ascertained. Thus, in text Fig. 1 the edge A-B, indicated by the same letters in Plate IV, Fig. 5, is parallel to the diagonal of the cube to which the specimen could be related from a crystallographic point of view; and the degree of irregularity of the individual can be seen. Although some surfaces can be properly ascertained, the remainder of the external surface facets on the specimen cannot be accurately determined. They all show striations and a kind of general corrosion, while the main edges and corners are distinctly battered as by water erosion. Characteristic chatter cracks are visible in Plate IV, Fig. 5, on the edge A-B towards B, for light is reflected from these cracks and gives white, spindle-shaped marks in the dark shadow.

Such mechanical erosion may have occurred at any time since the crystal was dislodged from the parental rock, and may have happened close to the place where it was found. If there had been pot-holes in the bed of the Woyie stream above the point of location, the chattered edges might be explained, and the original source might not be far distant; but diamond is so hard that the specimen might have travelled a considerable distance, or might have been washed out of some more ancient gravel bed before incorporation in the present gravel.

On the other hand the presence of not one, but three, large stones in fairly close proximity to one another, favours the presumption of a local source. Careful physiographic surveying of the area upstream, and detailed geological mapping of the rocks and superficial gravel beds in the vicinity may indicate whether this presumption is correct.

Reverting to the largest specimen, however, it can be stated definitely that it has not suffered much attrition since the largest cleavage face was produced, for the smaller edges peripheral to that face show no sign of battering. The area of this cleavage face is 11·5 sq. cm., and it is so clean a fracture that the blow which produced it must have been a sudden, sharp impact in precisely the correct direction. The surface is exceedingly smooth, whereas most cleavage faces show a certain stepping from layer to layer while keeping in the same general direction. The blow need not have been a heavy one, but the marvel of the smoothness of the fracture-face can only be appreciated by those who have tried to cleave a diamond, using the usual cleavers' tools.

Certain of the other facets suggest that the history of the stone is not so simple. There are sometimes slightly conchoidal ridges, indicating fractures that took place at an earlier time, and that have been corroded during the period that elapsed between that event and the production of the latest cleavage surfaces (Plate IV, Fig. 4). These conchoidal fractures might have been produced while the diamond was in its original rock and subjected to earth strains. A possible history might be hazarded. There seems to be common consent to the idea that diamond is formed in molten rock material, and that the diamond crystallises out at an early stage as the magma (rock liquid) cools. Thus is explained the observation that diamonds are usually individual crystals, and their faces more or less alike as regards size and depth of pits. Elongated or flattened crystals are common, it is true, and indeed, a mathematically exact octahedron is very rare. On further cooling of the magma, other minerals will crystallise out of the rock melt on the faces of the diamond, and the resulting group of contiguous crystals would form a mass that might migrate from place to place as a result of currents in the semi-congealed rock. In consequence, the mass may reach a part of the magma where the conditions of crystallisation were reversed, and re-solution supervened. The crystals round most of the diamond might melt again, and even the diamond itself might be attacked by the liquid, which would, of course, be somewhat similar to that from which it had originally crystallised; or the attack might be by gaseous magmatic constituents like oxygen. The mantle of the other crystals might not melt completely, however, in which case parts of the diamond would be protected from all these chemical changes. Explosions, too, might occur in the magma, because of sudden evolutions of gas, and these might result in a brecciation of the solid contents, among them the diamond itself.

In the light of these ideas, examination of the large specimen can be pursued from another angle. The pitted face might have had other minerals crystallised on it, and might, therefore, have been protected from re-solution by the magma, whereas the rest of the specimen was subjected to corrosion and to impacts that caused the conchoidal ridges and grooves. The general corrosion would occur on all surfaces that had been produced and exposed up to that time. Complete disentanglement from the parent rock, after the latter had weathered and had been subjected to mechanical disintegration, would permit the diamond to be washed into a stream, with other stones, and to be battered, may be, in some pot-hole or whirlpool. The chatter cracks would be most apparent on the edges and corners, as is the case. Finally, perhaps after an interval, the last cleavage would have some edges that were not battered. Such a story would fit in reasonably with the characters of the specimen.

There are some other interesting speculations: How large was

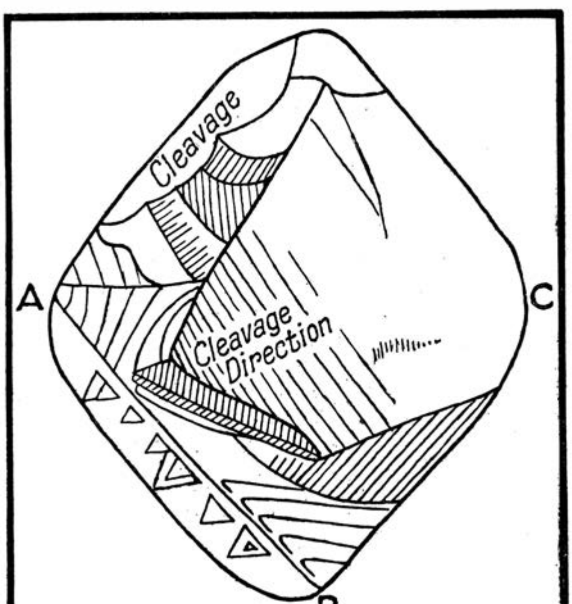

Fig. 1. Top plan of largest diamond (No. 1) set so that cleavage directions are across the corners of the cube, *i.e.*, parallel to the octahedral faces.

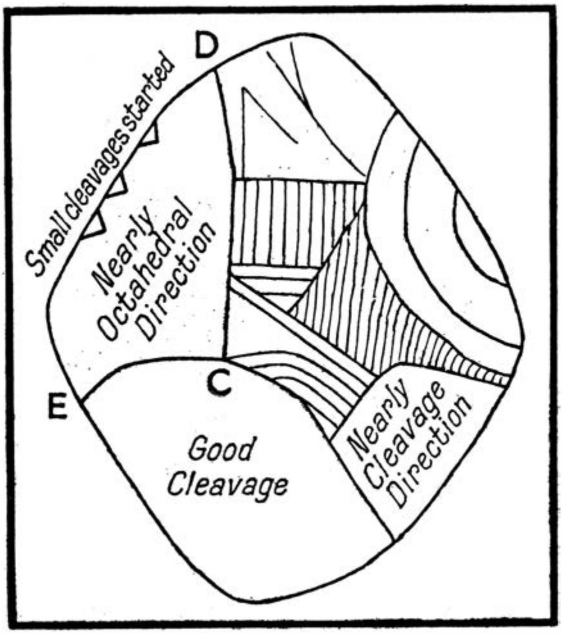

Fig. 2. Basal plan of largest diamond (No. 1) set as in Fig. 1.

the original stone, for example ? The only natural face is the one with the triangular pits and its longest edge is about 55 mm. A perfect octahedron with this length of edge would have weighed around 1,400 carats. If, however, we place the specimen so that the one natural face and the cleavage planes are set in their proper orientation with respect to a cube, as has been done in text Fig. 1, it is significant that the edge A-B is parallel to the diagonal of the cube, which seems to suggest that the original octahedron was elongated in growth, the edge A-B taking the place of an octahedron point. In that case no simple calculation for the original size is possible, and the crystal may have weighed even more than has been suggested. Turning the crystal over, and again setting it by the cleavages, it appears like text Fig. 2, and the prominent edges C-D and C-E are almost in the direction of octahedral edges, *i.e.* in planes perpendicular to cube edges. It is true that the edges are rather curved, but corrosion might have attacked the crystal so that the original direction of prominent edges was irregularly preserved.

There is no special significance about these speculations, except to suggest that the original crystal was irregular in shape, one side being more nearly pyramidal than the other, the latter having an elongated edge replacing the apex in the former. Hence the edges in the second would be parallel to the cube diagonal ; in the first to the cube edge. These speculations are probably rather futile, but the net result suggests that the stone was once larger, though there is no sign that it is merely the smaller piece of a *much* larger specimen.

The second diamond (No. 2), which was found in June, 1943, weighs 532·00 carats, *i.e.* 106·4 gm. or about 3¾ oz. It has one flat side, which is parallel to the cleavage direction, and the remainder of the stone rises to a crest, as shown in Plate IV, Fig. 1. The front and back surfaces are domed and covered with somewhat irregular facets that show corrosion striations. The shape is not unlike that of the Jonkers diamond from South Africa. The large flat side is practically along the cleavage direction, and this fact might be taken to suggest that the stone was part of a rather larger specimen.

With the exception of the more recent cleavage facets, the surfaces are all corroded, and, if the flat is regarded as the separation-surface of the two parts of an original crystal, then the break must have occurred at a very early stage in the history of the specimen, because that flat is grooved and corroded. The prominent edges and corners, again, have been battered by mechanical attrition.

Setting the specimen in crystallographic relation to a cube, as in text Fig. 3, amounts to turning the photograph (Plate IV, Fig. 1) nearly through 45°, and it is interesting to note that in this stone also an edge is parallel to the cube edge. This might imply that the large surfaces on this side of the stone were faces of a six-faced octahedron form. The reverse face (text Fig. 4) again has an edge parallel to the cube diagonal, and the surfaces are very nearly octahedral planes. Three of them, being cleavage surfaces, actually *are* octahedral planes. The fourth is more irregular but is still

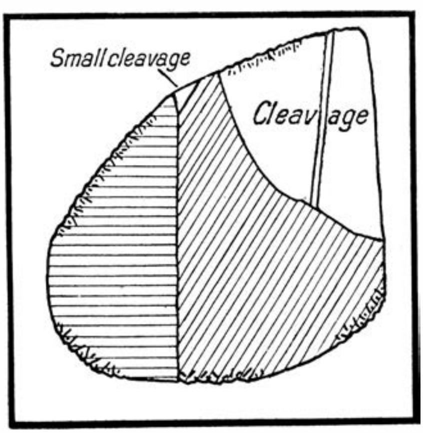

Fig. 3. Basal plan of second diamond (No. 2). Setting as in other figures. Water worn edges shown by irregular shading.

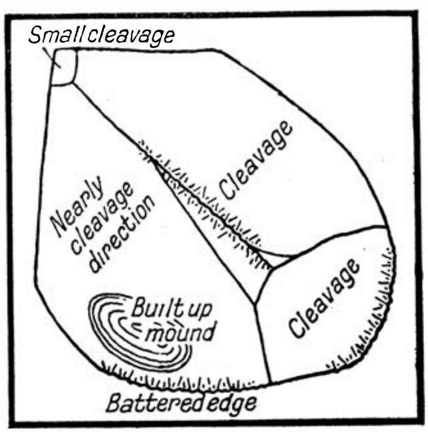

Fig. 4. Top plan of second diamond (No. 2) set as before. Shading represents water worn edges.

almost parallel to an octahedral face. When viewed in this position the edges are all more or less battered by mechanical erosion.

The smallest of the important diamonds (No. 3), found in March, 1943, weighs 249·25 carats, *i.e.* 49·85 gm. or about $1\frac{3}{4}$ oz. As a crystal it is more interesting than the other two, though as a diamond it is not as spectacular. The dimensions are 53 mm. long by 21 mm. broad at one end and 36 mm. at the other. The thickness is 13 mm. When placed in proper crystallographic position (text Fig. 5) it is seen that the long rectangular face is a cube face, and this is confirmed by the pits that are four-sided, with these sides set diagonal to the cube edge. Pits of this type are characteristic of cube faces on the diamond. The sides of the pits are at such an angle that they are really small, negative, octahedral faces, and some of them have the characteristic triangular pits of the octahedral faces themselves. In other words, the bounding surfaces of the pits are reverse octahedral faces and are themselves pitted, as might be expected, like octahedral faces.

There is, however, another interesting feature shown on this cube face. Relatively smooth areas have curious, minute, shallow, square-shaped hollows set in series so that their curved surfaces meet in edges that are parallel to the diagonals of the cube. The general appearance of these dimple-like depressions (text Fig. 6) suggests that they are real etch hollows, *i.e.* that they are due to chemical action removing the substance of the diamond. The

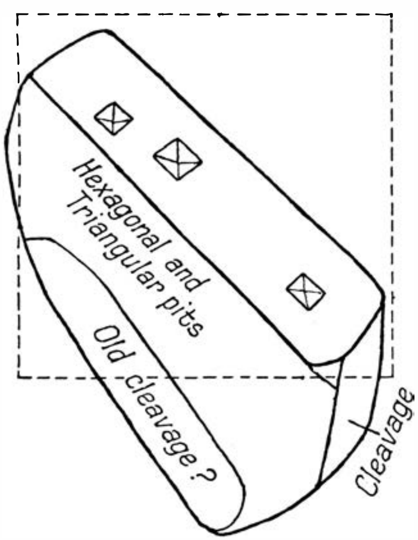

Fig. 5. Sketch of smallest diamond (No. 3) showing cube face on top and octahedral face on side. Dotted square represents top face of the cube to which the crystal has been related.

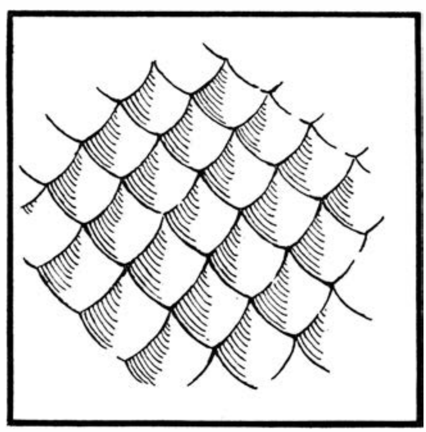

Fig. 6. Diamond No. 3. Minute hollows in regular sequence on cube face, edges diagonal to cube edges. These are regarded as ablation pits.

author has seen very similar hollows, though on a much grander scale, on the surface of a *névé*-field that was disappearing by ablation, in Novaya Zemlya, during the summer of 1937. In that case the hollows had hexagonal boundaries, as would be expected, since ice is hexagonal in crystal structure. On the vertical edges of this *névé*-field a series of vertical flutings were associated with the hexagonal hollows on the top surface. In other words there was a prismatic crystal structure in the mass that was evidently being brought out during the melting of the whole by ablation.

Now, on the cube face of the diamond, one would expect square outlines associated with any similar ablation hollows, and the occurrence of precisely that kind of curved hollow drives one to the conclusion that the phenomenon is probably due to some kind of chemical attack on the diamond. Oxidation to carbon dioxide and consequent disappearance as gas is the most obvious explanation.

When the long narrow surface is set parallel to the diagonal of a cube face (text Fig. 5) the relationships of the several natural crystal planes become apparent. The front face, sloping towards the lower corner of the cube, is an octahedron, as is also the back parallel face. The cleavage surface on the lower end comes into its proper position on the adjacent corner of the cube. What appears to be an old cleavage surface also fits in appropriately.

The large flat octahedron faces (the largest surfaces on this specimen) are equally interesting. One is shown in Plate IV, Fig. 3, and is covered with pits of two kinds, triangular and hexagonal. The latter have been recorded on diamond previously, but rarely are so abundant as in this specimen. The edges of both types of pit are, of course, parallel (Plate IV, Fig. 7).

On the opposite side to the cube face there is a surface (marked "old cleavage" in the text figure) that has some interest. The surface is parallel to the cleavage. It has minute striations and a low ripple such as might occur on a cleavage surface; but there is also a glazed appearance that suggests some kind of corrosion after the break had taken place. A more recent cleavage is also shown and a conchoidal fracture of about the same date, but there is less evidence of battering on this specimen than on the other two.

Thus, all three stones seem to show a parallel history. In an intertelluric stage they seem to have suffered both mechanical attrition and chemical attack. The former produced fractures and the latter a kind of corrosion of the whole exterior, perhaps by gaseous attack; yet the ablation was so uniform that the direction of original edges seems to have been preserved and some faces have had the pitting preserved, possibly by protection afforded by other minerals that had crystallised on these faces, and had remained after the other parts of the diamond had been re-exposed to the action of the magma. Of course it is known that ablation of the diamond, when heated in air, produces similar triangular pits to those that have been taken above as produced in the original crystallisation. But the wonderful pitted face of the largest specimen, and those on the smallest, seem to be best explained in relation to the other surfaces if they are presumed to represent an earlier part of the history of the stones.

After release from the original parent rock by natural processes of decay, all three specimens have been subject to mechanical attrition. In the two larger the edges have suffered considerable battering, though it did not necessarily require a prolonged time to effect that erosion. The smallest did not suffer so much, but it also has recent cleavage fractures.

The quality of the material of these diamonds is high ; inclusions are present, and some cleavages have been started that do not go right through the stones, but, none the less, very beautiful gems will be cut from them.

The large size of all three of these diamonds militated against determining whether they were of the type I or type II variety of Robertson, Fox and Martin. (*Phil. Trans. Roy. Soc., Ser. A.*, 1934, **232,** 463-535.) But it is hoped that fragments of each may be made available, when the individual stones are being fabricated, so that this character may be ascertained.

It will be interesting to see whether further geological surveying of the neighbourhood proves the presence of diamond-bearing Kimberlite similar to occurrences in South Africa. A study of the minerals associated with the diamonds in the gravel might also be useful in determining provenance.

In conclusion, I would thank Mr. F. Hickenbottom for re-drawing the text figures, Mr. E. H. Cooper for preparing the prints used in Plate IV, and the Diamond Development Co., Ltd., and the Sierra Leone Selection Trust, Ltd., for permission to use the negatives of photographs of the diamonds.

PLATE IV

(opposite)

Photographs, natural size unless otherwise stated, of the three large diamonds described in the text. These are from untouched negatives in the possession of the Diamond Development Co., Ltd. and the Sierra Leone Selection Trust, Ltd.

Fig. 1. Diamond No. 2 (532·00 carats). General view. The straight vertical edge on the left is really parallel to an octahedron face.

Fig. 2. Diamond No. 3 (249·25 carats). Top view of the smallest diamond. This shows the deeply pitted cube face with squarish pits; the bottom edge is determined by a cleavage face.

Fig. 3. The same diamond as fig. 2, showing one of the flat octahedral faces. The pits are either triangular or hexagonal in shape. *See also* fig. 7.

Fig. 4. Diamond No. 1 (770·00 carats). The largest diamond set to show the general lozenge shape.

Fig. 5. The same as fig. 4, illustrating the large triangular pits and raised shields on the octahedral face. The edge AB shows percussion cracks well developed about two-thirds of the way from A to B.

Fig. 6. The same diamond, the side opposite to that shown in fig. 4.

Fig. 7. Top left-hand corner of fig. 3, magnified 3·5 diameters to show the triangular and hexagonal pits.

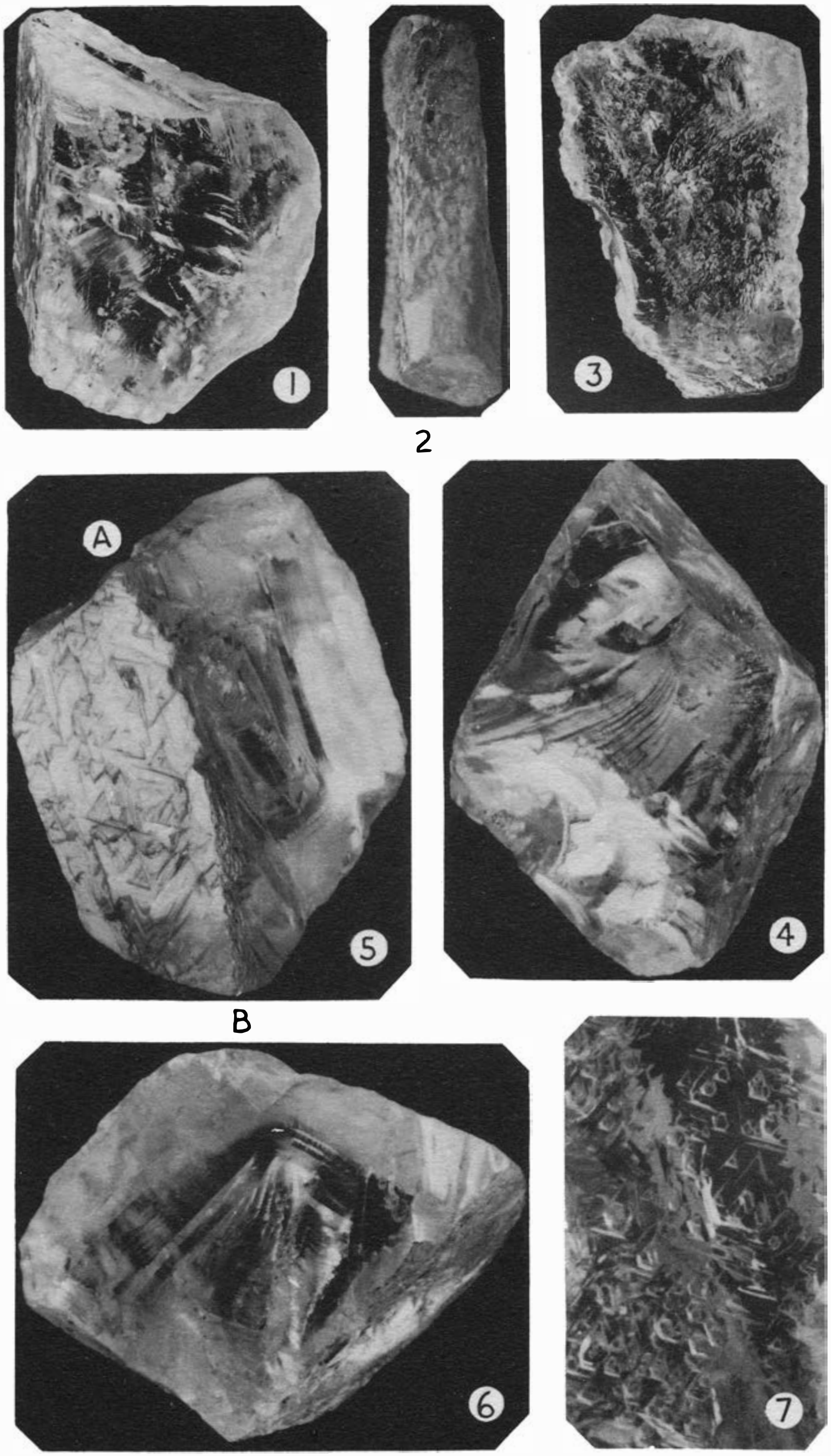

PLATE IV.—LARGE DIAMONDS FROM SIERRA LEONE.