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THE DEVELOPMENT OF MINERALOGICAL METHODS[1]

THOMAS L. WALKER, *University of Toronto*

The advance of mineralogy in the past has necessitated repeated divisions of the field. Two centuries ago, before the word *geology* was coined, mineralogy covered the field now differentiated into geology, palaeontology, inorganic chemistry, economic geology, and petrography. Like a banyan tree mineralogy has sent out new branches which have taken root, and which in turn have themselves become recognized self-supporting portions of the field of earth sciences.

The position of mineralogy in the general system of education is now somewhat different from that held a century ago when Mr. and Mrs. Lowry wrote their interesting "Conversations on Mineralogy" (in two volumes) for the use of young ladies. An echo of this condition comes from Ruskin's attempt to use crystallography in his "Ethics of the Dust" for the moral and philosophical education of school girls.

It may be of interest to glance over the history of our past and note the methods by which progress has been made. We are fortunate to live in a time of rapid mineralogical development and to be able to take part in the advancement of the subject. We wait on the progress of the related sciences which provide for us new tools and new methods and make more perfect those hitherto employed.

THE WERNERIAN METHOD

From the beginning students of nature have been accustomed to distinguish objects by their most obvious properties. The early mineralogists paid special attention to hardness, colour, heaviness, lustre, and form. For field work and for the purpose of elementary students such properties are still called upon for the differen-

[1] Presidential Address, presented at the third annual meeting of the Mineralogical Society of America, Ann Arbor, Michigan, December 29, 1922.

tiation of minerals. Werner had a strong preference for this method of distinguishing minerals as he considered the chemical and morphological methods too difficult of application and often less decisive.

He developed this method by introducing a precision into the descriptive terminology, particularly with regard to the colour of minerals, and by advocating, and providing from the School of Mines at Freiberg, suites of named typical minerals so that students in different parts of the world might have standard material for comparison. His crystallography was of the simplest, while in his system chemical tests were used sparingly. He admitted, for example, that one might test for lead by dissolving in aqua regia, driving off the excess of acid, adding vinegar and tasting to discover if the solution had the sweet taste of sugar of lead. The strength of the method in Werner's time lay in the backward condition of chemistry, physics, and crystallography.

The Geometrical Method

Although the geometrical form of minerals attracted the attention of the earliest scientists, the first exact observations were those of Steno who in 1669 published the results of his studies on crystals of quartz and enunciated the law of constancy of interfacial angles. From this time onward, the recognition of the determinative value of crystallography made steady progress. With the goniometer of Carangeot, Rome de l'Isle was able to indicate the characteristic forms of most of the minerals known at the time. He recognized the regularity of the truncations of the primitive form and was led to the conclusion that "all crystals of any one substance are of the same grade of symmetry." To him we owe the law of symmetry of crystals.

Haüy built on the foundations already laid, and from his observations on the structure of crystals, was led to regard them as built up of particles, similar in form to the characteristic cleavage units. From this hypothesis he was able to indicate what forms might be expected to occur along with the primitive and to calculate beforehand the angles which they should make with other already known faces. As a result of the work of Haüy and of the backward condition of chemical mineralogy the geometrical properties were for the time most highly favoured in the definition and classification of minerals. Haüy's conception of crystals as built of molecules, resembling the cleavage units into which crystals split, led to an explanation of the fact that only faces with certain inclinations were observed on crystals, and to the statement of the law of rationality of axial parameters.

More exact measurements followed the introduction in 1809 by Wollaston of the reflecting goniometer which after a century has become the instrument of precision now found in most laboratories. During the last thirty years the two-circle goniometer developed by Goldschmidt has done much to simplify crystallographic research. The mathematical obstacles have been largely overcome by simplified calculations based on gnonomic projections and two-circle measurements. As a result, at the present time crystallography is becoming more and more a common aid in the study of minerals.

The Chemical Method

The changes brought about in minerals by heating in the air or by immersion in some corrosive have been used for many centuries as a means of differentiating minerals from one another. This type of investigation developed rapidly in the seventeenth and eighteenth centuries. The history of this advance is the history of the development of a branch of mineralogy first into chemical mineralogy or mineral chemistry and then into inorganic chemistry as understood to-day. With advancing knowledge this method has progressed till now its aim is the complete knowledge of the reactions of all minerals, directed particularly toward their distinction and classification. One branch of chemistry has remained to this day almost exclusively a method for mineralogists. It was introduced by Cronstedt and described by Engestrom in 1770 in an account of the Pocket-Laboratory or blowpipe set. This method, with certain additions and modifications due to our use of gas and platinum is fundamentally that employed to-day in the determination of minerals by means of the blowpipe. It provides a speedy and in many cases decisive determinative method.

In our time chemistry is the fundamental element in the system of classification of most mineralogists so that the most accurate quantitative analyses are desirable. With the advance in the methods of the inorganic or mineral chemist, our chemical data become gradually more complete and reliable. Some of the oldest mineral analyses refer to gemstones. Being very hard, they acquired in grinding iron and silica from the mortars in which the samples were prepared. Some earths which we now separate were then not separated and in some instances not known to be different. It is a long step from such primitive chemical data to those now published by the chemical division of the United States Geological Survey.

The Petrographic Method

Modern petrography began with Sorby who indicated the methods by which thin sections could be prepared, and inspired Zirkel as the first great petrographer to use the microscope. After about ten years investigation Zirkel's great work on the "Microscopic Properties of Minerals and Rocks" appeared. While the optical and physical properties of crystals of the common minerals were already well known, the recognition of minerals in thin sections of rocks was no simple matter. Most mineral grains possess few crystal boundaries to aid in the geometrical orientation, and there was naturally no regularity in the chance cross sections observed. About the same time appeared the "Microscopic Physiography of Rock-Forming Minerals" by Rosenbusch. For forty years these two German workers continued to attract students of petrography from all parts of the world. Meanwhile Michel-Lévy, Fouqué, and other French petrographers added their part, particularly in the introduction of more exact methods for the determination of the optical constants of minerals in thin sections. With the advance of the subject new types of microscopes were evolved, each leading to further progress in the evolution of the petrographic method. With the opening of the present century, North America was able to take a distinguished part in the advance. Much of our progress is due to those responsible for the development of the polarizing microscope. We are to be congratulated on the manufacture at home of microscopes, designed and improved by our associates, which make possible the highest type of mineralogical and petrographical investigation.

The method of determining the optical constants on mineral powders quickly and accurately by means of the microscope has made rapid advance and now stands as one of the most useful aids to the mineralogist and chemist. The work of Becke and Wright has been rendered more readily available by the recently published work of Larsen in which the optical properties of all but a few of the very rarest minerals are systematically arranged.

The Synthetic Method

Experiments designed to determine the conditions under which minerals and rocks could be synthetically prepared were first carried on in France by a school of brilliant savants. The motive was twofold, the profitable manufacture of gem minerals and the desire to learn the conditions under which the different minerals could be formed. This knowledge, it was thought, might give a hint as to the physical and chemical conditions under which minerals are formed in nature. The researches of Van't Hoff and his pupils in Germany, into the laboratory conditions for the artificial preparation of the salts associated with halite and gypsum have been followed by the more difficult work of those who have sought to apply this line of investigation to the preparation of rock-forming minerals from melts at high temperature. It is a matter of congratulation and pride that so many of those most prominent in this method of research are associated with us as fellows in the Mineralogical Society.

The Mineralographic Method

One of the most fruitful of the recent methods is that which aims at the determination of opaque minerals by an examination of polished surfaces in reflected light. While this method is now so common in the study of metals and alloys as to be sometimes known as the metallographic method, it was probably first applied to the study of complex mineral intergrowths. Baumhauer in 1886 ground, polished, and etched with hydrochloric acid and potassium chlorate, crystals of chloanthite and smaltite, and found that there was a well marked zonal arrangement of the different substances. By means of this method he was the first to give the correct interpretation of the chemical complexity of the smaltite-chloanthite aggregate. This method had been highly developed for the examination of iron and steel and from the metallurgists in its modern form it was taken over by our fraternity. One of its first modern applications to the mineralogical field was by Campbell and Knight who by this means were able not only to recognize the disseminated pentlandite in the pyrrhotite ore from Sudbury, but to indicate the genetic relationship of the component minerals to one another. In the past decade this mode of research has been perfected, largely by mineralogists of this country interested in the study of economic mineralogy.

The Method of Friedel and Laue

Within the last decade much progress has been made in the study of the molecular structure of crystalline substances. Friedel and Laue were the first to study the photographic projections of a beam of X-rays through a crystal plate. The continuation of such studies by Sir W. H. Bragg, his son Professor W. L. Bragg, and others has confirmed the hypothesis of mineralogists and crystallographers as to the lattice spacing of the crystal building units and has shed new light on the arrangements of the atoms of the substance within the fundamental particle. More recently workers in this field have learned how to determine the crystallographic constants for opaque minerals which have never been observed in any form of crystals. Owing possibly to their familiarity with the necessary technique and the possession of the laboratory equipment, most of the work in this field up to the present time has been carried on by physicists rather than by mineralogists.

With the passing of time, the introduction of new methods and the progress of the fundamental sciences there has been a repeated division of the field in which the early mineralogists worked. For our part it is desirable that we should keep in close touch with the branches which have separated and that the mineralogists of the future should be so widely trained that the broad interest in the earth sciences which we share jointly with the geologists, petrographers, and economic geologists, may be preserved.

THIRD ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA

Frank R. VanHorn, *Secretary pro tem*

The Mineralogical Society of America held its third annual meeting at the University of Michigan, Ann Arbor, Michigan, on December 29, 1922, in affiliation with the Geological Society of America. The meeting in the Mineralogical Lecture room was called to order at 9:30 A. M. by President Thomas L. Walker. In the absence of the Secretary, Herbert P. Whitlock, it was moved, seconded, and carried that Frank R. VanHorn act as Secretary *pro tem*. On the motion of the Secretary, the reading of the minutes of the last annual meeting was dispensed with, in view of the fact that they have been printed on pages 45–50, Vol. 7, Number 3 of The American Mineralogist.