ON A REMARKABLE COMPOSITE DIAMOND

BY

B. G. ESCHER

(With plates 14—17).

1. INTRODUCTION.

In June 1937 the State Museum of Geology and Mineralogy at Leiden received from Mr. A. S. DRESDEN at Amsterdam a diamond crystal of a hitherto unknown shape.

The crystal is colourless and transparent. Mr. J. BOLMAN determined its weight at 0.1698 g and its specific gravity at 3.4165.

This diamond can be characterized as a parallel grouping of a central octahedron which carries an octahedron on each of its faces. In our figures the corners of the central crystal are named A—F and its faces **1**—**8**. The by-octahedrons are numbered I—VIII in such a way, that octahedron I is attached to face **1** of the central octahedron, octahedron V to face **5** etc.. The corners of the by-octahedrons are called a—f in such a manner that the edges ac // AC, bf // BF, etc.. If the edges of the eight by-octahedrons equalled the half of the edges of the central octahedron, the crystal grouping would, in clinographic projection, look as in fig. 1. Fig. 2 is the orthographic projection in the direction of a tetragonal axis, fig. 3 in that of a trigonal axis and fig. 4 in that of a diagonal axis.

In reality the central octahedron, is, to begin with, distorted. The edges radiating from A measure: AC 3360 μ, AE 2830 μ, AF 4150 μ, whereas the corner D is invisible. The by-octahedrons have different sizes and different distortions. Partly they have grown in such a way as to cover the edges and corners of the central crystal.

The corners A and F of the central octahedron are distinctly developed, E and C are less distinct whereas B and D are wanting. All edges and faces are convex. Moreover there are no sharp edges; they are replaced by grooved edges. All the nine octahedrons are of the "notched or grooved" type (A. F. WILLIAMS, 1932, II, p. 501).

It is a well known fact, that photographs do not give a good impression of diamond crystals, because the internal reflections disturb the image of the surface.

In the figures 5, 6 and 7 three photographs are given in the direction of a fourfold, threefold and twofold axis respectively. They give but a poor impression of the wealth of faces of our composite diamond.

On the other hand photographs are apt to elucidate the minor details of a single face of a diamond crystal. A. F. WILLIAMS (1932) made an extensive use of them in a fine collection of photomicrographs.

The habit of diamond crystals can only be approximated by drawings. FERSMANN (in FERSMANN and GOLDSCHMIDT, 1911) gave the best drawings of diamond crystals ever published; SUTTON (1928) published several pencil drawings which give a good idea of their diversity.

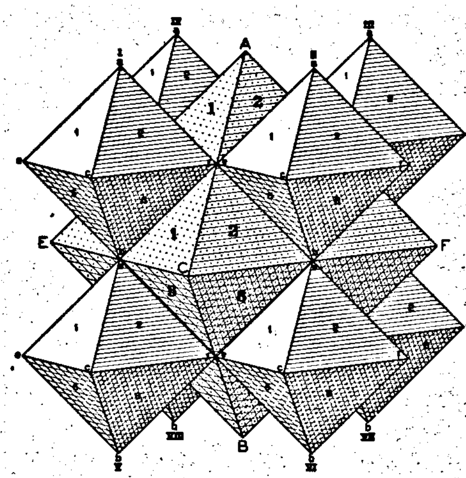

Fig. 1.

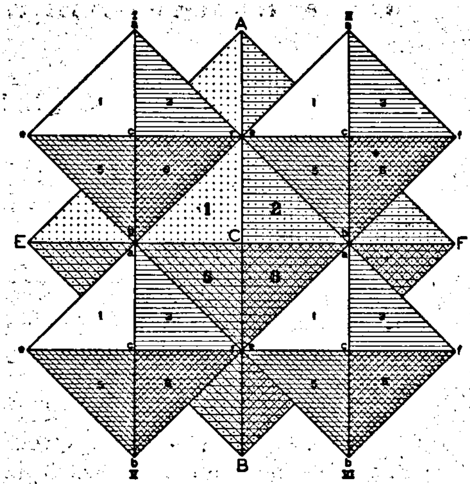

Fig. 2.

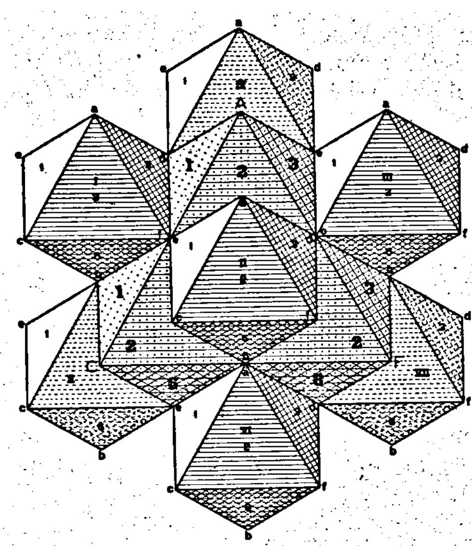

Fig. 3.

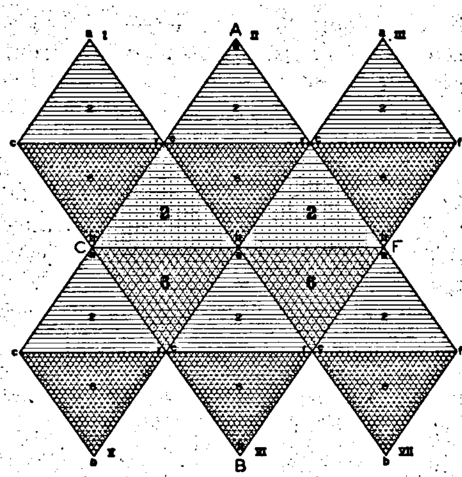

Fig. 4.

The details of the crystal forms of diamond become only perceptible by oblique incidence of the rays of light; and a small change in the direction of the striking rays will generally show new details. So the choice of the details drawn must be in some measure subjective. The writer has attempted to give at least the most important details exact. Notwithstanding the numerous little faces and edges our pencil drawings remain diagrammatic.

It would have been impossible to perceive the wealth of faces and edges with an ordinary monocular microscope. Only the perspective view of a binocular microscope enables one to distinguish the direction of these forms in the third dimension. The diamond has been studied under a Leitz Greenough microscope with oculars 8 × and objectives 2 ×, 4 × and 8 ×. Most of the pencil drawings were made with the aid of a camera lucida.

Measurements were taken with a monocular tube put in the same stand, with a micrometer eye-piece 10 × and an objective 5.5 ×. As it proved difficult to define beginning and end of the edges, in connection with their grooved character, their lengths were rounded off to tens of microns. A black inclusion in the by-octahedron VII served as aid in the orientation of the crystal.

Six drawings were made in the directions of the tetragonal axes, one towards each of the corners A—F and eight in the directions of the trigonal axes, perpendicular to the faces I_1, II_2 etc., moreover some drawings of details (Plates 14–17). Only incident rays of light were used from the upper left hand corner with a Leitz Monla-lamp.

Most of the drawings were executed with a magnification of 22 ×.

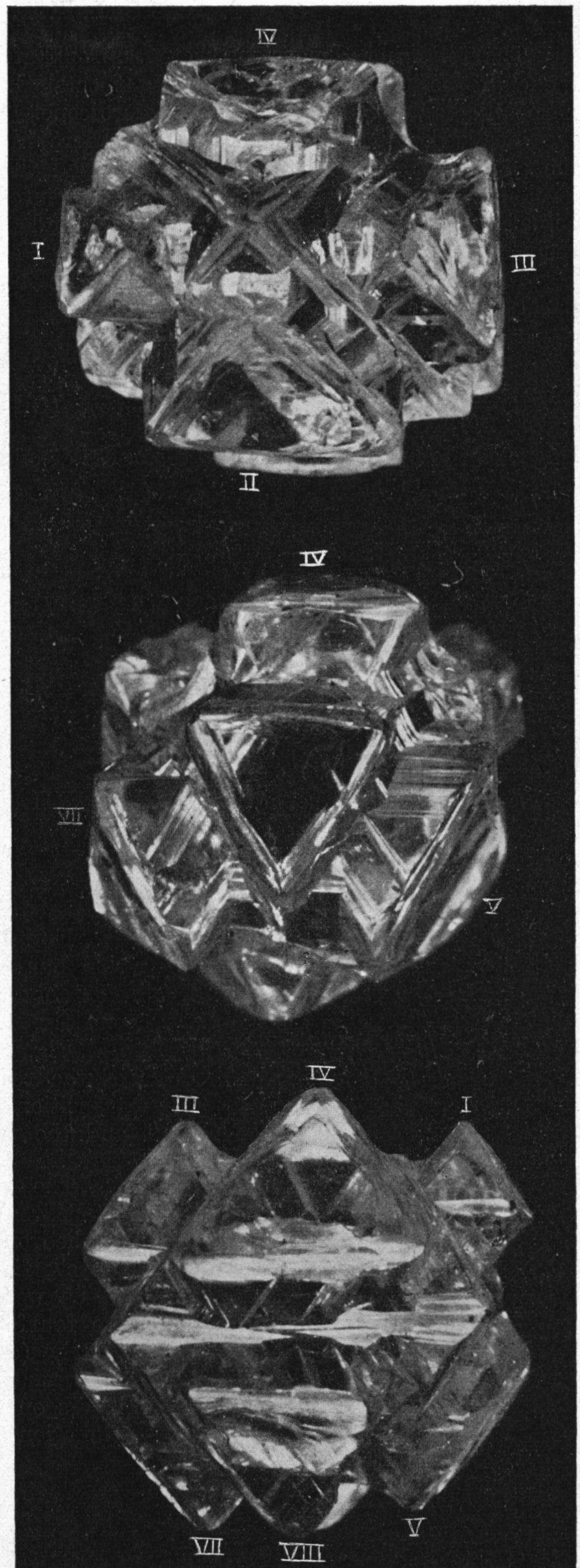

Fig. 5, 6 and 7.

2. DESCRIPTION.

The following dimensions were approximately established in microns in the eight positions in which the eight octahedron faces stood in succession perpendicular to the axis of the microscope. The situations correspond to the idealized fig. 3. The face II_2 lies here in the highest level and in it the edges II ac, af and cf can be measured. The face ACF lies in a lower level in which AC, AF and CF can be measured as well as the face I_2 with ac, af, cf and the perpendicular on ac, and the faces III_2 and VI_2 with their three corresponding edges.

In reality the faces I_2, III_2 and VI_2 lie in different levels more or less parallel to the face ACF.

Edges of the central octahedron.

AF = 4150, AE = 2830, (AC = 3360), (CE = 2600), (CF = 4380) *)

Edges of the by-octahedrons and distances of edges to the central octahedron.

I	ac = 1420	⊥ac = 920	V	bc = 2800	⊥bc = 1000
	ae = 1600	⊥ae = 890		be = 2560	⊥be = 890
	ec = 1350	⊥ec = 840		ce = 2780	⊥ce = 410
II	ac = 2510	⊥ac = 920	VI	bc = 1970	⊥bc = 700
	af = 2780	⊥af = 730		bf = 1860	⊥bf = 700
	cf = 2700	⊥cf = 810		cf = 2160	⊥cf = 810
III	ad = 2100	⊥ad = 860	VII	bd = 2600	⊥bd = 1080
	af = 2130	⊥af = 1030		bf = 2320	⊥bf = 810
	df = 2350	⊥df = 780		df = 2650	⊥df = 590
IV	ad = 1670	(⊥ad = 700)	VIII	bd = 2260	⊥bd = 890
	(ac = 1900)	⊥ae = 760		be = 2250	⊥be = 730
	de = 2100	⊥de = 810		de = 2210	⊥de = 1025

*) The measurements between ( ) are less trustworthy.

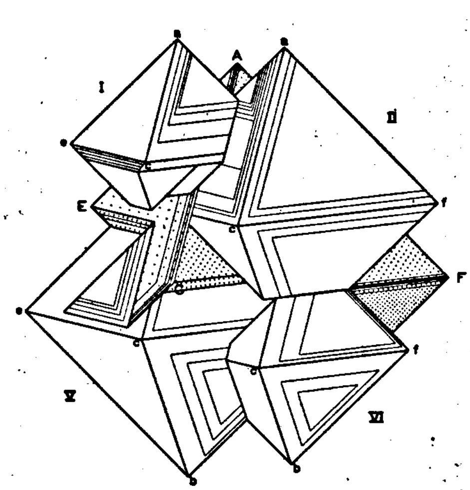

Fig. 8.

From these dimensions follows, that our composite crystal differs considerably from the idealized form of our fig. 1.

Fig. 8 gives an approximate idea of the real shape and is meant as a transition between the idealized form and the very intricate reality.

The **grooved edges** from the central octahedron as well as those of the by-octahedrons tell to full advantage in the six figures A—F (pl. 14 and 15), which were drawn in the direction of the fourfold axes. Some figures show clearly (e. g. fig. B and F) that the grooves were formed by growth in layers on the octahedron faces; an explanation already given by A. L. W. E.

van der Veen (1911) in his excellent study on diamond. That most of the octahedron faces are only apparently convex and in reality built up of successive layers is a. o. shown by fig. B, C (pl. 14 and 15), II and III (pl. 16).

The **central octahedron.**

The corner A from the tetragonal axis AB is distinctly developed, whereas the corner B is wanting; it is replaced by an extremely complicated set of faces between the octahedrons V, VI, VII and VIII (fig. B). In this figure a geniculated edge runs from V towards VII. From this edge, between V and the centre, the field 8′ descends scalarwise in the direction of VIII, the field 6′ in the same way towards VI. A similar picture is repeated between the centre and VII, where 8′ falls scalarwise towards VIII and 6′ in the direction of VI. This field 6′ ends in the longer side of a sunken rectangle, which belongs to form $\{100\}$.

These **scalariform fields** possess innumerable steps and imitate octahedral faces. They are indicated in our drawings by an arabic number with an accent. Their inclination is neither constant in one oscillatory combination nor the same in different scalariform fields. Sometimes they are convex, as follows from the course of the feigned edges in fig. D. Some steps belong to the form $\{100\}$.

A second geniculated edge (fig. B) runs from the middle towards VIII and less distinctly towards VI. From the former part of this ridge the field 7′ descends scalarwise towards VII and the field 5′ towards V. From the second part a distinct scalariform field descends towards the above mentioned rectangle, which is also to be seen on fig. VIII. Fig. B′ shows the complications round this sunken rectangle with the dimensions $190 \times 245\ \mu$.

If we contemplate fig. A, we see here too a sunken rectangular figure, which shows still more complications (fig. A′).

The fourfold axis CD possesses a corner C, which is abnormally developed (fig. C), whilst, next to it, a double scalarwise descending oscillatory combination 1′ and 6′ runs towards I and VI. The abnormal development of the corner is caused by the fact that an edge between **1** and **2** is rightly developed but not between **1** and **5**.

From C an edge runs thus towards A, but not towards E, while there is an edge running from E to the right, where C might be supposed to be. The second edge, which meets in C, runs parallel to the edge AE. Fig. I also shows the corner C clearly.

In stead of the corner D there appears a truncated hollow pyramid (fig. D), in which the four inclined faces are replaced by scalariform fields 3′, 4′, 7′ and 8′ which run out into a rectangle, belonging to the form $\{100\}$. Its dimensions are $135 \times 162\ \mu$.

The tetragonal axis EF possesses in E an abnormal corner (fig. E), whereas the corner F is clearly developed as the summit of four grooved edges (fig. F). In fig. E a complicated cavity appears below Vc with one scalarwise descending field and a tangle of plane and curved facets.

Here and there little **triangular figures** are developed, which are distinct only under a definite illumination. They are little holes, sunken trigonal pyramides, with numerous steps. They were observed a. o. on the face VII 8 (fig. B), on the face II 2 (fig. II pl. 16) and on I 4 (fig. IV pl. 16). Their limitation is opposite to that of the face on which they appear, that is, their corners point to the sides of the face in which they are sunk.

A. F. Williams (1932, Vol. II, p. 491 and 494) has made it clear that they are *growth cavities* and not etch cavities, which latter are extremely rare and possess quite an other patterning, whereas here the distinct scalarwise flight of steps is typical.

The figures I—VIII (pl. 16 and 17) show, once more, the frequent appearance of scalariform fields between the central and the by-octahedrons.

Fig. I shows the face AEC (1) of the central octahedron, the octahedron I which has grown thereupon and the octahedrons IV, II and V.

Fig. II is more complicated as besides the four by-octahedrons II, III, VI and I, which are visible from the nature of the thing, parts of the octahedrons VII and IV are seen too.

Fig. III shows the edge AF from the central octahedron and all by-octahedrons except V.

In fig. IV the deep groove with its rounded forms near E is clearly visible in the direction of ec between the central octahedron and octahedron V. Attention must also be paid to the conchoidal development of the upperhand corner of IV 4.

Fig. V shows, in the growth of the face V 5, numeraus curved faces of which the hinges run partly more or less parallel to the edge ec, partly with hinges which are more or less perpendicular to the face V 5, and by which trigonal or rather ditrigonal patterns were formed with curved sides. This phenomenon is also to be seen on the face VI 6 (fig. VI).

Fig. VII shows the fourfold scalariform cavity already mentioned with fig. D. The longest stair against VII (4' in fig. D) appears here as the shortest by perspective foreshortening.

In conclusion attention may be directed to the curved faces on III in fig. VIII and the conchoidal faces near VI 8.

If all details of this composite crystal were to be described, numerous photomicrographs would have to be made from every octahedron face and moreover the same place would have to be photographed with different illuminations.

Above we have tried to elucidate at least the most characteristic forms.

3. SPECULATION.

Growth of the by-octahedrons.

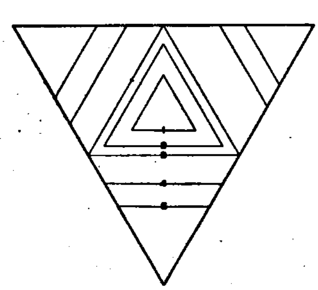

Fig. 9.

The composition-plane, along which a by-octahedron has grown on the central crystal, is originally a triangle, of which the vertex points to the base of the corresponding face of the central octahedron (e. g. in fig. 3 △ I, dbf in respect of AC). If such a by-octahedron grows, the triangular contact-plane becomes first larger, till its corners reach the sides of the face of the central octahedron, and than the contact plane becomes hexagonal (fig. 9). The three original sides now become smaller and the three new sides grow.

Grooved or notched edges.

The central octahedron as well as the by-octahedrons possess grooved edges. Van der Veen (1911) has made it clear, that this habit of diamond is the consequence of the growth by layers of the octahedral faces, by which every new layer has a slightly smaller area than its predecessor. These layers are in the beginning triangular, whereas the later layers get a more ditrigonal shape, by which the grooved edges get wider at the corners than between two corners (fig. B, VII and VIII; fig. C, II; fig. D; fig. E, IV; fig. F, VI). If we look upon the grooved edges as formed by imaginary faces, these must belong to curved hexakisoctahedrons. In that case the crystals are bordered by hexakisoctahedrons with different indices which are truncated by curved octahedron faces.

Cube faces.

As a real plane face the form $\{100\}$ is rare with diamond. Diamond crystals with hexahedral habit do occur, but their faces are replaced by numerous fourfold sunk pyramids (octahedral faces) of which the diagonals run parallel to the edges of the cube.

FERSMANN and GOLDSCHMIDT (1911) describe plane, shining cube faces, which truncate the octahedral faces of a diamond. VAN DER VEEN (1911) mentions hexahedral faces as steps of scalariform fields, which form fourfold pyramidal cavities.

In our crystal similar cavities are likewise bordered by scalariform oscillatory combinations in which the form $\{100\}$ appears, but moreover the bottom of the cavity is formed by a rectangular plane face, a real cube face. These cavities, which are parties that remained behind in the growth of the composite crystal, appear in our case always between octahedrons: in fig. A between III and the central octahedron, in fig. B between VI, VII and the central octahedron, in fig. D between III, IV, VIII and VII.

4. CONCLUSION.

After what has been said above it is clear, that our composite diamond exclusively shows in every octahedron and in each detail, as well as in its whole habit, signs of growth. Of the important rôle which FERSMANN and GOLDSCHMIDT (1911) attribute to solution, which rôle is strongly denied by SUTTON (1928) and A. F. WILLIAMS (1932), nothing could be detected in our crystal.

BIBLIOGRAPHY.

A. L. W. E. VAN DER VEEN: Physisch en Kristallografisch onderzoek naar de symmetrie van diamant. Proefschrift, Delft, 1911.

A. VON FERSMANN und V. GOLDSCHMIDT: Der Diamant. Heidelberg, 1911.

A. L. W. E. VAN DER VEEN: Die Symmetrie des Diamanten. Zeitschr. f. Krystallographie usw. Bd. 51, S. 545—590, 1913.

J. R. SUTTON: Diamond. London, 1928.

A. F. WILLIAMS: The Genesis of the Diamond. London, 1932.

Fig. A.

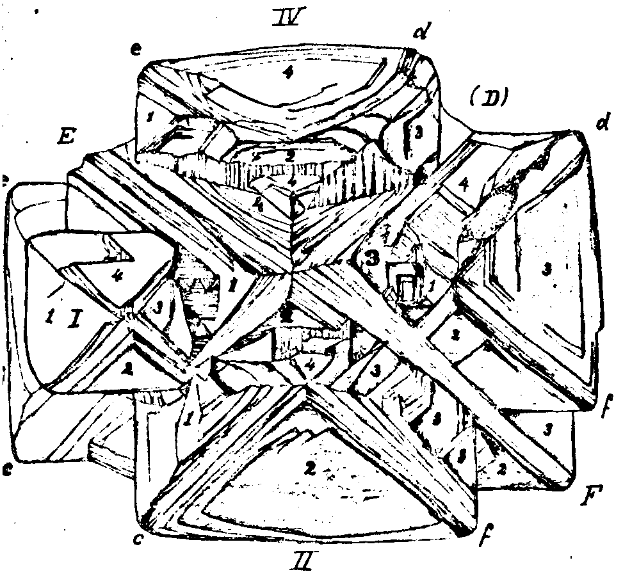

Fig. C

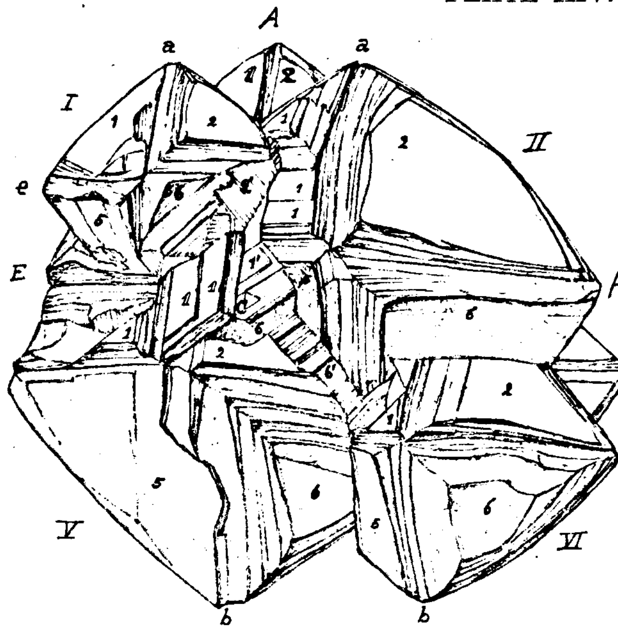

Fig. D

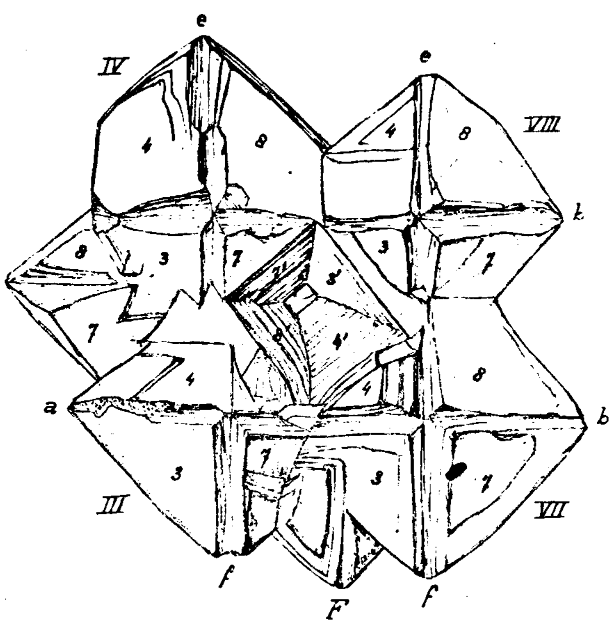

Fig. E

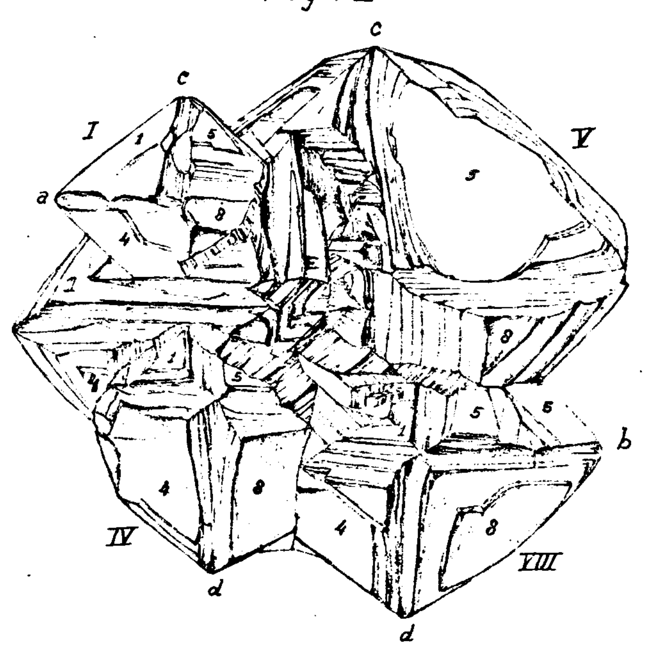

Fig. F

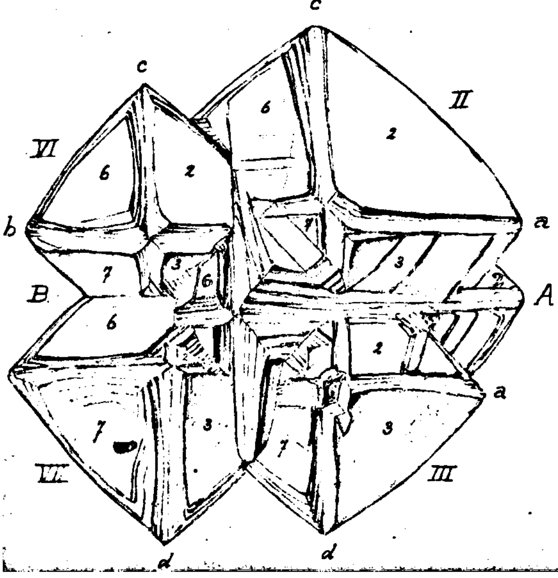

Fig. A'

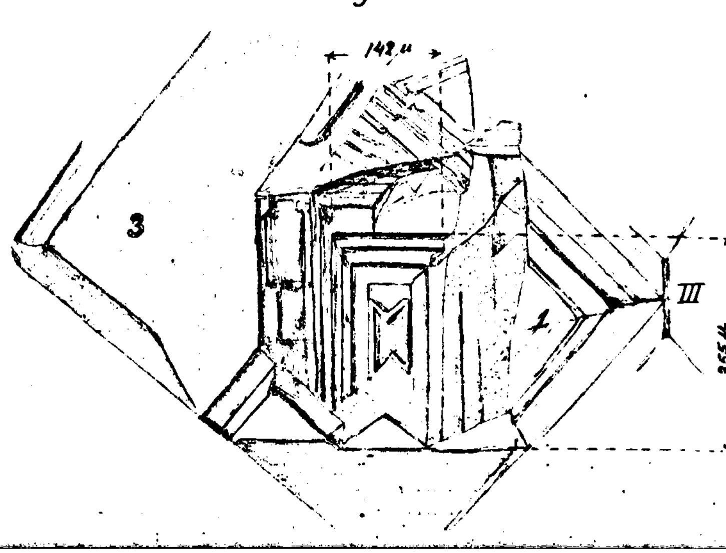

Fig. B

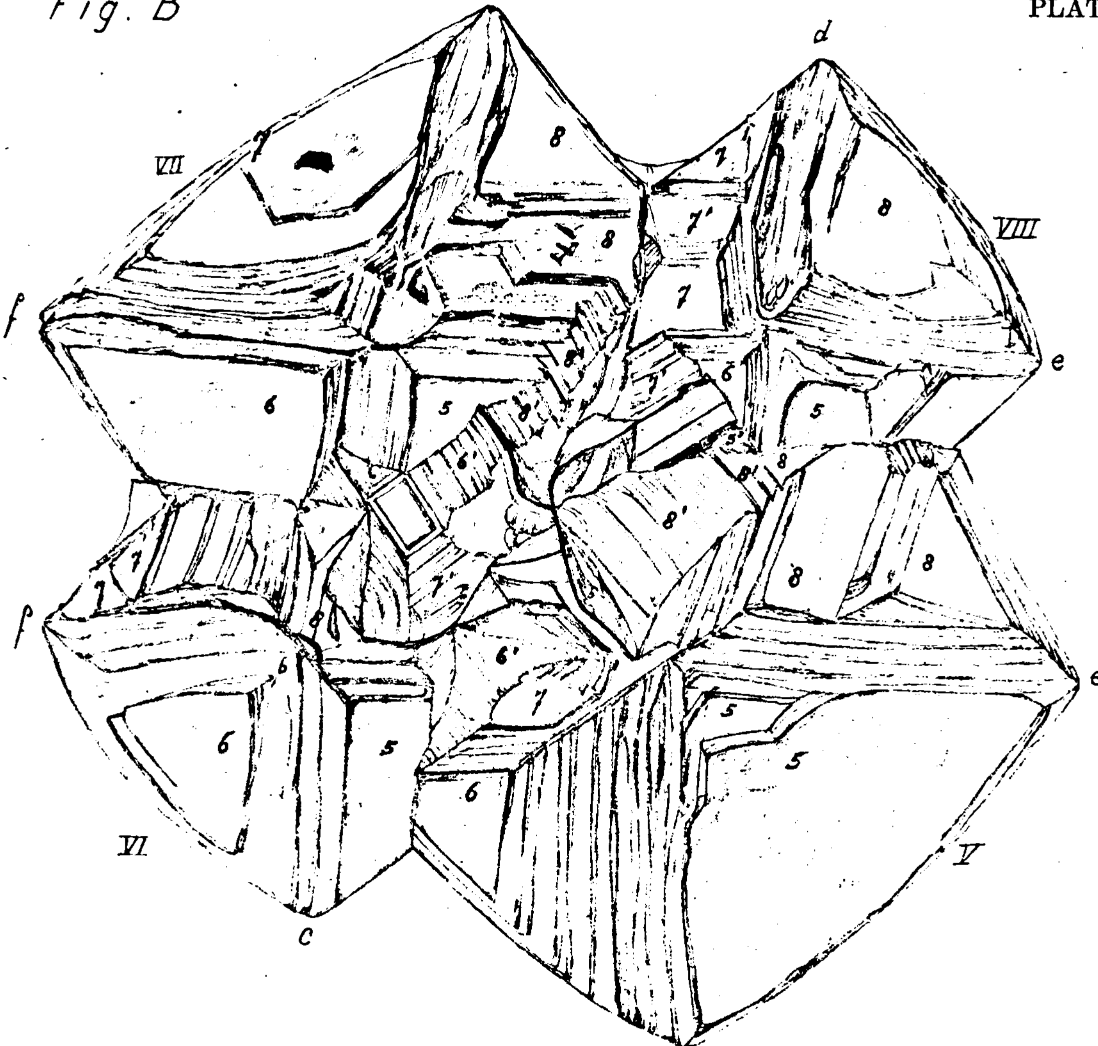
d
d
8
7
VII
VIII
7'
8
7
f
6
e
5
5
6
8
7
8
8
f
6'
6
e
5
6
5
5
6
VI
V
c
c

Fig. B'

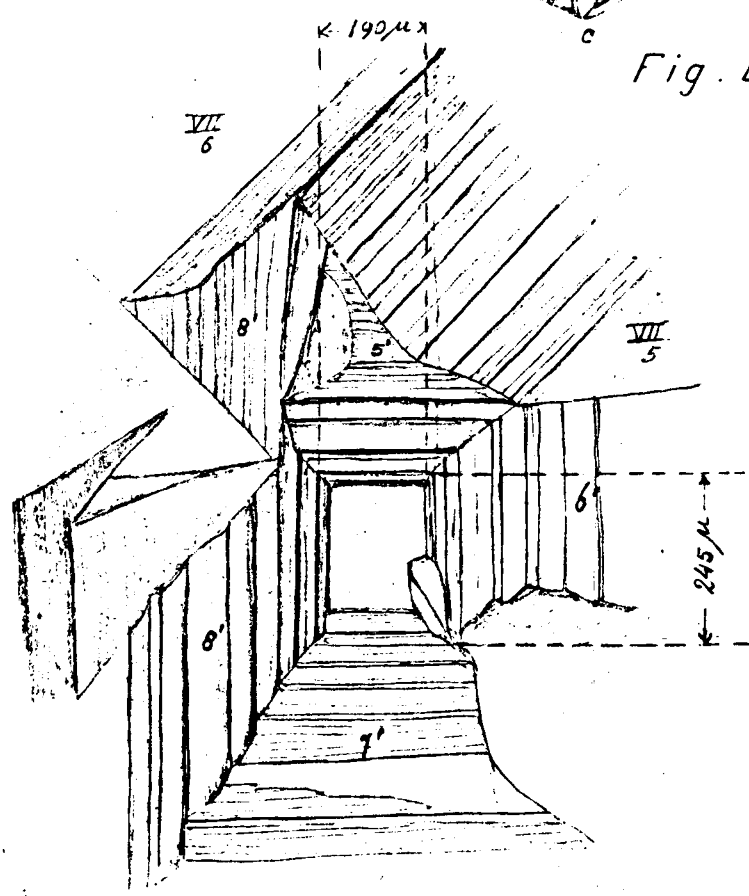
190 μ
VII
6
8'
5'
VIII
5
6'
245 μ
8'
7'

PLATE XVI.

Fig. I

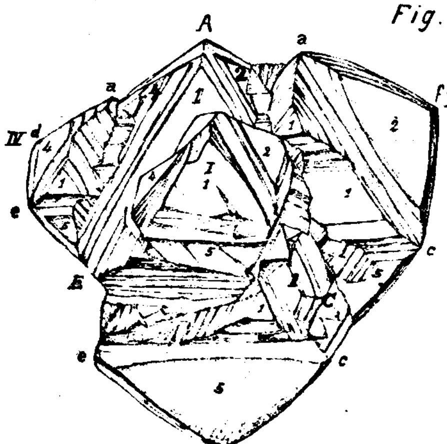

Fig. II

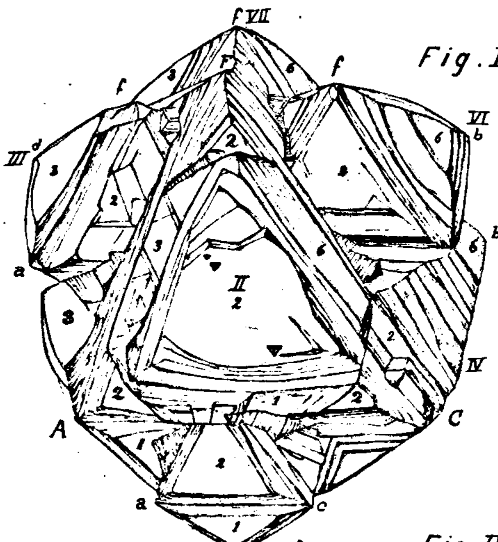

Fig. III

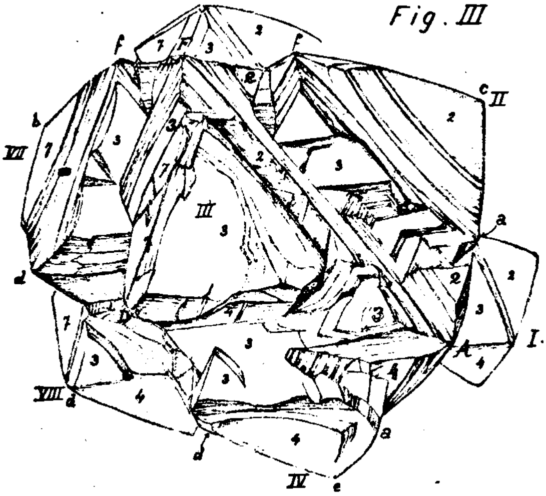

Fig. IV

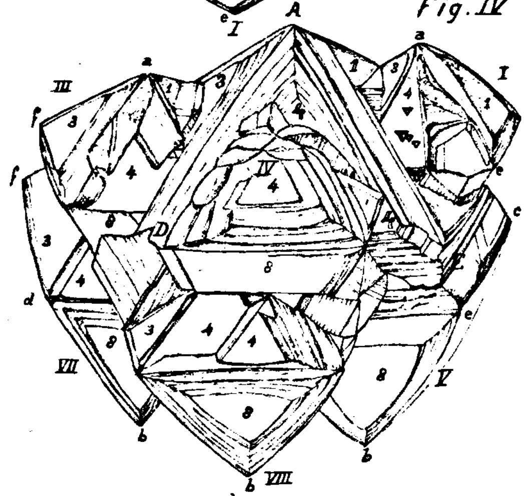

PLATE XVII.

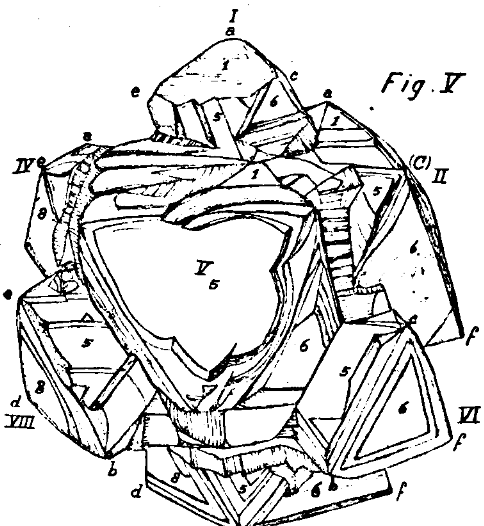

Fig. V

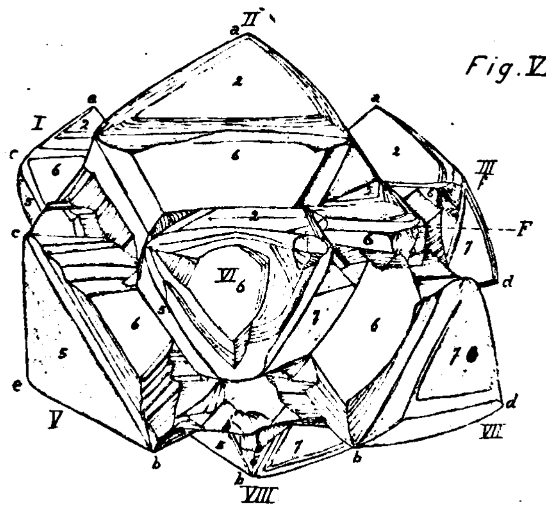

Fig. VI

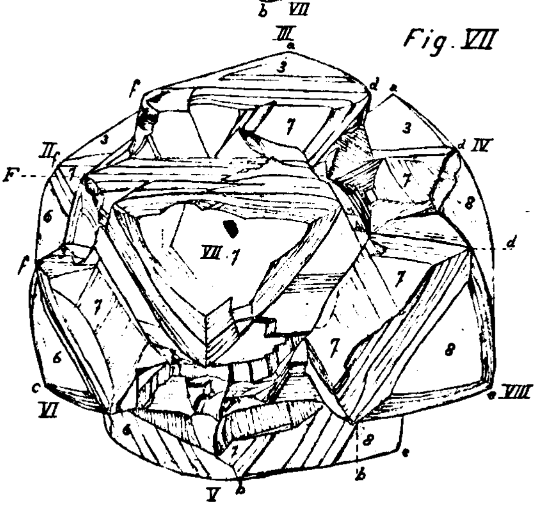

Fig. VII

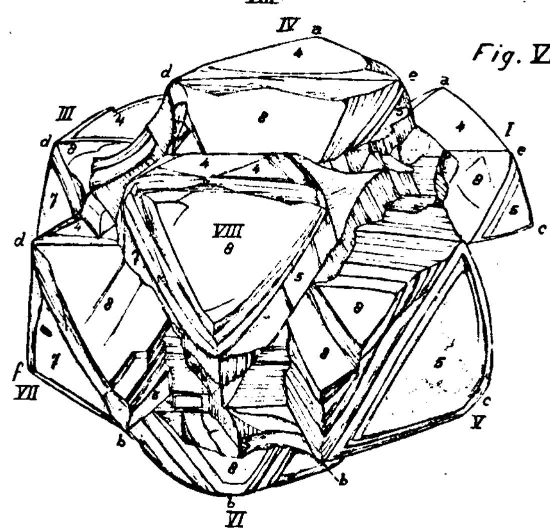

Fig. VIII