

PLATE 14.

TRAITÉ
DE
MINÉRALOGIE,
PAR LE C^{EN}. HAÛY,

Membre de l'Institut National des Sciences et Arts, et
Conservateur des Collections minéralogiques de l'École
des Mines.

PUBLIÉ PAR LE CONSEIL DES MINES.

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TITLE PAGE OF THE FIRST EDITION (4 volumes) of the *Traité de Minéralogie*
by Abbe Haüy.

HAÛY'S TRAITÉ DE MINÉRALOGIE

BY THE LATE LOUIS POPE GRATACAP

RENÉ-JUST HAÛY became a distinct intellectual phenomenon when he dropped botany and adopted mineralogy. It might perhaps be cynically suggested, by some, that Haüy's retreat from the ministry was the initial step in his intellectual promotion. The broken calcite crystal, which lay at his feet, revealed to a very keen mind an interpretation of mineral forms that embodied, if not exactly the deepest truth, such a very considerable portion of crystallographic precision, as to ensure mineralogy's development upon mathematical principles. A crystallized calcite fragment slipped from the observer's hand and was sundered into cleavage pieces, which were rhombohedrons. A moment's hesitating inspection, and soon the observer, now become an experimenter, was engaged in slicing the rhombohedrons into smaller ones. The process continued, under the excitement of an illuminating suspicion, and, as in the progressive subdivision, the endless rhombohedrons sprang repetitively into view, the suspicion became a conviction, and the formative theory of *molécules intégrantes*—irreducible nuclei—was born. And a structure of geometrical symmetry, built up by ultimate and equivalent particles, ushered in at once the conception of the "law of equal numbers."

From this foundation, guided by an already well-stored memory, knowledge of contemporaneous research, and access to the cabinet of the École des Mines, Haüy industriously prosecuted his studies, arranged his facts, and offered to the scientific world a formulation of mineral science, which took the shape of the *Traité de Minéralogie*, a work in four volumes, with an Atlas of plates, published in 1801, and which far superseded any previous attempt to create a mineralogical system. It is a work of comprehensive insight, and much of it, written with literary fluency, repays to-day the casual curiosity of the antiquarian, while more appropriately enlisting the admiration and sympathy of the mineralogist.

It seems an adequate response to the expectations connected with this 175th anniversary of the great Abbé's birth, to turn over the pages of this masterpiece, and disclose to those, un-

familiar with its contents, some phases or aspects of its method and its style. The treatment is rather diffuse, but all the more interesting from its detailed amplification, and the personal intimacy of its confessions and reflections. The work opens with a Preliminary Discourse which assumes the character of a literary dissertation, generally philosophic, frequently eloquent, and always dignified and learned. Our author first approaches his theme with some comparisons—rather deprecatingly drawn—between the obvious charms of zoology and botany, with their living subjects of study, and the “larger part of minerals, concealed in the recesses of the earth, emerging in a pile of debris, and carrying the marks of violence from the tools which drag them out of their beds, and seeming, to the ordinary man, dull masses, without expression, without language, and created solely to be appropriated to our needs.”

The next paragraph cumulatively displays the profundities and mysteries of mineral science heaping up, as it were, in a phalanx of claims its various aspects of interest. “The polyhedral forms of which it might seem a directing hand had shaped the outlines and angles, with the assistance of a compass; the variations that these forms undergo in the same substance, without losing their regularity, and offering, by means of exact calculation, a revelation of the nature of the Proteus concealed beneath their metamorphoses; the confirmation of experiments, concurring with the features which appeal to the eye, to disclose properties otherwise unnoticed; the principles of Archimedes applied to the relations of weight and volume; the refractive power made use of to separate substances, thru which the image of an object appears single, and those which astonish our inspection by forming two; the application of heat, replacing friction, to develop electric poles, in a body whose crystal shape, by its special modifications, indicates beforehand the position of the same poles; the natural magnetism inhering in some minerals, revealing iron; the various chemical agents furnishing means to dispel the doubts that other tests have failed to allay; the resources secured by analysis for the further elaboration of chemical knowledge; all unite to make mineralogy a science worthy of reception among spirits naturally susceptible to the charm of precise research, inclined towards those studies which present the most intellectual problems, and show us a group of facts most inseparable thru their mutual unions.” The modern

treatise on mineralogy would hardly venture into these fields of embellishment; such a treatment belongs to ages of genial dogmatism.

Haüy notes the easy separation of natural substances into stones (*pierres*), salts, bitumens, and metals, the quick recognition of crystals, the artificial and purely empirical classification of minerals, by their external characters, combined with a few simple reactions, as the effervescing of carbonates, the later more scientific systems of Cronstedt, Bergmann, Born, Kirwan, etc., when analysis usurped the place of mere inspection. He emphasizes, as he proceeds, the importance of distinguishing varieties, as in calcite, a conviction inordinately incorporated in his description of that mineral. He illustrates the value of analysis in alluding to the mineral smithsonite (old style, calamine), which at first was regarded as a zeolite, later as heavy spar, and shown conclusively by the chemist to be a salt of zinc.

He concludes: "We see by what precedes, that chemistry and mineralogy concur necessarily in the construction of a method—whatever it may be—which has for its object the classification of inorganic substances; and that it is chemistry which lays the foundations of such a classification by its separation of species." But in geometry we procure direct assistance for the interpretation of those "pure jewels of nature" which are known as crystals. Haüy here touches the nucleal thought of his mineralogical speculations *les molécules intégrantes*, "of which the faces are to be regarded as natural joints, indicated by the mechanical division of these crystals, and of which the angles and the dimensions respectively are determined by calculation, aided by ocular inspection." These nucleal molecules, relative to different species, exhibit between themselves more or less well-marked differences, except in a few instances, where the regular character of the forms offer points of contact between certain species, or—as we would say to-day—distinguish minerals belonging to the same system.

Haüy then says: "It follows from all this, that the determination of the nucleal molecules must have a great influence upon the definition of species, and this consideration has led me—more than once—either to subdivide into many species a group, formerly united into one, or to bring together the scattered members of a single species, of which custom has made many distinct species." These distinctions he further says—and not without

conscious elation—have been confirmed by chemical analysis, while he seems willing to believe that under the guidance of this principle of ultimate crystallographic reduction, species may be determined whose systemic relations would only remain to be fixed by chemical research. The purpose of his Treatise is then fully enunciated: “The principal purpose of the Treatise is the exposition and the development of a method founded upon certain principles, and which may serve as a frame to enclose all the facts offered by mineralogy, assisted by the different sciences which lend their hand to it, and advance with it on the same path. It is the gathering together of all the known minerals, under one point of view, to compare them with each other, to study their characters, and to question both experience and theory upon the different reactions (*phenomènes*) of which they are susceptible. All the information that can furnish to the student the double assistance of being guided and illuminated in his advance, will be employed; confirming the thought that a science is made up of all of those facts which are needed for the deepest penetration of its subject.”

With reference to one modern method of classification, that of field association, our author's words, of course utterly unrelated to any criticism, are of interest, when he writes: “In such a treatise we have minerals brought together and arranged in a symmetrical order, whereas Nature leaping over, on all sides, these artificial limits, outlined by our method, separates what we unite, associates and confounds together what we have separated;” and this theme inspires our author to further enlargements, always in a vein of appropriate eloquence. He soon professes his adherence to the chemical method, and asks: “Where may we discover relations more intimate to bind together various mineral substances than those founded upon the existence of an identical principle (*constitution*), or discover differences between them more clearly cut than those which are conditioned upon the individual principles (*constitutions*) of each?” This comparison, he urges, “will then be the most exact and at the same time the most natural, and also the least arbitrary, if the means selected for its guidance is that which unveils for us the intimate composition and nature of each substance, which teaches us what it is in itself, rather than that which shows us only its associations, or, at most, its exterior features.”

And then, restricting the compass of his work, he adds: “There

are two problems to solve. The first consists in dividing and subdividing the totality of substances, reviewed in such a way that each may secure its correct position. This is classification. The second has for its object to furnish easy and adequate means of characterization, that the substance may be recognized wherever found, and its position in the system discovered." He then alludes to chemical research and what it has accomplished, instancing the chemical design to characterize genera of minerals by the acid element or radical within them, and species by the diversity of bases combined successively with the same acid. This method is discarded by Haüy and he selects the metallic base as a more significant datum of reference: "The metals have a character so remarkable, so speaking (*parlans*), that they have been chosen by common consent as the fixed points around which unite all the combinations of which they form a part." But, with an abbreviated recognition of the nature of a salt, he separates the combinations of the alkaline earths and of the alkalis, from the metallic compounds, and disposes of them in groups as salts, mentioning separately, however, metallic salts. These salts, thus arbitrarily restricted, comprise three orders, under the class title of Substances Acidiferous. The orders were: Substances Acidiferous Earthy; Substances Acidiferous Alkaline; Substances Acidiferous Alkaline-Earthy. A second class is formed of substances denominated Earthy which "have no acid in combination with the earths of which they are composed," and over the limitations and contents of this poorly defined section Haüy evidently is seriously disturbed. He hopes that mineral chemistry, as developed by Cronstedt, Bergmann, Klaproth, and Vauquelin, will continue to throw more and more desired light upon the minerals thus grouped together, albeit he feels constrained to observe that he has himself contributed to the improvement of this section in details, as "by a more exacting rearrangement of the substances constituting its species, and also by the care I have taken to call species only those minerals which really merit it, those having a type capable of a rigorous determination."

It is in this more or less ambiguously defined section that are found quartz, zircon, *telésie* (sapphire), cymophane (chrysoberyl), spinel, topaz, emerald, euclase, garnet, amphotene (leucite), the feldspars, the pyroxenes, the amphiboles, (schorl) and generally a confusion of silicates, with oxides and titanates, etc., whose

elements were unquestionably by Haüy more carefully isolated and individualized, than had previously been the case. Their very technical separation under the more or less pedantic assumption of various silicic acids had not then, could not then, have been dreamed of. Haüy's third class was made up of combustible substances, as the diamond, sulfur, bitumens, and these again were composed of two orders, as *simple* and *compound* combustible substances.

The fourth class is made to embrace metallic compounds, with a metal as a generic symbol, and under it the species arranged consecutively as, first the native metal, and then its combinations "whether with another metal (as alloys), or with oxygen (oxides), or with combustibles (as sulfur), or with acids." And our author, in view of the consideration that he should present a distribution "conceived as to the essential nature of the things it concerns, at once symmetrical, and better fitted to appease our mentality and to impart order and a logical succession of ideas," reapportions the metals into orders, as they are fusible but not oxidizable by heat (gold, platinum); as oxidized upon heating but not at once fusible (lead, nickel) and those oxidized but not fused by heat (manganese, iron). The treatise closes with three appendices of which the first treats of "substances of which the nature is not yet sufficiently known to permit us to assign them a place in the system." Many of these our author explains are substances he has never possessed except in small amounts, but which, with scientific instinct, he asserts will yet take their proper place in the series. Others he insists demand prolonged chemical investigation. Here we encounter amianthus, aplome, aragonite, anhydrite, coccolite, diaspore, sepiolite, jade, kopholite (prehnite), lepidolite, tourmaline, the zeolites, and other familiar species, whose excellent descriptions as presented by Haüy afford to the modern reader, luxuriating in the affluence of present knowledge, most interesting diversion.

The second appendix is a contribution to lithology, with granite, schist, limestone, porphyry, argillite, serpentine, clay, breccia, conglomerate, oölite, and sandstone described, and introduced by an observation often repeated elsewhere, and always symptomatic of the striking philosophic tendency, in a scientific sense, of this master-mind toward precision: "A mineral system which pursues an ordered law, and submits to the control of fixed and ascertained principles, namely a true system, should only offer

for our consideration substances which may be shaped into a series of unities distinctly detached from one another. I have attempted to construct such a series, starting from the idea that the nucleal molecules should be allowed the larger rôle in making specific distinctions. Yet this preconception is subordinated in practice to certain special considerations which, without doing violence to it, in a sense, constrain it to bend to the travail of nature."

Hauy mentions with undisguised admiration Werner's system of mineral identification, by means of a tabulation of minerals' physical qualities, alluding to it as a complete system, "where all the qualities of a mineral which affect our senses, all that there is in it, in such a way accessible to observation, is carefully discriminated; where all the indications which an attentive student can recognize are well formulated, forming in themselves a picture of each species." He inclines, however, to reject this, following a method of description wherein he establishes distinctive characters, those which are the most constant, the most closely linked with the constitution of the nucleal molecules (*molécules intégrantes*). And his reflections, as if part of a soliloquy, take this form: "The picture of a species should offer first a summation of its characters, by which it may be determined; second its varieties, and, the specific characters being fixed points from which we derive an impression of the species, I shall exclude colors, at least in connection with earthy or acidiferous substances, as variable, fugitive, and foreign to the specific type, which is the nucleal molecule.

"I will mention the specific gravity and the hardness of the mineral. I will not omit the property of double or single refraction, as that inheres in the very nature of the substance, altho not always easily observed. The luster shall be given, not as to its intensity, an attribute easily modified, but in relation to an aspect less easily altered, as such as are unctuous, nacreous, vitreous, etc. And according to conditions new characters shall be quoted associated with these, as electricity developed by heat, or phosphorescence by fire.

"I will above all aim to give precision to the character of a mineral's mechanical division, and in place of limiting myself to a general enumeration of its nature, if it occurs in several ways, I will add the value of the angles which the natural cleavages make between one another, and as these cleavages, being the

first indices for the exact determination either of the primitive form or that of the nucleal molecule, it will be essential to indicate those forms the knowledge of which is so important to a correct conception of the species.

“Finally I will enumerate its reactions, with acids or with heat. It will then be necessary to consider its varieties, and at first those relative to *form*, as most important. Each shall have its name and description, and, if the form is the product of a regular crystallization, I will indicate it by symbols, composed of letters and exponents, indicating the laws of decreescence upon which it depends, and which, united to an exact figure, will furnish the best of all possible descriptions. I will add the respective inclinations of its faces determined by calculation, in which abides properly the imprint (*empreinte*) that a crystal carries of the species to which it belongs.

“Lastly the modifications of color, of transparency, will be included as the finishing shading (*nuances*) to the picture.”

With these elements of identification fully drawn, Haüy unites in his system an enumeration of the principal localities of each species, an explanation of the different views held by authors as to its nature, with the addition of his own criticisms, and an elucidation of the manner by which its correct position was ascertained.

He also dwells upon any interesting physical property of the mineral, and, with a generosity of interest, scarcely permissible to-day, in the vastly more extended compass of mineral science, dwells upon the industrial uses of minerals, and even therapeutic values.

This outline of the method of the famous *Traité* reveals at once the scientific penetration of its author, and especially emphasizes his exacting attitude towards definition, and the rigor of an encompassing conception of the signs and essence of mineral specificity. It particularly too brings into view the province of crystallography with whose foundation Haüy is so clearly and closely associated, for at almost every angle of elucidation he reiterates the systemic force—the *vis fabricans*—of crystallographic constants. Let us now briefly inspect this fundamental hypothesis of his method.

Haüy seized upon the accidental hint revealed to him in a fractured calcite, that the ultimate components of crystals are irreducible initial formative nuclei (*molécules intégrantes*) whose

addition upon each other in varying numbers constitute the mechanical constructive basis of a series of derivative crystals. He applies this hypothesis relentlessly to almost all of the mineral species described in his *Traité*, and may be said to most convincingly show its plausibility in the hexagonal and isometric systems, as illustrated in calcite, galena, pyrite, halite, fluorite, etc.

"Such then," he urges, "is the action of these laws [of attraction] upon the nucleal molecules (*molécules intégrantes*) that when uninterrupted the grouping of these compose plane surfaces, from which result the regular forms similar to those of geometrical solids. We possess frequent examples of this regularity in garnet, topaz, emerald, carbonate of lime, sulfate of baryta, etc., and in a great number of metallic substances.

"The contemplation of the polyhedrons always conjures surprise in those meeting them for the first time, and it is often necessary to show examples of these minerals covered with the native matrix to assure such that they are not artificial, and compel them to acknowledge the geometry of nature," a naïve allusion to the familiar incredulity, such as all collectors encounter in their uninformed mineralogical friends. Recalling his botanical studies, he speaks of a flower made up of elements, in each example equal in number, and similar in outline, with the parts always identically arranged, and with their variations limited to slight and fugitive shades, "so that we can say anyone who has seen one has seen the entire species."

"It is quite different," he continues, "with minerals. Frequently the crystals of the same substance assume very diverse forms, all equally sharply developed and outlined with equal precision. The carbonate of lime, for example, takes according to circumstances the form of a rhombohedron (*rhomboïdé*), that of a regular hexagonal prism, that of a solid terminated by twelve scalenohedral triangles, that of a dodecahedron with pentagonal faces (rhombohedral and hexagonal prism), etc. The sulfide of iron or pyrite produces now cubes, now regular octahedrons, here dodecahedrons with pentagonal faces (pyritohedrons), there icosahedrons with triangular faces (pyritohedron and octahedron)."

Haüy indicates combinations of forms as phases of transition from one form to another, as a cube modified by octahedrons, while he calls the wondering attention of the student to "certain crystallographic forms which most remarkably conceal all

indications of common elements and would indicate a complete metamorphosis of the mineral to which they belong. To illustrate with one example let one place by the side of a hexagonal prism of calcite the dodecahedron with scalene faces [scalenohe-dron], it would be difficult for any one to imagine how two polyhedrons, so contrasted at first inspection, should unite, and, so to speak, lose themselves, in the crystallization of the same mineral."

With this introduction he begins his Theory of the Structure of Crystals and, in a section of 115 pages, discusses in a manner quite unapproached at that time the crystallographic unity of series of faces, and the derivation of faces from each other; and he gathers within the voluminous and exacting scope of his inquiry the obedient services of mathematics.

His mechanical division of minerals enters the base of his system, and practically constitutes the platform of its superstructure. "This," he avers, "is the sole means of recognizing the true primitive form, and proves that this form is invariable in the same substance, however diversified, however contrasted may be the forms of the crystals belonging to that substance." Then he takes a hexagonal prism, and slicing alternate edges, above and below, develops an upper and lower rhombohedron, terminating a hexagonal prism (Haüy's "dodecahedron with pentagonal faces"). Continue removal of these cleavage plates, and the prism disappears, leaving a rhombohedron of which the vertical angle and its opposite is $101^{\circ} 32'$. This observation he properly maintains has developed his ideas on the structure of crystals, and has been the key to his theory. It was made upon a specimen shown to him by M. DeFrance. A prism detached itself from the group with a fracture at its base by which it had adhered to the rest of the specimen. His exact language here may prove of interest: "instead of putting this specimen in my growing cabinet I determined to attempt its division differently, and, after some experiments, I succeeded in extracting the rhombohedral nucleus, which caused me much surprise, mingled with the hope of not being forced to stop at this first step."

His second example, illustrative of what might be descriptively called divisional crystallographic analysis, is the so-called *metastatique* crystal, or the scalenohedron, which Bergmann had already reduced to a nucleus. Slicing this on the equatorial edges as he describes (Plate I, Fig. 6) he obtained the primitive

rhombohedron. He continues: "If it is remarkable to see this nucleus issue from varieties (of calcite) which are contrasted among themselves, by their configuration it might have been less anticipated to find it in crystals which are themselves rhombohedrons, but of different angles." He then instances five of these rhombohedrons, one more obtuse, and the rest more acute, than the nucleus, from all of which, however, he extracted the primitive crystal, with its angle of $101^{\circ} 32'$, and "thus," he triumphantly concludes, "the paradox born of the diversity of the angles is cleared up by the double employment of the rhombohedron, which here inserts itself in disguise, and conceals its fixed character under a variable exterior."

He attacks other minerals by his divisional analysis, and elicits from them formative nuclei, as the octahedron from fluorite, the rectangular prism with rhombic base from barite, a hexagonal prism from apatite, a cube from galena, "and each of these forms will be constant relatively to the entire species, in such a manner that the angles undergo no appreciable variation." And with respect to those crystals which cannot be subjected to such mechanical division, the theory, assisted by other indications developed by him further on, permits him to determine their primitive forms, at least with much probability. He thus achieves his definition: "the primitive form is a solid of a fixed outline, always involved symmetrically in all the crystals of the same species, and of which the faces follow the direction of the plates which compose the crystals."

He reduces his primitive forms to six, the parallelepipedon, the octahedron, the tetrahedron, the regular hexagonal prism, the dodecahedron with rhombic faces all equal and similar, and the dodecahedron with triangular faces, made up of two pyramids united at their bases.

The word *noyau* as used by Haüy is not necessarily the nuclear molecule, for which he designs the appellation *molécule intégrante*. It may be the last term of his mechanical subdivision, or it may not be. Thus he makes a tetrahedron the *molécule intégrante* of tourmaline, though the *noyau* might be a parallelepipedon. In apatite one may divide the crystal parallel to the side of a prism, but will finally reach a term which is a triangular prism, only, and that is the *molécule intégrante*. Refining his distinction he concludes that it is possible to reduce his *molécules intégrantes* to three, the tetrahedron or the most simple pyramid,

the trigonal prism or the most simple of all the prisms, and the parallelepipedon or the simplest of solids, with faces parallel to each other in pairs; in all a group of solids with four or five or six faces. "If these forms," he insists, "are not those of the real *molécules intégrantes* employed in nature, they deserve at least to take their places in our conception, as, with such a moderate expenditure of means we can establish a theory which includes so many contrasted cases."

Haüy yields to a rather elastic interpretation of his ultimate forms, giving them varying dimensions and angles, according as they subserve the purposes of one species or of another. The parallelepipedon could be oblique or rectangular; it could be the type of the calcite rhombohedron, or of the fluorite cube. All vary, according to the requirements made upon them, to form the crystal discussed. In building crystal forms, Haüy makes use of a regular decrescence or of a regular accrescence, from or to the primitive form, by the removal or addition in successive tiers of the *molécules intégrantes*, on all faces. Thus a nucleal cube concealed in the primitive form of a rhombic dodecahedron is revealed at once, by removing the six solid angles, and this can be easily conceived as practical by considering them built up of superimposed layers (*lames de superposition*), each layer consecutively widened, and made up of cubical *molécules intégrantes*, until by their successive removal the nucleal cube remains.

"Thus," he observes, denoting the enlarged figure of the regularly piled up small cubes, whose abstraction, in this orderly manner, reduces the rhombic dodecahedron to the cube, "if to this sort of rude masonry, appealing to the eye, we substitute in thought the infinitely delicate architecture of nature, we can conceive of the nucleus as being made up of an incomparably greater number of imperceptible cubes. The number of the superimposed layers will also be incomparably greater. As an inevitable result the furrows that these layers make, by the alternate prominence and retreat of their edges, will be imperceptible to our senses; thus takes place the growth of those polyhedrons which crystallization has leisurely elaborated, without being either hastened or disturbed in its progress."

Haüy then discusses at length processes of decrescence, as those in width and height, and visually, by means of figures, demonstrates the formation of the pyritohedron from the cube. The discussion here proceeds at some length, and cannot and

need not be inserted here. The illustrations of the development of the calcite scalenohedron from the nucleal rhombohedron by diminishing additions of successional nuclei is clearly drawn. The argument becomes variously extended, and the diagrams of his Atlas accompanied by his commentary ingeniously adapts his fundamental thought by hypotheses as to the rate and manner of accretion, to explain the derivation of crystals of differing inclinations; and he establishes two processes of decreescence, that *sur les bords* (by edges) and *sur les angles* (by angles), and the latter serviceably meets the requirements of securing an octahedron with equilateral triangular faces from a cube. He observes "that the striations and furrows which roughen the faces of secondary crystals, where the process of nature has not attained the degree of finish and perfection of which it is susceptible, indicate frequently by their direction, those that follow the layers of superposition, and these accidents which, in mechanically divisible bodies, confirm the theory, permit us to interview the progress of crystallization, and the manner of superposition in those crystals which are incapable of such division, and thus assist us, by analogy, to divine the form and position of the nucleus, which escapes visual detection."

Haüy defines "mixed decreescences" and "intermediate decreescences," and distinguishes between simple secondary forms, or those developed by a single law of decreescence, and composite secondary forms, resulting from the action of many laws simultaneously effective. The theme assumes much complication, but is developed with skill under the guidance of geometrical premises. It must in this connection be fully understood that Haüy by decreescence did not necessarily mean a shrinkage in size, but a serial addition of *diminishing* superposition.

Finally, to complete this imperfect rendition of Haüy's voluminous treatment, it is important to call attention to his observations under the heading of "Difference between Structure and Accession." He here tells his readers that the steps of crystal development are not observed in nature, that the minutest crystal, having the same form, as perfectly developed as the largest, must be conceived of as enclosing already a minute nucleus, proportioned to its size, and enveloped in such a number of decreescent layers as are required for the growth of all of its faces. We never are permitted to see the intermediate steps of approach from the nucleus to its completed crystallographic end.

"It is necessary then," he concludes, "to conceive from the first instant a dodecahedral crystal, for instance, as a very small crystal, containing its cubic nucleus, appropriate to its minuteness, and that in the succeeding intervals this sort of embryo increases, without change of form, by new depositions around it, as *pari passu* the nucleus increases in its turn, always conserving an unchanged relation to the whole crystal." This singular hypothesis cannot readily be subjected to serious consideration. With painstaking assiduity the author demonstrates, at least pictorially, this barren supposition.

Haüy outlines his laws of crystallization; he summarizes for us, and very interestingly, his views of the process thru whose agency these iconic marvels have arisen. His language, always carefully adjusted to his purpose of definition, can be most acceptably quoted. "We conceive in general that the stony molecules or the metallic or others suspended in a liquid and disposed to unite in the formation of a crystal, are at the same time attracted towards each other and by the molecules even of the solution itself; and it is because their mutual affinity exceeds that of the solution that their combination operates. Now the attraction of the solution varies, and thus this variation, conjoined with the mutual attraction of the molecules, which remains constant, undergoes changes which exercise an influence upon the diversity of crystal forms. And furthermore if there are foreign substances dissolved, they will, in their turn, modify the action of the liquid upon the coalescing molecules. It would indeed appear as a proof of this, that in certain crystals of axinite, some are colored violet by manganese, and others green by chlorite. The former show additional faces not observed on the latter, which moreover is more regularly shaped, and has not a striated surface, as in the violet-tinted crystals.

"An excess of some of the essential principles would also have an influence upon the form of the crystal, in adding its particular value to that of the solution. For, we can scarcely doubt that there is a fixed proportion of elements in each mineral substance, which constitutes its true nature, so that what exceeds a given limit should be to that degree regarded as accidental and foreign." There are of course here intimations of many facts now clearly established in the retinue of phenomena accompanying crystallizing solutions.

In these introductory pages almost redundantly expanded and yet constantly stimulating, readable, and suggestive, a section describing twinned conditions in crystals is inserted. To one phase of these juxtapositions Haüy assigns the name of *hemi-trope*, and this in the body of his work he especially illustrates by spinel. He detects the twinned relation of staurolite crystals, and, with a noticeable *naïveté*, penetrated by the scientific insight of the philosopher, he remarks: "But altho in general the position of crystal groups may be infinitely varied, we find, upon a closer scrutiny, that they are subjected to certain laws analogous to structure, and that these crystals, in place of precipitating themselves tumultuously one upon the other, have, in a manner, prearranged their disposition." The intersection of crystals interests him, and the involution (*enfouissement*) of one crystal in another—"but which always have a plane of juncture, produced by decrescence, so that the two structures follow their regular development, each in its sphere, towards their common plane, which forms their respective limits."

Haüy advanced in all directions the technique of crystallography, and while his devices in applying signs to crystals have become quite obsolete, or are today unknown, his suggestions were animated by the true and abiding spirit of scientific inquiry and of systemic insight. The section of his work which is devoted to the Theory of the Laws which govern the structure of crystals, in its geometric discussion, displays the prestige of his mathematical accomplishments.

Under the heading of *La Crystallization Indeterminable*, he considers concretions, stalactites, incrustations, pseudomorphs, and thruout these pages the modern student will discover paragraphs of vivid description and attractive speculation. The section upon mineralogical methods might be aptly styled a mineralogical polemic. The discussion is profuse, the argumentation with analogies drawn from botany rather abstract, while the conclusions are neither pedantic nor futile, but practically operative to-day. His belligerency over feldspar in controverting the position taken by Kirwan has quite a modern asperity, and terminates in his definition of a mineral species, as "a collection of bodies of which the nucleal molecules are similar and composed of the same elements combined in the same proportions." Along by the side of many utterly obsolete distinctions, these pages evince the remarkable prescience of a strictly logical mind,

imbued with an enthusiasm that increased with every added step its author takes into the profundities of his chosen field of investigation.

Take the section on Mineral Nomenclature; it readily excites admiration from the lucidity and reasonableness of its positions, and again distinguishes Haüy as a master systematist bringing order into the confusion of previous miscellaneous terminologies. In the Nomenclature of Crystals, again Haüy struggles to improve contemporaneous conditions, and his efforts throw an illuminating light upon the coördinating regulative efficacy of that later institution of the six systems, which, with the 32 classes of symmetry, at present receive the allegiance of mineralogists. We probably have done scant or imperfect justice to the variety of contents and the novelty of prediction and affirmation contained in the introductory chapters to the System itself of Haüy's great work, but under the limitations of space we could not have more generously embodied its results. It is certainly incumbent upon this *aperçu* to look further into some features, interesting to mineralogists, of the System itself.

Haüy's ardor for varietal separations on crystallographic grounds appears conspicuously in his treatment of calcite (*chaux carbonatée*), wherein he lists some fifty form varieties and names each one, all of them being simply different crystal forms and different combinations of crystal forms. These are well figured in his Atlas (Plates 23-28). Among these occurs naturally the *chaux carbonatée métastatique* which is a scalenohedron, $v(21\bar{3}1)$, denoted as a dodecahedron and which indicated to him a *métastase* or transposition of the angles between two faces of the nuclear rhombohedral molecule to the faces of the scalenohedron. The name survived a long time in mineralogical literature. Here are arranged the calcite *mixte*, the calcite *cuboïde*, calcite *unitaire*, calcite *binaire*, calcite *imitable*, calcite *contractée*. As an example of this tiresome partition take calcite *bibinaire*, which is a prism terminated by a scalenohedron and an obtuse rhombohedron. Haüy seems to revel in these form distinctions and met the nomenclatorial problem they created with consummate ease. The amorphous phases of calcite he also describes at some length and groups in this connection Saussure's dolomite, Kijnor's dolomite (*chaux carbonatée aluminifère*) of which the analysis records 1.40 per cent. of magnesia, de l'Isle's *mine de fer spathique* as *chaux carbonatée ferrifère* or siderite and which he

is inclined to consider as a calcite into which has been accidentally drawn (*entraîné*) more or less iron in its crystallization.

Our "Fontainebleau limestone" is *chaux carbonatée quartzifère* and the real dolomite is *chaux carbonatée magnésifère*. His observations upon calcite are interesting and especially perhaps his reference to its protean character, its amazing aptitude for crystal diversity as well as its suggestiveness in the geometrical alignment of its various forms. His discussion of double refraction is very extended and a series of experiments (*observations*) illustrate Haüy's scientific profundity, but altho there is clearly distinguished the extraordinary ray (*rayon d'aberration*) and the ordinary ray (*rayon ordinaire*) the phenomenon of polarization was not recognized and Haüy's speculations were practically almost barren in results.

The second mineral considered by Haüy is the phosphate of calcium (*chaux phosphatée*), apatite. This mineral had been regarded by Romé de l'Isle as a variety of emerald, and pyramidal forms were named by him Oriental chrysolite. Klaproth, Proust, Bertrand, and Pelletier analyzed the phosphate of calcium and Vauquelin showed that Romé de l'Isle's chrysolite was the same substance. Haüy had already detected its spuriousness as a gem from its lack of hardness and its unresponsive surface.

Fluorite attracts Haüy from its perfect cleavage and the ease with which such a treatment develops the nucleal octahedron but in this case the *molécule intégrante* is a tetrahedron as a three-sided pyramid standing on a trigonal base. He has a passion for the geometrical resolution of solid forms and it is by pursuing this to its limit that he devises the "nucleal molecule." It is here that he speaks of his conception that the nucleal molecules must be similar; it seems to him probable that the structure is perforated by a multitude of vacuoles "filled either with the water of crystallization or with some other substance" (vol. II, p. 252). He makes in this species rhomboidal units formed from an octahedron and attached tetrahedrons, for to a central octahedron two terminal tetrahedrons can be conjoined and the resultant form is an inclined rhombic prism. In fluorite as in calcite our author separates varieties of crystal combinations and indicates them by geometric names. His allusion to chlorophane has some interest. He writes: "There is found in Siberia a violet substance which shows a strong resemblance to calcium fluoride, but whose phosphorescence is developed under peculiar

circumstances. It has been given the name of chlorophane meaning a body emitting a green light. If a fragment is put upon hot coal it does not decrepitate, but soon diffuses an emerald glow, producing a very beautiful effect. The light slowly languishes, and disappears, at the end of a certain time; the stone has then become decolorized and limpid."

In his analysis of gypsum (*chaux sulfatée*) he makes an informing reference to La Hire, who in 1710 undertook to determine the structure of calcium sulfate and resolved it into triangles; this fallacy Haüy exposes and makes the molecule a parallelepipedon and, as he says, there is a much greater number of parts of contact between the lateral faces than between the base of the molecules; its perfect cleavage along the base is thus explained, and he reasserts in another place the feebleness of cohesion as relating to the surfaces of contact between the molecules.

Barite receives its crystallographic variations, with 13 distinctive names applied to them. He tells us that at the beginning of the eighteenth century one Carascialo, suspecting from the weight and luster of this mineral that it contained silver, subjected it to fire and was amazed to obtain only a red light shining in the dark. Such was the origin of the Bologna phosphorus (vol. II, p. 307).

It would interest the members of the New York Mineralogical Club to examine the excellent figures given by Haüy in his Atlas, and it forms a subject also of agreeable surprise, perhaps, to note the nucleal molecule invariably prefixed to these figures as their geometrical unit. In a discursive review of the system and for the illustrative purposes simply of our inspection I will only disengage those statements or assertions that either demonstrate his perspicuity or contain some detail of possible piquancy or interest to ourselves. For instance, remarking the chemical relationship of barium and strontium, he reiterates the crystallographic resemblances between minerals, as in barite and strontianite, saying "There is almost an identical crystal germ (*noyau*) in each and the secondary crystals furnish ocular resemblances, so that one may compare them to what botanists term a 'family resemblance' (*air de famille*)."

Haüy in 1791 received two crystals of the borate of magnesia, which were the first specimens of this mineral—early considered as a cubical quartz—that the Abbé had seen. Intent upon

eliciting their physical properties he heated them, exposed them to an electric test and observed at once that the heat had electrified them. By comparison with known electrical dispositions in tourmaline where, however, there is but one axis (axis of symmetry) while in the case of the boracite there are four, each one of which passes thru two opposite solid angles, he deduces the existence of electric poles—two for each axis. He then recalls the contrasts in electric character of the opposite ends of the tourmaline crystal according as they are made up of solid angles or are faceted, and guided by analogy determines that resinous (positive) electricity resides in the completed angles, and the vitreous (negative) in the opposed faceted angles. It is impossible to restrain the impulse to quote the Abbé's reflections at this point: "I do not know whether, in the midst of the imposing apparatus of an artificial equipment and amid the density of phenomena that they afford, there is anything better calculated to excite the interest of physicists than these minute electric instruments, built up by crystallization, than this union of distinct and opposite reactions confined within the compass of a crystal which has not more than 2 mm. of thickness; and here is renewed the observation already often made, that the works of nature which seem most desirous to escape our scrutiny, are sometimes those which have the most to show us" (vol. II, pp. 343-344).

Hastening along many pages of instructive comment upon saltpeter, common salt, carbonate of soda, the alums, cryolite—which he informs us was brought by a missionary from Greenland and left in Copenhagen quite unnoticed until it attracted the attention of M. Abildgaard, who first identified hydrofluoric acid as one of its components—we encounter quartz in his Second Class of Earthy Substances (*Substances terreuses*). Haüy makes a rhombohedron the primitive form, but the nucleal molecule (*molécule intégrante*) is an irregular tetrahedron, into which he analyzes the primitive rhombohedron (rhomboïde). The varieties are quite exhaustively enumerated and distinctions based on form, texture, color, described with much particularity. Silix or flint, which had been regarded as a separate species, he unites with quartz, remarking, "what has above everything else confirmed me in this opinion is that reflecting upon the systematic disposition of minerals I have realized the advantage of a system when the species were restricted within their veritable

limits, when the differences which defined these limits were made to reside in the intrinsic nature of the objects rather than in their exterior character. In examining the matter in this light no line of separation is discoverable between quartz and silice" (vol. II, p. 439).

His remarks on the occurrences of varieties of quartz are most interesting and ample. Opal is not distinguished by Haüy as anything else than a variety of quartz, and in the case of hydrophane he is at much pains to explain the translucency of the substance when water-soaked.

In the determination of his nucleal or building molecule (*molécule intégrante*), when the opportunities of nature deny him the easy cleavage of calcite, fluorite, or galena, Haüy resorts to his geometrical facility in a theoretical subdivision of the primitive form. Thus he takes the octahedron of zircon and splits it up into tetrahedrons, and, applying these to each other simultaneously in two series by their faces or by their edges, composes the crystals of that mineral. The hint drawn from his calcite leads him on by reason of his strong prepossession to impart to it the widest relevancy into speculative diversions that must be regarded as purely fanciful.

Télésie, or a perfect body (*corps parfait*) is the name applied to sapphire and ruby. The opening paragraph of Haüy's notes may seem deserving of quotation. "The most anciently known crystals of télésie have been brought from the royalties of Pegu and the island of Ceylon. It has been found, since, in Bohemia, between Meronitz and Bilin; and in France a league from the city of Puy, in the sand of a neighboring stream of the village of Expailly, where the specimens are mixed with garnets, zircons, and particles of iron. They have been called the "Sapphires of Puy" (vol. II, p. 485). He exhibits a scientific impatience at the confusion caused by making color a significant token of species, but indulges in a curious conceit of arranging the gems in the order of the spectrum, as red, ruby, red mixed with orange, vermeille red saturated with orange, hyacinth *la belle*, orange-red garnet, orange-hyacinth (zircon), yellow-topaz, yellow-green chrysolite, green-yellow peridot, green emerald, green-bluish aquamarine, blue sapphire, and dark sapphire (male sapphire of authors). Thruout the pages dealing with gems there is much interesting specification of their quality, and the current nomenclature of lapidaries in his day is detailed.

Cymophane (chrysoberyl) is briefly touched upon, but the twinned alexandrite was unknown to Haüy. He refers the species to Brazil as he has detected a large number acquired in Portugal mixed with Brazilian topaz. Spinel interests him from its hemitrope twinning, which he very lucidly explains and figures, suggesting that this combination depends upon a sort of polarity exercised upon the *molécules intégrantes*. He notes their previous confusion with sapphire (ruby) before their crystal shapes were fully separated.

The topaz is submitted to the crystallographic differentiation which Haüy applies to minerals, and we read of the topaz biocahedral, the topaz *subtractive*, the topaz *monastique*, the topaz *soudouble*, the topaz *distique*, the topaz *dissimilaire*, the topaz *cylindrical*. He notes that topaz of the ancients was a green stone (chrysolite of Pliny?) which was found in an island of the same name in the Red Sea. The name was derived from a Greek word (*τοπάζειν*) meaning to hunt for something, to follow it by guessing, in allusion to the nebulous nature of the place which caused the navigators to search for it. The largest crystal seen by him was a topaz *distique* of a bluish-green, about 35 mm. in thickness and length, weighing a little over 100 grams. The topazes of Saxony and of Brazil had been separated and were regarded as different species, and Romé de l'Isle claimed an angular distinction, which Haüy correctly denies.

The primitive form of emerald is a hexagonal prism but the *molécule intégrante* is an equilateral trigonal prism. Here again the varietal forms receive names and are symbolized by letters and exponents. Romé de l'Isle and Haüy both were instrumental in identifying the beryl with emerald, and the latter (after experimental tests for the double refraction of the beryl) concludes: "Thus all of the physical and geometrical characters agree and invite a union of emerald and the aquamarine, for which I trust that chemistry may yet furnish justification" (vol. II, p. 528); this Vauquelin later supplied.

The mineral euclase derives its name from its easy cleavage, this being given it by Haüy himself. The crystallography of this mineral perplexes Haüy and his system of decreescence seems to fail to account for the terminal modifications of the euclase prism and even the secondary prismatic planes. A hypothesis helps him out, but he admits that "perhaps the actual thread by

which to escape from this sort of labyrinth, may have escaped him" (vol. II, p. 538).

Haüy makes the rhombic dodecahedron the primitive form of garnet and the tetrahedral pyramid with isosceles triangular faces equal and similar the *molécule intégrante*. The figures in the Atlas of the usual forms and combinations are excellent. Klaproth's and Vauquelin's analyses are quoted. Leucite—changed by Haüy into amphigene—had only recently been separated from garnet. The variations in the analyses of garnet naturally disturb him, but the staying power of his reliance upon form led him to accept their specific identity. He says: "In a word, altho there can be no question that naturalists have too carelessly placed certain bodies under garnet, following the guide of exterior form, which is not decisive in the present case; it yet seems to me that our knowledge in this is not sufficiently advanced and that in attempting to rectify unions already made, we may flatter ourselves not to trace any false line of separation" (II, 555). Constantly straining his geometric invention, Haüy finds in the garnet rhombic dodecahedron an interesting suggestion. This form can be interpreted as a hexagonal prism with two summits each made up of three rhombs, but among an infinity of possible dodecahedrons, that of garnet, of which the planes and terminal faces are equal of similar rhombs, is the one which offers a minimum surface. He then considers the form of a bee's cell as identical, and finds thus in the labor of the bees a double economy of time and substance (II, 557). This moderate and pleasing tone seems characteristic of a speculative mind which turns eagerly into all paths of suggestive comparison or illustration. In Haüy's day the garnet called *syrian* was especially in favor; it is described as red mingled with violet (probably a pyrope); in almost equal esteem was a stone of corncockle-red. He writes: "The red of these last is so intense that if cut in facets they appear almost black. They are therefore rounded beneath, and hollowed somewhat, so that the reflections of the side tint may become disengaged and display themselves with a greater liberty" (vol. II, p. 559).

Amphigene as Haüy terms it—something with a double origin—leucite in our terminology, affords this zealous geometrician further material for complicated divisions. The ordinary tetragonal trisoctahedron he styles amphigene *trapezoidal*, made up of twenty-four equal and similar trapezoids, and from these he

extracts the rhombic dodecahedron and the cube, and combining the divisions parallel to the faces of the former with those parallel to the cube he reaches at last, after the dodecahedron has been split up in forty-eight tetrahedrons (always a three-sided pyramid on a triangular base) and the cube also reduces to twenty-four tetrahedrons, a *molécule intégrante* which is a tetrahedron and "is the same whether one considers the cube or the dodecahedron as the primitive form" (vol. II, p. 565).

Leucite's volcanic associations were fully understood by Haüy, but his review of contemporaneous opinions as to this are interesting, and his own comment deserves attention; the existence of potassium, recognized by Klaproth in amphigene, is worthy of note in his eyes as revealing a substance which in a free state unites a high degree of solubility, a distinctive taste and fusibility, but fading into the composition of a tasteless, insoluble and infusible substance; while, more important still, potassium is discovered in the mineral kingdom where until this chemical research it had escaped detection, and was regarded as belonging exclusively to the vegetable kingdom.

Idocrase, meaning confused or mixed form, is Haüy's substitute name for Werner's vesuvian. He notes its analogy with zircon, meionite, etc., and his name alludes to these perplexing resemblances. Dana has taken much exception to the nomenclatural innovations of Haüy and has recounted them with censure, remarking that "Haüy's own names are remarkable, in general, for their indefiniteness of signification, which makes them etymologically nearly as good for one mineral as another, and very bad for almost none." Perhaps in extenuation for Haüy's indifference or neglect of the Law of Priority it might be insisted that as names simply, his names have enough significance to keep them applicable, and have in addition an unmistakable euphonic dignity superior to the names they are intended to supersede, while they embody an inexpressible remonstrance against the monotony of the terminal *ite* which seems to make commonplace and trifling so many mineral terms. In his description of idocrase he asserts the fixity and regularity of crystallographic forms, and observes the nearness in angle between the rhomboid (rhombohedral) and a cube but points out the axial direction in the former as passing thru the solid angle. Meionite, a Haüyan name meaning less or inferior, alluding to a

shortened vertical axis, had been confused by Romé de l'Isle with zircon. Haüy recognizes its specific isolation.

Corindon (corundum) separated from sapphire (*télesie*) by authors, is recognized by Haüy as closely related to sapphire and, tho he hesitates to decide this identity, he publishes his belief in support of the same attitude of Bournon.

Pleonaste is Haüy's name for Delamétherie's ceylonite, and he instances its close resemblance to spinel. "Spinel," he remarks, "compared to pleonaste furnishes an instance of a unity of character quite uncommon between two minerals of differing character. They both have the same primitive form and almost the same specific gravity; the difference in hardness is not great so that there remains for their distinction only characters less decisive as texture, fracture and color" (vol. III, p. 20). The name pleonaste, or superabundant, is intended to denote the excess of faces on the solid angles of the octahedron, which are absent in spinel.

Axinite, Haüy's substitution for yanolite of Delamétherie and certainly a better name, indicating the hatchet-shaped form of the crystals, receives from this undiscouraged analyzer of crystal forms this ingenuous tribute: "No substance has longer defied the application of the laws which govern the structure of crystals than axinite. The difficulty of understanding its natural joints, the numerous structures with which most forms are loaded, the slight deviations of which the clearest faces are rarely exempt, in fine, the nature of the primitive form that I can only deduce theoretically by assuming unequal edges of its basal planes, all concur in offering one of those complicated problems which often times revolved in a thousand ways does not leave the mind fully satisfied with the results" (vol. III, pp. 30-31). He refers to the polish of axinite and its agreeable colors but denies it a place among "stones which are material for the lapidary's art."

Tourmaline solicits Haüy's careful study and his descriptions—now over a hundred years old—of occurrences have yet a vivid reality. Its electrical properties particularly excite his curiosity and he gives the record of many experiments with considerable theorizing explanations. He does not seem to have examined rubellite, altho he alludes to the tourmaline of Madagascar.

Amphibole is another Haüyan name replacing the hornblende of earlier years and means equivocal, ambiguous; he rejects hornblende as too incorrect (*trop impropre*) to be retained. He

regards it as abundant in primitive mountains but rarely in good crystals. The crystals found in granite are short, irregular lamellas, tho forming at times over two thirds of the rock. In steatitic, micaceous or chloritic rocks the amphibole is developed in long prisms but poorly terminated. It is met with rarely in the cavities of veins, wherein it might have more easily taken the regular forms peculiar to it. Volcanic masses furnish fine single crystals; not indeed does he think that they should be regarded as an immediate product of the volcano "but because having been incorporated in the rocks where they originated, previous to the action of the subterranean fires, they have been subsequently separated from their base, by the effects of scorification, to be thrown out at the moment of eruption with the lighter scoria, which envelop them" (vol. III, p. 66).