

ON CRYSTALLOGRAPHIC CLASSIFICATION

VICTOR GOLDSCHMIDT, *Heidelberg*¹.

FORM-SYSTEMS AND CRYSTAL-SYSTEMS

Every crystal species has its *form-system*, which includes all the morphological structures known to the species. These include growth- and solution-structures. Each crystal species has its growth-form-system and its solution-form-system. The two together constitute the form-system of the crystal species. The general scope of morphology is the study of these structures, which means the study of all form-systems.

Until recently, only the *growth-structures* were objects of morphological study, and at first only plane faces with edges and coignes were considered. Later, curved growth-structures and growth-accessories were included. My *Atlas der Kristallformen* (1913–23) records almost exclusively plane-faced growth-structures; it is these which form the foundation of our morphological knowledge.

Of *solution-structures*, only accessories, etch-pits and etch-ridges, were at first the objects of observation; only in 1903 were the solution-bodies from the sphere included.²

Classification referred at first to the growth-form-systems; it appeared, however, that another classification was not necessary for the solution-structures. The same classification serves for both. This is a valuable unification. Even to-day our **crystallographic classification** is a classification of **crystal forms**. This is not self-evident. One could also classify crystals according to other properties, such as chemical, optical, thermal or röntgenographic, according to the properties of the crystal-building particles.

A classification according to the properties of the crystal-building particles would have the advantage of a close relationship with our definition: "*A crystal is a rigid system of similar, similarly oriented particles.*"³

It would be in error, however, in that the particles comprising the structures are not directly observable; indeed their existence, and hence the definition, has been questioned.

¹ Appeared first in German: VICTOR GOLDSCHMIDT, "Zur kristallographischen Systematik," *Cb. f. Min.*, 1930, A, pp. 177–190, figs. 1–6. Translated into English, at Professor Goldschmidt's request, by M. A. Peacock, Vancouver, B. C.

² V. GOLDSCHMIDT AND F. E. WRIGHT, *N. Jb. f. Min.*, Bl. Bd. XVII, p. 355, 1903; XVIII, p. 335, 1904.

³ V. GOLDSCHMIDT, *Ostwalds Ann. Nat. Phil.*, 9, p. 372, 1910 (*trans.*).

A classification according to chemical properties fails with crystals since the objective of chemistry is the structure of the molecules, while crystals are built of particles.⁴ Chemically, one cannot distinguish rutile, anatase and brookite; all three are forms of titanic acid. Calcite is indistinguishable from aragonite; both are carbonates of lime.

Optical properties fail with opaque minerals. The röntgenographic properties are still but little understood. They will probably not suffice for a comprehensive classification of all crystal species; at present they are certainly inadequate.

Thus morphology, the crystal forms and the form-systems with growth- and solution-structures, remains as the basis of crystallographic classification.

And so the classification of crystals is equivalent to classification according to their **form-systems**. Each crystal species has its proper form-system which is peculiar to the species, and is the material of morphological study.

The morphological properties of crystals have the advantage over all other properties in giving the largest amount of information on the growth and solution of crystals, their formation and decay, and the nature of the operating forces and movements.

Definite relations exist between the morphological and the remaining properties of crystals. In a classification, these relations should be taken into consideration, in accordance with the following acceptance: *A Morphological classification should accord as well as possible with the remaining properties, as far as they are known.*

As we saw above, a classification of growth-structures is at the same time valid for solution-structures. We include the two in the collective conception, form-system. We then arrive at the conclusion: **A Classification of crystals is a classification of their form-systems**. Among these, the growth-forms are the most important as they are better known and our knowledge of them will increase. Solution postulates growth; the reverse however does not hold.

The plane-faced structures are the groundwork of the growth-structures, and until recently they were the exclusive objects of morphological study. Indeed, the definition was: "A crystal is a natural body bounded by plane faces."

According to this a crystallographic classification was a classi-

⁴ V. GOLDSCHMIDT, *Zs. f. Krist.*, 17, p. 25, 1889.

fication of plane-faced crystals. Now curved structures also belong to the form-system.

Each crystal species has its plane-faced form-system which is completed by the addition of the curved faces. Now it has appeared that the classification for plane faces has also served satisfactorily for the classification of collective form-systems (including accessories and curved structures). Thus our classification is given further simplicity and precision. We come to the conclusion that: *A classification of crystals is a classification of their plane-faced form-systems.*

The following questions arise: What is characteristic of a form-system? What property is common to them all? What distinguishes one from another?

By projecting all the observed forms of a crystal species we obtain a view of the complete form-system. We call this a complete projection-diagram (Gesamtprojektionsbild). At this point the gnomonic and the stereographic projections come into consideration. The former has the advantage in that we can read (measure) the elements and symbols from it. We conclude therefore that: *The characteristics of a form-system are the characteristics of its complete gnomonic projection-diagram.*

The development of forms appears in the complete gnomonic projection in the following manner:

From a few points, the *primary nodes*, zones (primary zones) extend from primary node to primary node. In every zone further nodes (derived nodes) develop after the Law of Complication according to the harmonic numbers:

p=0	.	.	.	1	.	.	.	∞
p=0	.	$\frac{1}{2}$.	1	.	2	.	∞
p=0	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$	1	$\frac{3}{2}$	2	3	∞

The node 1 we call the *dominant*. The dominant of a primary zone we call a *primary dominant*.

Secondary zones extend from primary nodes to primary dominants; tertiary zones between two primary dominants; further derived zones between derived nodes. The development in every free zone-segment follows according to the Law of Complication, as indicated above. This development is common to all form-systems; it constitutes the given foundation of the classification. The

primary nodes are diagnostic and characteristic of single form-systems.

We characterize a form-system according to the number and arrangement of the primary nodes in the gnomonic projection.

The faces corresponding to the primary nodes (principal nodes) are in all crystal species so common and developed to such an extent that they (or some of them) are found on almost every single crystal. Accordingly, measurement and projection of a small number of crystals, indeed usually of a single crystal, suffices roughly to characterize the form-system of the species. This rough characterization forms the outline of our classification.

The characterization of the principal nodes follows, as from every other face-pole, from their co-ordinates referred to suitably chosen co-ordinate axes in the gnomonic projection, measured with suitable unit lengths ($p_0' q_0' h=1$), from a conveniently chosen origin.

The axial direction and the origin are characterized by the axial angle ν and the co-ordinates of origin ($x_0' y_0'$). The quantities $p_0' q_0' (h=1) x_0' y_0' \nu$ are called the projection elements. They are at the same time the projection elements of all forms derived from the primary nodes, and thus of the entire form-system.

In choosing the axes the following is to be kept in mind; the axial direction should follow a principal zone; the origin shall lie, if possible, at the pole; the axial angle ν shall be, if possible, 90° or 60° .

We make the statement, the **characterization of a form-system** is given by the projection-elements of the principal nodes, which are at the same time **elements of the form-system**:

$$p_0' q_0' (h=1) x_0' y_0' \nu$$

We distinguish six cases:

	Crystal system	p_0'	q_0'	h	x_0'	y_0'	ν
1	Regular	1	1	1	0	0	90°
2	Hexagonal	p_0'	p_0'	1	0	0	60
3	Tetragonal	p_0'	p_0'	1	0	0	90
4	Rhombic	p_0'	q_0'	1	0	0	90
5	Monoclinic	p_0'	q_0'	1	e'	0	90
6	Triclinic	p_0'	q_0'	1	x_0'	y_0'	ν

The six possibilities we call the **six crystal systems**; there is no seventh. We find the crystal system directly from measurement and projection, and thus we can place every crystal species into one of the six systems.

The six crystal systems thus defined constitute the foundation of the morphological classification, and, as shown above, of crystallographic doctrine. There is no better foundation. The crystal systems are characterized, as above, by the projection elements. We can express the elements as:

Polar elements: p_0q_0 ($r_0=1$) $\lambda\mu\nu$

Linear elements: a_0b_0 ($c_0=1$) $\alpha\beta\gamma$ or $a:1:c$; $\alpha\beta\gamma$

We may assume that the details are known.

The form-system of each crystal species is characterized by the special values of the elements in so far as these are variable. The length 1 and the angles 90° and 60° are invariable.

The **number of variable elements** is characteristic for each crystal system.

	Variable elements
Regular system.....	0
Hexagonal system.....	1
Tetragonal system.....	1
Rhombic system.....	2
Monoclinic system.....	3
Triclinic system.....	5

According to this we can characterize the crystal systems by the number of variable elements: 0.1.2.3.5. In this way the two systems, hexagonal and tetragonal, fall together as uniaxial, and are distinguished by the angle ν . This grouping has its advantages, as both are optically uniaxial.

The form-system of each crystal species has its own peculiarity; there are no two crystal species in Nature with the same form-system. The study of the form-systems of all known crystal species is the problem of morphology.

Each crystal species with its form-system belongs to one of the six crystal systems. Calcite is hexagonal; topaz is rhombic. By giving the values of the elements (*e.g.* topaz: $p_0q_0=1.8049$; 0.9539), the requirements of classification are largely satisfied.

The form-system of each crystal species, and thereby the crystal species itself, is broadly described by its **crystal system, elements**

and symbols. The table of forms with symbols and angles (angle-table), and the complete projection-diagram (gnomonic, stereographic, perspective), give us a comprehensive view.

The catalogues of forms, *Index* (1886-1891), *Winkeltabellen* (1897), and the *Kristallographische Projektionsbilder* (1897) of the author, and many single works, assist in this comprehensive view. Since then our knowledge of crystal systems has made great progress, and the development of the field still continues. The form-systems are being critically clarified and supplemented by new typical forms and by growth- and solution-accessories giving information on the origin and decay of crystals.

But the new observations have not altered the picture of the form-systems in its broad outlines. The rich and the poor form-system alike fits freely into one of the six crystal systems, is governed by elements, and is represented by symbols and projection-diagrams.

DIVISIONS OF THE CRYSTAL SYSTEMS

Divisions of the crystal systems may be constructed in the following manner:

The gnomonic diagram of each form-system shows a division into fields. The elements show, gnomonically, this same division. Every crystal system has its peculiar field-division; these are given in figures 1-6.

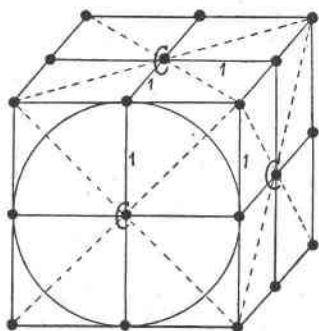


FIG. 1. Regular, 24 symmetry-fields.

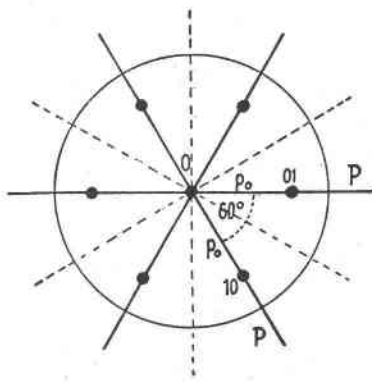


FIG. 2. Hexagonal, 12 symmetry-fields.

We designate similarly-shaped fields, bounded by zone-lines passing through the pole of the gnomonic diagram, as *symmetrical fields*. We have in the hexagonal system 12, tetragonal 8, rhombic

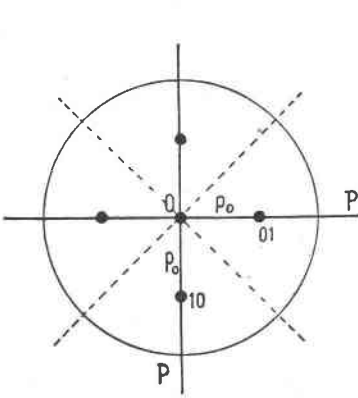


FIG. 3. Tetragonal, 8 symmetry-fields.

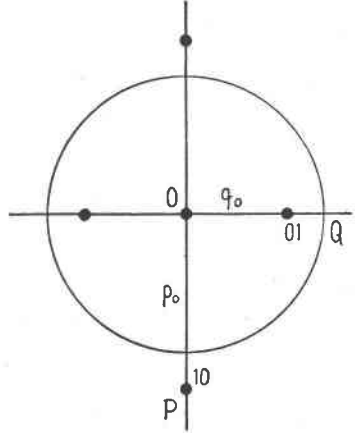


FIG. 4. Rhombic, 4 symmetry-fields.

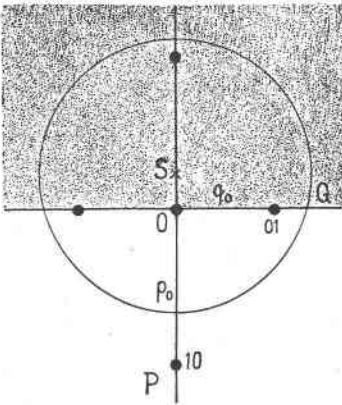


FIG. 5. Monoclinic, 2 symmetry-fields.

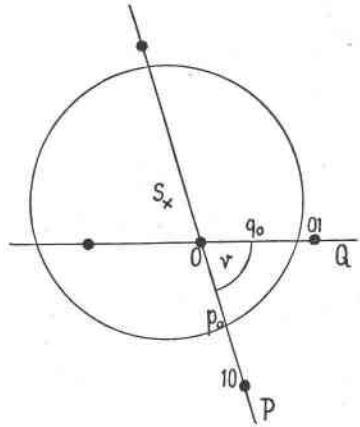


FIG. 6. Triclinic, 0 symmetry-field.

4, monoclinic 2, and triclinic 0 symmetrical fields, and in addition the counterfields of the lower projection-plane. In the regular system the 24 similarly-shaped fields of the projection on the polar form (cube), with their counter-fields, are symmetrically distributed.

We make divisions of the crystal systems according to the equivalence of the symmetrical fields.

Equivalent fields may be defined as symmetrical fields occupied by equivalent points.

In each crystal system we distinguish between:

- Holohedrism:** equivalence of all the symmetrical fields.
- Hemihedrism:** “ “ half of the symmetrical fields.
- Tetartohedrism:** “ “ one fourth of the symmetrical fields.
- Hemimorphism:** non-equivalence of the upper and lower projection-fields.

For the types of hemihedrism we have the following subdivisions:

- | | | |
|---|---|--|
| A | { | F = G: field and counter-field equivalent. |
| | { | F = G: field and counter-field non-equivalent. |
| B | { | Equivalent fields alternating in quadrants, |
| | { | “ “ “ in pairs, |
| | { | “ “ “ singly. |

For the details you are referred to the author’s papers: “Über Kristallssysteme, deren Definition und Erkennung,”⁵ and “Über Abteilung der Kristallysteme.”⁶

THE THIRTY-TWO SYMMETRY CLASSES

In 1899 I wrote the following:⁷

“Until recently, the six crystal systems constituted the undisputed primary grouping of crystals, the foundation of crystallographic classification. The hemimorphisms and hemihedrism appeared as subdivisions. Lately there has been a strong tendency to throw the six systems overboard and place thirty-two symmetry classes in their stead.

“This movement, which intrudes didactically, introduces a new nomenclature, and also influences the course of investigation, was notably furthered by the fact that P. GROTH adopted the divisions according to classes in his widely used *Lehrbuch der physikalischen Kristallographie* (Ed. III, 1895) and in his *Tabellarische Übersicht* (1898).

“Other crystallographers have done likewise, and it appears as if most of those who have not already done so would follow—most of them probably with an uneasiness which is particularly evident in teaching; and as the result many accept the thirty-two classes in principle, but retain the six systems and their divisions for instruction and for their own use.”

⁵ *Zs. f. Krist.*, 31, p. 135, 1899.
⁶ *Zs. f. Krist.*, 32, p. 49, 1899.
⁷ *Zs. f. Krist.*, 31, p. 135, 1899 (*trans.*).

Since then thirty years have passed. In that time crystallography, especially morphology has made great progress. I have followed the development as observer and collaborator, and now I again ask the question: *Is it proper in a crystallographic classification to retain the six crystal systems and their divisions (A), or the thirty-two symmetry classes (B), or to carry A and B side by side?*

We shall first decide that to carry two classifications, A and B, side by side would not be desirable; it would be an unnecessary burden, and particularly onerous if both classifications were to be inflicted on the beginner. So either A or B must be dropped; but which shall it be? On general principle, we may say:

Of two classifications, one must decide; (a) Is one better? (b) Is one indispensable? We shall examine the question from these aspects, and attempt to reach a decision.

Question (a): **Is A better than B?**

Against B we may bring the following arguments:

1. The postulated symmetry is not found on the forms of crystals.
2. Symmetry is a bad classificatory principle for crystals.
3. Six units of classification can be viewed at once, but not thirty-two.
4. No given crystal can be placed in one of the thirty-two classes on the basis of measurement.
5. The thirty-two classes are pedagogically difficult.
6. Measurement, without which a crystal cannot be classified, according to A or B, gives first the crystal system and sometimes the division, but never the reverse.

For B the following is contended:

7. The thirty-two classes may be derived from a single principle.
8. One can derive the thirty-two classes from the principle of symmetry without being acquainted with the forms which nature offers. Since there are no other possibilities (on this principle), natural structures, both known and as yet unknown, must fit into the system.
9. A more important relation exists between the thirty-two classes and the physical properties of crystals than between the crystal systems and the physical properties.

We shall examine these arguments singly.

Arguments against B.

1. *The postulated symmetry is not found on the forms of crystals.* Among the thousands of topaz crystals that I have handled, I have not found a single one showing the required symmetry. Of the required eight faces for $u = \frac{1}{2}$, or $o = 1$ of topaz, more than four faces were seldom present, and these were never of equal size. The same holds true of the remaining forms of topaz; in like manner for calcite, quartz, pyrite; in brief, of all the crystal species that I know. I can assume with certainty that no other crystallographer has had contrary experience.

This argument alone should suffice to rule out symmetry as the main, indeed the only classificatory principle.

2. *Symmetry is a bad classificatory principle for crystals.* A good systematic principle allows the simple to appear simple, the complicated to appear complicated. But the symmetrically simplest crystals (triclinic) are in every other respect the most complicated, while the symmetrically most complicated (regular) crystals are in every other respect the simplest.

3. *Six units of classification can be viewed at once but not thirty-two.* Our ability of simultaneous apprehension reaches three, at most five units. Even six oversteps the limit, and six systems can be viewed simultaneously only by separation into three groups.

1. Regular.
2. Uniaxial: hexagonal, tetragonal.
3. Biaxial: rhombic, monoclinic, triclinic.

The divisions, also, are small in number:

- holohedral, hemihedral, tetartohedral;
hemimorphic.

No group has more than three components; this is a simple arrangement, and simultaneously visible.

Thirty-two co-ordinating unities are never simultaneously visible. One can make them so by a grouping according to corresponding relations. By doing so, one arrives at the crystal systems and their divisions by a laborious detour, which is not necessary.

4. *No given crystal can be placed in one of the thirty-two classes on the basis of measurement.* Having measured a calcite crystal, I can determine the crystal system easily and with certainty, also the division (hemihedrism), the elements and symbols. The symmetry class I cannot determine at all. The same holds true for all

crystals. Neither knowledge nor experience helps us over this impossibility.

5. *The thirty-two classes are pedagogically difficult*, even though a number of distinguished mineralogists and non-mineralogists have tried to make them more acceptable by means of suitable nomenclature and synoptical tables. Having mastered them, the student finds the path difficult in transferring to the crystals in Nature.

If he wishes to overcome the contradictions, he has no choice but to go to Nature and measure and discuss crystals for himself. If he does this, he arrives, on the basis of measurement, at the crystal systems, the elements and symbols, and eventually at the division. He fails wholly to find the symmetry class which he was seeking to understand clearly, and so the contradictions remain for him unsolved.

It would be particularly inappropriate to introduce the thirty-two symmetry classes in the school (or college) and equally bad to have one classification for the school and another for the university.

6. *Measurement without which a crystal cannot be classified, gives first the crystal system and sometimes the division, never the reverse.* If the co-ordinated thirty-two classes be arranged, and several of them included (for simultaneous inspection) in one crystal system, one attains the simple and positive (the crystal systems) by grouping the complicated and doubtful (the symmetry classes). This is irrational. Instead, the attainment of what is most certain and comprehensive is to be recommended first and then (if desirable or possible), the separation of the simple divisions into still smaller subdivisions; that is the rational procedure.

Arguments for B.

7. *The thirty-two classes may be derived from a single principle.* This statement was cited as an advantage and placed at the head of the publication by A. Gadolin,⁸ in which he introduced the thirty-two classes into systematic crystallography, and others have adopted it. But it is not an advantage to derive the system of a richer domain of Nature or of Art from a single field. And this is even less desirable the farther our knowledge progresses.

⁸ Deduction d'un seul principe de tous les systèmes cristallographique avec leur subdivisions, *Act. Soc. Fennic. Helsingfors*, 9, pp. 1-71. (1867), 1871.

In other sciences we do not proceed thus. Zoology divides animals into vertebrates and invertebrates (according to the presence or absence of vertebrae), and the vertebrates are divided into mammals, birds, reptiles, amphibians and fishes, not according to the vertebrae but according to other characters.

The history of art is divided into architecture, sculpture and painting. Painting is classified according to countries and periods. Every subdivision has another principle. To carry through a system for an entire domain according to one principle would be impracticable and barren.

So it is in every field; crystallography is no exception.

8. *One can derive the thirty-two classes (deductively) from the principle of symmetry without being acquainted with the forms which Nature offers. Since there are no other possibilities, natural structures, both known and as yet unknown, must fit into the system.* This is a dangerous argument. It releases the crystallographer from his duty of occupying himself with Nature, for the deductively derived system already contains everything that is possible. Experience will and can contribute nothing new beyond, at most, a few hitherto overlooked examples. Why then pursue the investigation of Nature? Everything worth knowing is already in the system.

But there is only one way to the truth: approach Nature and learn to understand her language and read her writing. Her hieroglyphics will become words, and these will range themselves in melodies singing the exalted song of the beauty and harmony of ever-regenerating creation.

9. *A more important relation exists between the thirty-two classes and the physical properties of crystals than between the crystal systems and the physical properties.* This rather widespread assumption is, as far as I can judge, without application.

We proceed to the second question.

Question (b): **Which of the two classifications is dispensable, A or B?**

The answer is unequivocal: **B can be dispensed with, A cannot.**

Crystallography is the science of crystals as shown by Nature; it is a natural science served by a system. Each crystal must be placed in the system, and for this purpose must be measured, projected and discussed. In this way we arrive first at the crystal system (A), and then at the division, which means that the path

leads from A to B, not from B to A. Thus A cannot be dispensed with.

We have reached the conclusion; the decision is:

System A is to be retained, B set aside.

RETROSPECT AND HISTORY

The arguments against B, particularly 1-4, are so conclusive, that it appears incomprehensible that so large a proportion of our mineralogical teachers, among them distinguished, even prominent men, have decided in favor of B.

We will try to trace this historically.

The thirty-two classes were founded by A. Gadolin (1867), and introduced to wider circles by P. Groth (1895), who says:⁹

"The systematic treatment of crystallography developed above proceeded from the simple crystal forms, *i.e.* those with the lowest grade of symmetry, and, by addition of further symmetry elements, gradually reached the most symmetrical of the thirty-two classes, each of which represents an independent unity characterized by definite symmetry relations.

"The gathering of certain symmetry classes into one group (crystal system), which was used for ready survey, rests on purely practical considerations, and is, in a certain sense, even arbitrary. These groups constitute the foundation of the earlier crystallographic presentations."

At that time P. Groth stood in high esteem and others followed him. Respected mathematicians (Schönfliess) consolidated the system. One admired mathematics which was able to review a rich natural science (crystallography) and give it a system, without having concerned itself in detail with crystals by way of natural research. One forgot that crystallography is a natural science and not a chapter of mathematics.

Crystals cannot be understood, no more than lizards or frogs, or classified according to their characters, without studying them in detail. If we classify without detailed study we go astray, for Nature is always right.

We have had this case once before in crystallography. It was believed that crystal forms were to be seen in the regular bodies of stereometry; this was true in the case of the tetrahedron, the cube, the octahedron, and the rhombic dodecahedron, but failed with the pentagonal dodecahedron. That way was abandoned, and the same should be done again to-day.

⁹ *Physikalische Kristallographie*, Ed. III, p. 523, 1895 (*trans.*).

The introduction of the thirty-two classes by P. Groth was welcomed and greeted as an advance. How did this come about?

At that time morphology was concerned only with plane-faced crystals; it consisted of one-circle measurement of crystals, calculation with spherical trigonometry, and drawing on the axes, so difficult an art that only masters like Gerhard Vom Rath could handle complicated cases. Thereby the catalogues of forms expanded, and drawings and tables multiplied to such an extent that they could not be reviewed. The morphology of that time also lacked important objectives. Stagnation supervened.

Then the *petrography of thin sections*, with its wealth of new appearances and new problems, appeared as a new light. The mineralogists threw themselves into the new field. The young men went to F. Zirkel in Leipzig and to H. Rosenbusch in Heidelberg. The polarizing microscope replaced the goniometer.

Now the forms of crystals were no longer interesting, only the optical properties as they appeared in rock-sections in polarized light. In his *Physikalische Kristallographie* Groth attempted to bring together in easily understandable form such theory of crystal optics as was required for petrography.

The crystal systems interested the petrographers only as the carriers of the symmetry which could be recognized optically in the crystal grains of thin sections. In particular one was concerned with the distinction between monoclinic feldspar (orthoclase) and triclinic feldspars (plagioclase), between rhombic amphibole and pyroxene from monoclinic and triclinic representatives. Symmetry now became the leading criterion; the monoclinic system became the monosymmetric and the triclinic the asymmetric.

The crystal systems were classified and defined according to the number of symmetry planes: asymmetric, 0 symmetry plane; monosymmetric, 1; rhombic, 3; tetragonal, 1 principal and 4 common symmetry planes; hexagonal, 1 principal and 6 common symmetry planes; regular, 3 principal and 6 common symmetry planes. But these definitions failed for the divisions of the crystal systems, for the hemihedrisms, the tetartohedrisms, and the hemimorphisms, even with the models themselves. The tetrahedron lacked the symmetry planes demanded by the regular system, the rhombohedron those of the hexagonal system. Then appeared the thirty-two Gadowian classes which took into consideration also the hemihedrisms, tetartohedrisms and the hemimorphisms. They were wel-

came as the salvation for the symmetry principle of the crystallographic system. The discrepancies of the divisions disappeared; but there remained against this system the above-detailed serious counter-arguments, especially point 1.

In the meantime petrography developed further; it became a great independent science; it concerned itself largely with magmatic formations and structures; it assisted in the problems of geology. Petrography regarded crystallography, especially morphology, as a preparation to its own problems, and welcomed a system which relieved it of the labor of pursuing studies in morphology. Such a system was found and retained in the symmetry classes.

Then a new epoch-making discovery entered our science, namely, the Laue diagrams with Röntgen rays. Now it was believed that the internal particle-structure of crystals was concretely visible; and thereupon the physicists and the mathematicians rushed into the new field of research, especially since the Röntgen diagrams gave information of structures far beyond those of crystals, and entered and assisted in technical fields.

The glitter of the new invention, eagerly pursued by excellent people, outshone the gentle light of the quiet, but steadily progressing study of crystal-morphology.

The conclusion reached was as follows: Röntgenography shows the internal structure of crystals from which the forms may be derived. We can do without morphology; at best it contributes only confirmation and supplementary information. The morphologists are old-fashioned folk; their methods are superseded. They have their place since we can take our material to them to have it arranged, but we, the physicists and the mathematicians, pursue the true science.

But it is not so. Röntgenography is an important chapter of crystallography. Its development to-day engages many investigators. Crystallography, as the complete science of crystals, will thankfully receive the valuable results of this research, when they are clarified, and fit them in its structure.

Happily, crystallography has in the meantime made such progress in its main field, morphology, and in the extension of its problems, and is thus so much strengthened, that it is in the position to incorporate serviceably into the whole single fields, such as röntgenography and crystal optics. This will eventually come about.

As long as the Röntgenographers, occupied with the cultivation of their special field, do not search for the relationship of their field with the entire science, a system which relieves them of the trouble of entering morphology is welcome. In this way system B serves them. But when the work in the special field has progressed to such a point that, after overcoming the present lack of agreement, it can be fitted into the whole, then that system which best serves the whole will be generally adopted. That is system A.