



XLIX. On crystallography. Translated from the last Paris edition of his *Traité de Minéralogie*

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ment. The importance of the subject cannot be doubted, and it appears to me to have been very undeservedly neglected of late.

I am, sir, your obedient servant,

Nov. 17, 1809.

ENCEPS.

XLIX. *On Crystallography.* By M. HAUY. Translated from the last Paris Edition of his *Traité de Minéralogie*.

[Continued from p. 302.]

Of secondary Forms, the Molecules of which differ from the Parallelopipedon.

IT is a character common to all the primitive forms to be divisible parallel to their different faces. In the parallelopipedon, this division, when not joined to any other which can take place in different directions, evidently leads to a form of molecule similar to the nucleus. In the regular hexahedral prism, it gives as a molecule an equilateral triangular prism, as we have already seen in another place. In the octahedron, it seems to tend towards molecules of two different forms, some tetrahedrons and others octahedrons. This mixed kind of structure takes place also with respect to the tetrahedron. But every probable reason concurs to exclude the octahedron, and to adopt the tetrahedron in preference, as being, in these cases, the true integral molecule. Under the head *Fluited Lime* more particulars will be found on this subject.

If we divide in the same way the dodecahedron with rhombic planes, the molecules will be, without equivocation, tetrahedrons with triangular isoscele faces. Under the article *Garnet*, every thing relative to this kind of structure will be found.

With respect to the dodecahedron with isoscele triangular planes, we cannot extract the molecules that compose it without dividing it in directions different from those which would be parallel to the faces. The tranchant planes in this case ought to pass by the axis, and by the ridges contiguous to the summits, whence irregular tetrahedrons result as molecules. This point of theory will be treated of in the article *Quartz*.

The other primitive forms are also sometimes subdivided in directions which are not parallel to their faces. We have already had an example of this, relative to the rhomboid of the tourmaline, whose subdivision, following planes
which

which pass by the axis and by the oblique diagonals, gives the result represented in fig. 10, where we see that the molecules are tetrahedrons. Observation also proves that the oblique quadrangular prism which is the nucleus of pyroxene, has natural joints situated parallel to a plane which would pass by the small diagonals of its bases; from this we may conclude that its molecules are triangular prisms.

I shall not insist further on these modes of division, which will be explained at greater length when we come to speak of the articles which represent them; but I ought not to pass over a result which serves to connect the crystallization of substances, whose molecule is the tetrahedron or triangular prism, with that of substances which have, as primitive forms, simple assemblages of elementary parallelopipeds.

This connection consists in the tetrahedral or prismatic molecules being always assorted in such a manner, in the interior of the primitive form and of secondary crystals, that on taking them by small groups of twos, fours, sixes, or eights, they compose parallelopipeds, so that the ranges subtracted by the effect of decrements are nothing else than sums of these parallelopipeds.

That we may better conceive how this takes place, let us conceive for a moment that the small rhomboids which represent the molecules of carbonated lime are divisible into tetrahedrons, as we have seen with respect to the rhomboids which belong to the tourmaline. This view does not change the explanations which we have given of the different secondary forms of which carbonated lime is susceptible: *i. e.* in order to determine these forms by the help of theory, we should always confine ourselves to the consideration of decrements by one or more ranges of rhomboidal molecules.

What is only an hypothesis with regard to carbonated lime, is changed into reality with the tourmaline. Although the rhomboids produced at first by the mechanical division of the crystals of this substance are ultimately resolved into tetrahedrons, the decrements which give the secondary forms are produced by subtractions of these rhomboids similar to the primitive form; so that we may suppose, in calculations relative to the determination of these forms, that the tetrahedrons which represent the true molecules are connected with each other in an invariable manner in each rhomboid.

Let us cite another example drawn from a very simple structure,

structure, which is that of crystals whose primitive form is the regular hexahedral prism. Let AD be always (fig. 40) one of the bases of this prism subdivided into small triangles which are the bases of so many molecules. It is evident that any two given triangles adjoining the other, such as Api , Aoi , compose a rhombus, and consequently the two prisms to which they belong form by their union a prism with rhomboidal bases, which is one of the kinds of parallelopipedon.

Let us now imagine that the triangular prisms, which are the elements of these parallelopipedons, are invariably connected with each other. We may substitute for the arrangement represented in fig. 40, that of fig. 41 merely composed of rhombuses, which will be the bases of so many parallelopipedons.

Now if we suppose a series of laminæ piled up on the hexagon $ABCDFG$, and which undergo, for example, on their different edges, subtractions of one range of parallelopipedons similar to those now in question, these edges will be successively arranged like the sides of hexagons $ilmnrh$, $kuxyge$, &c.: hence we see that the quantity in which each lamina shall exceed the following one will be a sum of parallelopipedons, or prisms with rhomboidal bases; and it is easy to judge that the result of the decrement, supposing that the latter attains its limit, will be a straight hexahedral pyramid, which will have as a base the hexagon $ABCDFG$.

All the other different primitive forms of the parallelopipedon give analogous results. We might even substitute for each of these forms a nucleus similar to the small parallelopipedon, which are assemblages of tetrahedrons or triangular prisms; and we should also succeed in explaining the secondary forms by laws of decrement referred to this nucleus, which would also be given by mechanical division. We shall use it in this manner with respect to quartz, because in this case the substitution of the parallelopipedon for the bipyramidal dodecahedron leads to more simple decrements for certain varieties*.

I shall

* We are acquainted with crystals whose mechanical division gives first a prism with rhomboidal bases which have different angles of 120° and 60° . This prism may be afterwards subdivided in the direction of one of the diagonals of its bases: from which it results that we might also extract immediately from the secondary crystal a hexahedral prism; but which would not be regular. In these cases we shall adopt the prism with rhomboidal bases for the nucleus, because this form, besides being simpler, has a character of regularity

I shall give the name of *subtractive molecules* to those parallelopipedons composed of tetrahedrons, or of triangular prisms, and whose ranges measure the quantity of the decrement which the laminæ of superposition undergo when applied on the faces of the primitive form.

We find from what precedes, that, to speak precisely, theory would not admit of our proceeding towards its principal object, on stopping at the parallelopipedons given in the first place by the mechanical division of crystals; and the kind of anatomical dissection afterwards undergone by these parallelopipedons, when we try to ascend to the true form of the integral molecule, is an ulterior step, without which, observation, rather than theory, would leave something unfinished. The parallelopipedon here represents unity, at which all the results of the theory end; and fractions formed of its subdivisions beyond this unity are of no consequence.

We see at the same time, that by means of this conformity between the results given by the various forms of integral molecules, theory has the advantage of generalizing its object by chaining to a single fact the multitude of facts, which from their diversity seem little susceptible of concurring in one common point.

regularity which the other has not, and which consists in the equality and similitude of its lateral faces.

Here a consideration presents itself which we ought not to omit. Let $ABCD$ (fig. 42) be the upper base of one of the prisms we have mentioned. Let us suppose for a moment that this prism cannot be subdivided except parallel to its four panes and to its two bases. The arrangement of the small rhombuses situated on both sides of the rhombus $ABCD$ will represent the effect of a decrement by one range on the two longitudinal ridges terminated by the points A and C ; and it is visible that this decrement will produce for the secondary form, a hexahedral prism, whose base is represented by $B'l m D' r h$.

Now if we conceive that the rhomboidal prism which has for its base $ABCD$, may be subdivided in the direction of the diagonal BD into two triangular prisms, all the small rhomboidal prisms of which it is the assemblage being susceptible of the same division, we shall suppose that the small vacuums which existed between l and m on one hand, and between h and r on the other, in the hypothesis of the decrement, are filled up by triangular prisms, in which case the hexahedral prism will be immediately given without any decrement. Nevertheless we cannot admit of considering the faces which will be in this case as being produced in virtue of a decrement by one range, because then the form of the secondary crystal is merely composed of small rhomboidal prisms similar to the primitive form, as would have taken place if the decrement was produced by two or more ranges; so that here it is only a particular case which should seem to have been assimilated with all the others for the sake of uniformity in the laws of structure. The same reasoning applies to primitive forms different from the parallelopipedon, as we shall find in the course of this work.

Difference

Difference between the Structure and the Increment.

In the preceding development of the theory, we have supposed that the component laminæ of crystals originally of one and the same species, issue from one common nucleus, undergoing decrements subjected to certain laws, upon which the forms of these crystals depended. But here it is only a conception, adopted to make us more easily perceive the mutual connections of the form in question. Properly speaking, a crystal in its entire state is only a regular group of similar molecules. It does not commence by a nucleus of a size proportioned to the volume which it ought to acquire, or, what comes to the same thing, by a nucleus equal to that which we extract by the aid of mechanical division; and the laminæ which cover this nucleus are not applied successively over each other in the same order in which the theory regards them. The proof of this is, that among crystals of different dimensions which are frequently attached to the same support, those which can only be distinguished by the microscope are as complete as the most bulky; from which it follows that they have the same structure, *i. e.* they already contain a small nucleus proportioned to their diameter, and enveloped by the number of decreasing laminæ necessary, in order that the polyhedron should be provided with all its faces. We do not perceive these various transitions of the primitive to the secondary forms, which ought to take place if crystallization constructed, as if by courses, the species of pyramids superadded to the nucleus, in going from the base to the summit*.

We must therefore conceive, for example, that from the first instant a crystal, similar to the dodecahedron with rhomboidal planes derived from the cube (figs. 11 and 12), is already a very small dodecahedron, which contains a cubical nucleus proportionally small, and that in the following instants this kind of embryo increases without changing its form, by new strata which envelop it on all sides; so that the nucleus increases on its part, always preserving the same relation with the entire crystal.

We shall make this idea apparent by a construction relative to the dodecahedron now mentioned, and represented by means of a plane figure. What we shall say of this figure may easily be applied to a solid, since we may al-

* This, however, is only generally true; for it sometimes happens, in artificial crystallization, (and it is very probable that we may say as much of that of natural bodies,) that a form which had attained a certain degree of increment suddenly undergoes variations by the effect of some particular circumstance.

ways conceive a plain figure like a section made in a solid. Let $t s z s'$, therefore, (fig. 43 A) be an assortment of small squares, in which the square BNDG, composed of 49 imperfect squares, represents the section of the nucleus*, and the extreme squares $t, p, i, B, f, c, s, e, h$, &c., the kind of steps formed by the laminæ of superposition. We may conceive that the assortment has commenced by the square BNDG, and that different piles of small squares are afterwards applied on each of the sides of the central square; for example, on the side BN: in the first place the five squares comprehended between f and h , afterwards the three squares contained between c and e , and then the square s . This progress corresponds with what would take place if the dodecahedron commenced by a cube proportioned to its volume, and which afterwards increased by an addition of laminæ continually decreasing.

But on the other hand, we may imagine that the assortment had been at first similar to that which we see (fig. 43 C), in which the square BNDG is only composed of nine molecules, and bears on each of its sides only a single square s, t, s', z . If we refer, in imagination, this assortment to the solid of which it is the section, we shall easily judge that this solid had for its nucleus a cube composed of 27 molecules, and of which each face, composed of nine squares, carried on that of the middle a small cube, so that the decrement by one range is already exhibited in this initial dodecahedron.

This assortment, by means of an application of new squares, will become that of fig. 43 B, in which the central square BNDG is formed of 25 small squares, and carries on each of its sides a pile of three squares, besides a terminal square s, t, s' , or z . Here we have already two laminæ of superposition, instead of one only. Finally, by an ulterior application, the assortment of fig. 43 B will be changed into that of fig. 43 A, where we see three laminæ of superposition. These different transitions, of which we are at liberty to continue the series as far as we please, will give an idea of the manner in which secondary crystals may increase in volume by preserving their form; from which we may judge that the structure is combined with this augmentation in volume; so that the law (according to which all the laminæ applied on the nucleus when it has

* This section is that which would pass by the points s, s' (fig. 11) of the dodecahedron, and by the centres of the ridges EO, AI, &c., of the nucleus. Thus the point B (fig. 43) is regarded as situated at an equal distance between the points E, O, (fig. 11,) and the point N, at equal distance between the points A, I, &c.

attained

attained its greatest dimensions decrease successively,) was already, as it were, displayed in the growing crystal.

A great deal remains to be done before we can terminate the theory of crystallization. We have only given the laws of the structure of crystals, and we are now enabled to unravel those of their formation. The affinity of the molecules for each other, the nature of the liquid in which crystallization takes place, its degree of density, temperature, and other similar circumstances, would be so many elements, which we ought to take into our calculation, and the solution of the problem would determine the law of decrement which ought to take place in each particular case in virtue of the same circumstances, and the form of the secondary crystal which would result from that law.

We can very well conceive in general, that stony, metallic, or other molecules, suspended in a liquid, and disposed to reunite in order to form a crystal, are attracted at the same time by each other, and even by the molecules of the liquid; and it is because their mutual affinity is stronger than that of the liquid that their union is produced. Now the attraction of the liquid varies on account of the circumstances which we have mentioned; and thus its difference from the mutual attraction of the molecules, which is always the same, ought also to undergo variations which influence crystalline forms in their diversity. And if there are heterogeneous matters in the liquid, they will act on their part in order to modify the action of the liquid on the true molecules. It would seem that we have a proof of this in certain crystals of axinite, one part of which is of a violet colour with manganese, and the other green, in consequence of chlorite being present. The former presents additional facets, which are not observed in the latter, which is besides more regularly formed, and has not a striated surface, like the violet part.

A superabundant portion of some of the essential principles, which would be, as it is said, *in excess*, might also have an influence on the form of the crystal, by adding its own particular action to that of the liquid. For it can hardly be doubted that there is for every substance a fixed proportion of principles, which constitute its true nature; so that all which exceeds the limit given by this proportion ought to be regarded as accidental, and assimilated to a heterogeneous substance.

But the above are only slight hints, by no means sufficient to clear up the subject. Our acquirements have more

progress to make, before geometry can have the data necessary for submitting to a precise and rigorous theory the combined forces of the different agents which concur in crystallization, and ascend from the facts already established, to other facts more general, and more allied to the true causes which depend immediately on the will of the Supreme Being. It is a rich mine, the working of which is merely commenced, and which waits for more favourable times and more scientific workmen to follow the vein to the greatest depth.

Of Crystals with a Moiety reversed, and of those which appear to penetrate each other.

We have hitherto considered crystallization as impressing on its results the character of the greatest possible perfection, and producing nothing but isolated forms, exempt from every thing that could affect their purity and symmetry. It remains for us to describe certain accidents, which, under the appearance of exceptions or anomalies, still possess a latent tendency towards the same laws to which the structure is subjected, when nothing deranges their progress or disturbs their harmony.

In ordinary crystals, the faces adjacent to each other always form saliant, and never re-entering, angles. But crystalline forms also exist which present these last angles; and Romé de l'Isle was the first who observed that this effect took place when one of the two moieties of a crystal was in a reversed position with respect to the other*. A very simple example will enable us to conceive this reversal.

Let us suppose that Bd (fig. 44) represents an oblique prism with rhomboidal bases, situated in such a manner that the planes $ADda$, $CDdc$, are vertical, and BD are the acute angles of the base; and the latter proceeds in a rising direction from A to C . Let us, besides, suppose that the prism is cut into halves, by means of a plane which should pass by the diagonals drawn from B to D , and from b to d , and that, the half situated on the left remaining fixed, the other half is reversed without being separated from the former. The crystal will be presented under the aspect which we see in fig. 45, where the triangle $b'd'c'$, which was one of the halves of the lower base (fig. 44), is now situated in the upper part (fig. 45), and forms a saliant angle with the fixed triangle ABD , while the triangle

* Romé de l'Isle.—Crystal. t. i. Introd. p. 93.

B D C (fig. 45), which was one of the halves of the superior base (fig. 44), is transported into the lower part (fig. 45), and forms a re-entering angle with the fixed triangle $a b d$.

We can easily conceive that the plane of junction D B $b d$ of the two halves of a rhomboid, is situated like a face produced in virtue of a decrement by one range on one or other of the ridges A a, C c, (fig. 44); and thus the manner in which these two halves join is in strict relation to the structure.

Now if we imagine a secondary form which has for its nucleus the same prism, and if we suppose that it has been cut in the directions of the plane D B $b d$, and that one of its halves is reversed in such a manner that the half of the nucleus which corresponds with it assumes the same position as in the preceding case, the assortment might be such that there is still a re-entering angle on one hand and a saliant angle on the other, which will result from the mutual incidences of the faces produced by decrements.

In certain cases the plane of junction, on which the two halves of the crystal are joined, is situated parallel to one of the faces of the nucleus, and the assortment does not admit of presenting a re-entering angle opposed to a saliant angle.

I have given to these reversed crystals the name of *hemitropes**, and I call *hemitrope crystals* such as are thus reversed. They seem to indicate a polarity in the integral molecules, as I shall explain more at length under the head of *spinell*. We shall also find under the articles *feld-spar*, *pyroxene*, *oxidated tin*, &c., remarkable examples of hemitropes.

Another accident extremely common, is the manner in which grouped crystals are inserted into each other†. This kind of *apparent* penetration is subject to so many diversities, that frequently, among crystals of the same group, we do not find two relative positions resembling each other. We must except, however, staurotide, the prisms of which, as we shall see, have their junction limited to two particular cases, which we shall make known when treating of the crystallization of this substance.

But although in general the positions in grouped crystals are infinitely variable, we find, on a closer examination,

* Romé de l'Isle calls them *matles*. But this name being already applied to a very common species of mineral, I have thought proper to avoid the double application of the term.

† The German word *druse* is sometimes used to designate a group of crystals.

that they are subjected to certain laws always analogous to those of the structure; and that these crystals, instead of being tumultuously precipitated on each other, have in some measure concerted their arrangement.

Let us also on this occasion choose a very simple example. Let AC' (fig. 46) be a cube, and MNR an equilateral triangular facet produced in the place of the angle A , in virtue of a decrement by one range round this same angle. Let us suppose a second cube modified in the same manner, and fastened to the former by the facet which results from the decrement indicated. We shall thus have the assortment represented by fig. 47.

We may now conceive that one of the two cubes, that for example which is placed below, is increased in all its dimensions, except at the places where the other forms an obstacle to it. In proportion as this increment becomes more considerable, the upper cube will be more and more engaged in the inferior one, and it may even finish by being entirely masked or concealed by it. We observe crystals effectually sunk into each other at various depths; but which have always a plane of junction situated like a face produced by a decrement, in such a manner that the two structures follow their ordinary progress, each on its own part, the length of this same plane, which serves as their respective limit. I have divided cubes of fluated lime inserted into each other; and I have remarked that the laminæ of each extended without interruption, until suddenly stopped by the common plane of junction.

The example now quoted relates to a very simple and very regular law of decrement. But frequently the laws which determine the plane of junction are more or less remote from this simplicity, and there are a few which are somewhat extraordinary.

When two prisms cross towards the middle of their axes, there are two planes of junction, which unite, crossing each other on one common line, as we shall find under the article *staurotide*, and both these planes also have positions analogous to those which would be determined immediately by laws of decrements.

To conclude: I have here presented the results of but a small number of particular observations. I propose afterwards to resume the subject now glanced at, and to give a fuller development to the theory of which I think it susceptible.

[To be continued.]