BOOK REVIEW

THE PRODROMUS OF NICOLAUS STENO'S DISSERTATION. An English version with an introduction and explanatory notes by John Garrett Winter and a foreword by William H. Hobbs, both of the University of Michigan. *Univ. Mich. Studies, Humanistic Series*, Vol. **11**, pt. II, pp. 169–283, 1916. The Macmillan Co., N. Y., 1916.

It is well for the earnest student of science to turn aside now and then from his activities in bringing new facts to light, and to gain relaxation and perhaps inspiration by delving into the history and development of his chosen subject. He will often be surprised at the extent of the knowledge possessed by some of the early workers, and at the applicability of many of their ideas o present-day conditions. Of this the book before us is an excellent illustration.

The name of Steno is familiar to all crystallographers, being associated with the fundamental law of the constancy of interfacial angles. But how few know anything about this pioneer of scientific research, beyond his authorship of this law! Now, however, as the result of the work of Professor Winter, we have a readily accessible translation of the Prodromus, Steno's most important contribution to mineralogical and geological science, as well as a most interesting account of his life and work.

"In reading the Prodromus of Nicolaus Steno," says Professor Hobbs in the foreword, "one should remember that the essay was written near the middle of the seventeenth century, when scientific observation was hardly thought of." Those who observed and recorded natural phenomena too closely in those days were likely to be burned at the stake; Steno escaped this fate by discussing at length the agreement between his observations and scripture, and was able to make highly important contributions to crystallography and to geology.

Steno was born in Copenhagen in 1638, and because of ill health in his childhood was so closely associated with older people that, as he himself wrote, he "grew to prefer the conversation of older people, especially when they spoke of religion, to the frivolous chatter of younger companions." In this circumstance is evidently to be found the principal source of the powers of observation and logical reasoning which he later displayed. [How much more rapidly the world's knowledge would be advanced, were more children granted the same opportunity!] He studied medicine at the University of his native city, and also in Amsterdam, Leyden, and Paris, where he carried on extensive and important investigations in anatomy; it is noteworthy that the list of his writings includes 24 titles on anatomical subjects.

In 1665 he went to Florence and became attached to the court of Grand Duke Ferdinand II. Here he became interested in geology and mineralogy, and prepared the Prodromus. He later returned to Copenhagen, but having meanwhile embraced the Roman Catholic faith, he turned from science to theology, and during the remainder of his life occupied himself with religious controversy. After a rather stormy career in various clerical positions, he finally died as a result of self-inflicted privations in 1686.

Plates of the two extant portraits of Steno are included in the book, one painted during his stay in Florence, and the other while he was Vicar of Schwerin, the results of his asceticism being strikingly shown in the drawn features of the latter.

The character of the Prodromus and the quality of the translation may be brought out by a few brief quotations. It starts out:

> Most serene Grand Duke: Travellers into unknown realms frequently find, as they hasten on over rough mountain paths toward a summit city, that it seems very near to them when they first descry it, whereas manifold turnings may wear even their hope to weariness. For they behold only the nearest peaks, while the things which are hidden from them by the interposition of those same peaks, whether heights of hills, or depths of valleys, or levels of plains, far and away surpass their guesses; since by flattering themselves they measure the intervening distances by their desire.

How this applies to scientific investigation is then pointed out.

Steno excuses his delay in preparing a report on his investigations on the above basis; his words concerning his experience will appeal to the active scientist of today:

> I should gladly have postponed everything until it had been possible for me, on my return to my native land, to perfect the details, were I not awaiting the same fortune there which I have hitherto experienced everywhere, in that new tasks have constantly stood in the way of finishing those first undertaken.

Accordingly this Prodromus or preliminary statement of principles was prepared, and a fuller report promised; the fulfillment of this promise being unfortunately prevented by the circumstances of his subsequent life.

The sub-title of the essay, "concerning a solid naturally contained within a solid" is his way of explaining that he intended to discuss the solid objects, fossils and crystals, found imbedded in the solid rocks of the earth. When we consider the absurd theories as to the origin of natural objects of this sort customarily held in those days, it is particularly surprising to read:

> That the strata of the earth, as regards the place and manner of production, agree with those strata which turbid water deposits. That the crystals of mountains [i.e., rock-crystal = quartz] as regards the manner and place of production agree with the crystals of niter [this term evidently referring to some familiar artificially crystallized substance] although it is not therefore essential that the fluid in which they were produced should have been aqueous. That those bodies which are dug from the earth and which are in every way like the parts of plants and animals, were produced in precisely the same manner and place as the parts of the plants and the animals were themselves produced.

He further pointed out the difference between the growth of animals and plants on the one hand and crystals (angular bodies in his terminology) on the other; the difference between the mode of deposition of incrustations, such as agate, onyx, eaglestone (limonite geodes), etc., and the mode of formation of crystals; and the fact that the earth's strata were deposited horizontally, but have subsequently been uplifted into their present inclined positions.

The chapter headed "Concerning the Crystal" is the one of particular interest to mineralogists, for in it he describes in detail the features shown by quartz, demonstrating among many other things that the angles between corresponding faces are constant, no matter what the shape of the face or its distance from the center of the crystal. Unlike most of his contemporaries and indeed many of his successors, he was willing to admit his lack of knowledge on certain points; thus he says:

> As regards the formation of crystal, I would not venture to declare in what manner its first shape is produced . . .

As a matter of fact the cause of its shape was not found out, until it became possible to study quartz crystals by X-rays, some 245 years after he wrote these words.

He further describes in some detail what we now know as phantom crystals, symmetrically arranged inclusions, and parallel growths of crystals, and it is evident that many of his conclusions as to the nature of crystal growth were founded on his studies of such phenomena.

Other crystallized minerals which came to his attention were hematite, referred to as "angular bodies of iron," native copper and silver, diamond and "marcasites," which from what he tells of its crystal form we can recognize as pyrite.

Of his accounts of fossil shells and plants, and of the mode of formation of mountains and other natural phenomena nothing need be said at this point except that they were also far in advance of the accounts written by his contemporaries. The attempt to reconcile these observations with scripture, which concludes the book, might be regretted, were it not that they enabled the whole essay to pass the religious censor, a copy of whose opinion is appended. Professor Winter is certainly to be warmly commended for making the work of this pioneer of scientific research available to his humble successors.

E. T. W.

REVIEW OF TWO RECENT PAPERS ON CRYSTAL STRUCTURE

THE CONSTITUTION AND FUNDAMENTAL PROPERTIES OF SOLIDS AND LIQUIDS. Part I. SOLIDS. Irving Langmuir, of the General Electric Co., Schenectady. *J. Am. Chem. Soc.*, **38,** (11), 2221–2295, 1916.

The present reviewer, having had five years experience in teaching mineralogy, and having become familiar with the methods of several other teachers both in this country and abroad, has long felt that crystallography has no more right to be considered an integral portion of mineralogy than dynamics would have to be classed as a branch of horticulture, merely because Newton formulated the laws of motion and gravitation as a result of his observation of the fall of an apple. It happened that crystallography was first developed as the result of the study of minerals, for the simple reason that minerals are more extensively and perfectly crystallized than any artificial substances known in the middle ages, or, indeed, at the present day. And so, to this day, the youth in college is burdened with a series of harsh crystal names which he does not understand and with crystallographic formulas which he never sees the use for, at the very outset of his course in mineralogy. Small wonder that, with the always dominating first impressions thus indicating the subject of mineralogy to be a dry and uninteresting one, so few become sufficiently interested in it to ever contribute to its advancement. Crystallography is fundamentally a branch of chemistry, and in particular of physical chemistry, so it is gratifying to find that at last one of the most eminent of the younger American physical chemists has found in the results of advanced crystallographic research a means of explaining certain hitherto obscure phenomena connected with the constitution of solids (and even of liquids!).

That the molecules recognized by the chemist as essential attributes of all chemical compounds are in general not present as such in the crystallized forms of these compounds is not a new idea; it has been urged by Professor Groth of Munich and some of his students and associates for many years; but only the work of the Braggs,[1] emphasizing the validity of this view by the actual demonstration of the exact positions occupied by the atoms in the crystals of some 20 crystalline substances, has succeeded in convincing the chemical world. The elaborate paper under review is an able presentation of the effect of this view on chemical theories. The portions of interest to mineralogists are outlined in the next paragraph.

The work of the Braggs and others on the study of crystal structure with the X-ray is reviewed, and the structures are described which have been found to exist in the minerals halite, sylvite, diamond, sphalerite, fluorite, pyrite, hauerite, calcite, dolomite, rhodochrosite, siderite, magnetite, spinel, copper, silver, gold, lead, sulfur, quartz, zircon, rutile, and cassiterite. The inevitable conclusion is admitted,—that in these crystallized substances the atoms can not be held together by the ordinary valence relations, but must be united by "secondary valence," the importance of which has been brought out by Werner and others in recent years. In these substances, which belong to the class of "polar compounds," the whole crystal must be regarded as a single molecule. From theoretical considerations it is argued that in "non-polar" compounds (mostly hydrocarbons and their derivatives), group-molecules are present, in which the atoms are held together by primary valence altho these in turn are bound together into the crystal by secondary valence.

[1] One or more articles on this subject will appear in this magazine in the near future. Ed.

All forces between atoms are therefore chemical, and the old conception of physical forces (adhesion, etc.) as distinct from chemical ones is untenable. Many solid crystalline compounds including minerals do not show the composition which would be predicted from the ordinary rules of valence. The remainder of the paper is occupied with consideration of various chemical phenomena such as evaporation, adsorption, etc., for details concerning which those interested are referred to the original. See also the following review.

E. T. W.

THE COMMON REFRACTORY OXIDES. ROBERT B. SOSMAN, of the Geophysical Lab. *J. Ind. Eng. Chem.*, **8**, (11), 985–990, 1916.

This article, while nominally a presentation of the properties and behaviors of oxides of high melting point, includes considerable discussion of the constitution of certain crystalline minerals, and in a sense is supplementary to Dr. Langmuir's paper, which was treated in the preceding review, altho the two papers were prepared entirely independently. The properties of the oxides of five elements (Si, Al, Mg, Ca, and Fe) and of the products obtained by melting two or three of them together are described. Some of these are known as minerals, others have not as yet been observed in nature. It is shown that these oxides tend to unite in simple numerical proportions, regardless of what might be expected from primary valence relations of the elements concerned. The silicates and other compounds of these oxides thus appear to be essentially "molecular" compounds, altho the conception of molecular compound now held is not that of Berzelius, in vogue a hundred years ago, according to which salts consisted of distinct acid and base radicals. The structural formula and the fixed valence theory have been of great value in organic chemistry, but attempts to extend them into the inorganic field "have resulted principally in confusion." For example, the mineral sillimanite, which according to the new views is a simple, normal compound of two oxides, Al_2O_3 and SiO_2 in the ratio 1:1, has to be laid aside when an attempt is made to assign a structural formula to it as a "possible basic metasilicate." The remainder of the paper comprises a brief outline of the results of the X-ray study of crystal structure and the practical applications of the theories discussed to such technical industries as the manufacture of porcelain, refractories, and abrasives.

E. T. W.