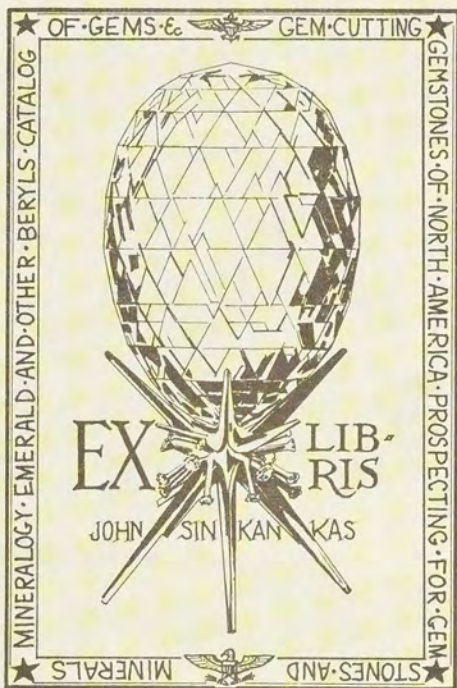


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TALKS ON MINERALS;

OR,

*THE STUDY OF MINERALOGY
MADE INTERESTING.*

BY

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NEW YORK AND CHICAGO.

(1883)

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INTRODUCTORY ADDRESS.

THE Museum of the Academy of Mount St. Vincent is being enlarged by the addition, from time to time, of sufficient birds and shells to afford instruction in those branches of natural history, with the view of thereby making it a source of instruction and improvement for all who may feel inclined to obtain, at least, a general knowledge of such matters. In pursuance of such plans, I was requested, after completing a few talks on minerals, to give a further address on the subject of post-graduate pursuits, among which the many different departments of natural history are not the least interesting to those young ladies of the mineral class who had been such patient and attentive listeners, thus affording evidence of an interest in the subject-matter extending far beyond the value of the discourses themselves. That address being here incorporated, the reason is obvious why the few words I have had to say on a single branch of natural history are preceded by so disproportionately long an introduction.

We often hear it said that Such a one has finished his or her education, and is now fit to enter upon the voyage of life. The latter part of this may be wholly true, the former never but in a restricted sense. The curriculum of school education is only preparatory to that of the great school of practical life, into which we are next to enter. The moral and the mental training acquired in common at either the school or the college, though they may not always determine the bent of the subsequent career, yet they exert a powerful influence on all our after-life; and the more thorough and general the early training, the better are we equipped to enter upon those pursuits

to which inclination, surroundings, or the force of circumstances may lead us.

In thinking minds there are certain tastes and faculties implanted, which, by cultivation, assist in keeping them in harmony with surroundings sometimes pleasant enough, at other times monotonous, occasionally almost unendurable. Then there are other minds whose bent in a particular direction is so powerful as to place them in direct antagonism with the pursuits and associations which seem to have been carved out for them, and who, when opportunity occurs, strike out independently, in their particular direction, with a force and concentration that break down all barriers, overcome all obstacles. Instances of such we find in the biographies of men of genius.

The little butcher-boy, Harry White, received, no doubt, many a scolding for his inadvertences and mistakes in taking and fulfilling orders, when carrying round his basket, and had he been seen after his day's work, by those usually around him, poring, by candle-light, in his mean little garret, over such books as he could get hold of, he would have been considered eccentric as well as stupid at his work. Behold him a few years later, when he had barely reached the age of manhood, carried to the grave, accompanied by the regrets of a nation! Henry Kirke White had found his vocation, and, in the few years allotted to him in this life, had taken a permanent position among the poets of England. There was another boy, who, in his classes, was said to be far from bright, and of whom little good was predicted. He was fond of roaming over the moors and mountains of his native land, picking up the tales and legends, in which they abounded, and lying around and thinking of them—upon the whole spending his time in a very unprofitable manner, so that, when he went into the law to practice as a plodding advocate, there was little on which to predict success. A novel appears by an unknown author, such as had not been seen since the days of Fielding, then another and another, from the pen of the mysterious author of "Waverley"; and to-day what educated person is there who has not dwelt with pleasure on the writings of Sir Walter Scott? When George Stephenson, the miner-boy, had got so far as to earn eighteen shillings a week, and had

married a servant-girl, he thought himself a made man. He could neither read nor write, indeed had had no school advantages, but there was something irresistibly attractive to him about the working machinery of the mine, and he studied it as another would have studied A B C. One of the pumps was out of order, and the engineering superintendent failed to remedy the difficulty. Stephenson modestly suggested that he thought he could do it. He was allowed to try, he succeeded, was promoted a few steps, and soon he advanced to employing a small gang himself. Leave him now diligently instructing himself and surmounting the educational disadvantages of his early life, and let us turn to another picture of some years later. There was a district on the eastern coast of England, embracing between ten and twenty thousand acres of land, regularly overflowed by the sea at the monthly high tides. Through this district, a small river, navigable by vessels of light draught, pursued its way by a tortuous course, out to sea. An engineer conceived the bold idea of constructing at the low-water level a sea-wall several miles in length; at the same time of straightening the river-channel and of carrying it out between the banks, into deep water; and of erecting light-houses at the entrance, thereby to gain the whole inclosed area for agricultural purposes. It was undertaken, the embankments raised within the month; and see him now, watch in hand, while the tide is rising, standing anxiously on the structure, to await the moment when the water shall begin to recede. If it pass over, he and his work will be engulfed together. It comes up within a few inches of his feet, plays there awhile, then begins perceptibly to recede; a shout of triumph from thousands of voices, and the work is accomplished, for, before another such tide rises, all will be made secure. The engineer was George Stephenson. Still later, a measure was laid before Parliament, to convey, in carriages, passengers drawn by steam-power, on a tramway or rail. The engineer insists that he can attain a speed of twelve miles an hour; he is laughed at in committee, he becomes excited, declares that, after a while, he will be able to increase the speed to twenty miles an hour, and is regarded by some as a visionary, by others as a lunatic. But a liberal member of the government seconds his views; the

thing is ultimately carried through, and, at no distant period thereafter, the first train moves out on its way from Liverpool to Manchester amid the cheers of assembled thousands. George Stephenson, the inventor of the locomotive, was the engineer, and, by overcoming the greatest engineering difficulties, he lived to construct some of the finest lines of railroad in the world. These sketches would hardly be complete without one more from the same life. There is a grand entertainment given to him who is regarded as England's greatest living engineer. The Brunels, the Rennies, and a host of notabilities, are there to do him honor. Again George Stephenson was the hero of the occasion, and it was a fitting tribute in his old age to him whose life had been a series of brilliant achievements.

From its peculiarly interesting character, I have dwelt somewhat at length upon one life. Of course, numerous others, equally striking, might be cited. We often see in the biographies of such men, their careers, whether in literature, in science, or in art, held up for imitation, as mere results of energy and industry, but I think wrongly. Much may be, and is, accomplished by industry, perseverance, and concentration of effort, but still there are heights that can not be scaled by the every-day mind. There are certain men, with God-given intellects or faculties, who seem to be from time to time sent into the world for the special purpose of advancing in some one of these departments our general knowledge; who achieve apparently with little effort, and who leave their hardest working and brightest competitors far behind. Such are the men of genius. Shakespeare and Milton, Raphael and Michael Angelo, are examples familiar to all. I am fully aware that the existence of what is called genius is denied by many, but with such examples before us as Mozart, who at the age of six years delighted the court of Vienna with his musical performances, and the calculating boy, and juvenile poet Chatterton, with his wonderful productions, considering his years and opportunities, and when we add the impossibility by the best of educational processes of bringing out like results at such early ages, I think we must admit that what we call genius is not a myth, but a practical reality.

I need not dwell upon this subject. If we can not reach the heights attained by, or emulate the labors of, the class I have alluded to, it is, nevertheless, within the grasp of every cultivated mind to enjoy the fruits of its labors, whether in the literary, scientific, or artistic field. Indeed, in modern days, everything has been so simplified, and brought to our notice in so many popular forms, that we can not afford to ignore entirely any subject of general interest, while every one of us has ample opportunity of following favorite pursuits as inclination may dictate.

Of course, individual tastes will vary very widely. Some love instrumental music, some song; and here let me say of these, as of all pursuits extraneous to your every-day duties, it is not necessary, in order that you may have enjoyment yourselves or afford it to others, that you be able to rival the efforts of a Patti or a Kellogg, or to interpret the most difficult compositions of a Liszt or a Chopin. Leave that to those who make it the business of their lives. How often do we hear people say, "It is useless to attempt to play in these days, unless we can accomplish something brilliant"!—and thus acts as a serious discouragement. Whether you play little or much, so long as you interpret what you do, well and with good taste, you will by simple pieces afford more pleasure to listeners than even by the successful achievement of compositions beyond the reach of the ordinary amateur, which after all will be unintelligible to the majority of your hearers, though attained at an expense of time, part of which might have been employed in equally interesting and desirable pursuits. The same principles will hold good in other departments. It is not necessary, in making a reasonable acquaintance with the various fields of natural history, that you mathematically examine or measure the angles of crystals, or discover something new in the botanical or insect world—or, in a word that you strive to do what nobody has accomplished before you. Leave that to *savants*. In accepting results, as they have been reached by acknowledged authorities, you will find enough to tax all your powers; you will have plenty to do to keep even moderately *au courant* with the ever-advancing knowledge of the day.

To return to those different tastes which may be regarded

as the embellishments of life, some prefer music, some song, others painting or poetry; some have a fancy for history or biography, some for general literature; others will like even those studies usually considered the province of the sterner sex, the ancient classics or mathematics. Some will devote themselves with ardor to a single branch; some will wander over the whole field, progressing in each as taste and talent may incline to special cultivation of any particular subject.

I have thus far alluded to the efforts of genius, lying as it were above and beyond the scope of ordinary intellectual attainment, as well as of those tastes apt to be called into activity by the higher courses of school instruction, which, cultivated, constitute what are called modern accomplishments. But there are other pursuits not less attractive, not less profitable to the inquiring mind, and so interesting in themselves that, if their votaries are fewer, it is only because they are not called more into activity by educational opportunities. Such, among others, are the various branches of natural history.

As I have said before, the real education of life commences virtually with the termination of school tuition. Boys enter upon college or university studies, or seek business knowledge, leading them into new channels; but with women education should not come to a stand-still. Who knows at the start which of those acquirements we have obtained will prove most useful in the course of our career? The changes in the up and down currents of social existence are so numerous, the results often so unforeseen, that we may find ourselves placed among surroundings entirely at variance with all our early calculations, and led to follow pursuits, for profit or pleasure, that seemed formerly most foreign to our ideas.

I would not have it inferred that I advocate rambling over a great variety of subjects without attaining a thorough knowledge of any, becoming as the saying goes, "Jacks of all trades, masters of none." The most shallow people are often the most pretentious; hence it is often true that a little knowledge is a dangerous thing. It is only so when we base false claims upon it. If by that little we learn to add to our store whenever we have an opportunity of conversing, on any given topic, with those in advance of ourselves, if we learn to separate the true

from the false, and further, if we learn how utterly impossible it is for any single mind to master even the elements of *all* modern knowledge, we shall have reached a point, starting from which, while we press on in the pursuits finally selected, we shall be apt rather to appreciate our own deficiencies than to plume ourselves upon our acquirements, while gradually attaining to that modest self-reliance which most surely wins the respect and esteem of those around us. In my earlier days, I knew a young man who, as a student, had already acquired reputation as a writer; indeed, I found a small work, translated by him, and included among those recommended as text-books in the universities of Germany. His accomplishments were so great and so varied that while his fellow-students credited him with knowing almost everything—it was the delight of his seniors at his father's numerous dinner-parties, the family being wealthy, to draw him out, and, almost imperceptibly to himself, make him the leader of conversation on general and literary topics. Always ready, when required, to impart what he knew, he was neither pretentious, nor shy, though modest, and, when asked a question, if he answered it, the information given might be relied on; but, if otherwise, often to the astonishment of his questioner, he would frankly say, "I do not know." How much better was this than to beat about the bush, until he had plunged himself into difficulties as insurmountable as those he had led his neighbor into! I need not add that that gentleman took high university honors, and to-day is distinguished equally in private life and in public position as a writer, lecturer, and as a physician in one of the leading medical institutions of England. Such as he was then, he is now.

All, then, that I would advocate is, that the broader as well as the deeper the foundations of knowledge are laid in school-time, the more certainly shall we find resources to fall back upon in all circumstances and in all conditions of life. It is, of course, to be hoped that the current will run smoothly; that whether you love etching or painting, music or poetry, languages or literature, science or natural history, you may be enabled to follow out your own tastes. If so, the above recommendations will have lost nothing in force; if, on the other hand, your energies are forced into unexpected channels, then

your varied acquirements may be turned to so valuable an account that you will have gained much in advance. I remember a story my father used to tell of a young lady brought up amid all the refinements and elegances of life. Shortly after her marriage her husband purchased a property on the border of one of the colonies, and, whether from losses or from what cause I know not, determined to emigrate thither. She took with her many things to which she had been accustomed, and among them a piano fine for those days. The last thing heard of the unfortunate instrument was that the inside had been variously disposed of, and among other precautionary measures taken against the attack of the hostile natives, the case had been set up as a sentry-box. Had she known anything of botany, it might have proved a solace to her in many a weary hour.

With regard to natural history, I would not press its claims beyond those of other pursuits, but simply as co-ordinate in interest with others, and as such worthy of attention. We often hear people say of minerals that they are but worthless stones; that shells are pretty enough to look at, but that they can not understand how any one can take a special interest in them; that it is truly absurd to see sensible people hunting butterflies; and as to collecting beetles and other vile insects, the taste that could delight in such pursuits is something incomprehensible. Yet it is singular, if placed among those who indulge in these pursuits, how soon we become attacked by the mania ourselves, how quickly the interest excited deepens into a fascination, I might almost say an infatuation. I do not, of course, intend to assert that such is invariably the case, but it often is so.

Among the tastes most strongly implanted in the human mind are a fondness of nature, a love of the beautiful (of course, from our own stand-points), and a desire of acquisition. Of the first we have illustrations in the attachment of the savage to his native wild-woods, in the love of the Alpine resident for the grandeur surrounding his mountain-home, and with ourselves in the pleasure we feel in escaping, at the opening of spring, from the crowded city to the parks, gardens, or green fields; in the exhilaration we experience in witnessing the

expansion of the new foliage, or the bursting of the buds of early shrubs into bloom; in listening to the carols of the returning birds, or plunging into the woods to gather a bouquet of the first wild flowers of the season. At such times we feel in the best of humor with ourselves and with everything around us, and we return home, invigorated and refreshed, with delightful anticipations of the time when we shall start for our summer resort, or leave on the proposed tour of pleasure. Of the love of the beautiful, according to our taste and cultivation, illustrations are afforded in objects pleasing to the eye, with which we surround ourselves, from the cheap pictures on the walls, or the spotted cats and dogs, bought from the Italian image-vender, and found on the mantel of the cottager, up to the delicate productions in Dresden or Worcester ware, or the still more costly Sèvres, ornamenting the houses of the wealthy. Of the love of acquisition we may find abundant illustrations in the striving after wealth, either for its own sake or as a means of procuring the objects we desire; in the miser over his hoards; in the merchant counting his gains; in the professor gloating over a newly acquired treasure, say a rare bug; even in the surroundings of the more humble student, who, not content with his books and instruments, his rugs and pictures, his odds and ends of all sorts, including his well-browned meerschaums, must needs variegate them with the brass knockers and bell-knobs of the neighboring Philistines. There is, perhaps, no pursuit affording a more agreeable as well as economical field for the indulgence of the above three passions than natural history in one or more of its branches.

Suppose one of you should happen to visit a lady friend, and should find in her boudoir a case of brilliant shells tastefully arranged and labeled. It strikes you as a thing of beauty, as indeed it is, and the chances are that you will begin to think you would like to have something of the sort yourself. A few choice specimens are given to you, you buy an elementary book on the subject, and at once become interested. You feel that you ought to have a few more specimens just to fill a nice little cabinet; then there is this or that interesting link missing, and you hunt round to supply it; therefore, you go on step by step, becoming more and more involved in the pursuit,

until you grow to be quite an enthusiastic student and collector. You make another visit: your friend tells you she will show you some of her treasures. She opens a cabinet drawer divided into inch-square or somewhat larger compartments, and glittering crystals of every variety of shape and color, cut and polished by Nature's own hand, meet your view. Your natural exclamation is, "Oh, how beautiful!" After a while perhaps you travel. In traversing mountains, or other localities of interest, you see similar beautiful little specimens for sale, and you conclude to carry one or two home from various places as mementos. After all, how much more sensible is this than to take with you bits of old brick and stone, labeled, "This is from such and such an old Roman wall"—"This is from the foundation of such a building," etc.—trash which, when you arrive home, you hide away in some drawer, only to be consigned in due season to its appropriate place, the rubbish-bin! Apart from the Vandalism which thus often recklessly aids in the destruction of truly interesting monuments, how much more is it in accordance with the tastes of a truly cultivated mind to be able to say, "These beautiful crystals I brought from the Swiss Alps, those from our own Western mountains; this lovely little wild flower I gathered from the walls of Tintern or Melrose, that from the borders of Como!"

This leads me to say a word on botanical pursuits. If you visit mountain scenery, or stroll into the woods, you can not fail to admire the exquisite and delicate fern-forms that fringe the crevices of rocks, and many persons carry some of them home and press them, and very beautiful they are in the tracery of their leaves. You will be surprised to find how many different species there are in the various localities. When pressed, you find they retain almost all their pristine beauty, and of course you try to collect as many different kinds as you can. You mount them and may with reason feel proud of your little herbarium. So with the grasses or wild flowers of any given neighborhood. You are seized with the idea of knowing something more about them, and you soon acquire an elementary knowledge of structural and physiological botany, thus another interest is aroused. How many a neighborhood, dull enough in the matter of scenery, has been enlivened and made inter-

esting by pleasant excursions, instituted for the purpose of collecting at the various seasons the wild plants, in which it may be particularly rich! Such excursions not only afford present enjoyment, but they will often find a place and be dwelt upon as pleasant reminiscences. When I was a boy I can not say I took much interest in botany, but while I was a medical student it was included in the necessary studies, forming part of the summer course. We had, in addition to the lecture-room instruction, weekly excursions during the season, and very enjoyable they were. Of the two thousand species of the British Flora, I collected, pressed, and arranged about five hundred, filling some four or five portfolios, and these, I believe, are still cherished among her household treasures by my sister in New Zealand, whom I have not seen for more than thirty-five years. Many of you, no doubt, are fond of painting in water-colors. This is of great utility in botanical studies. The flower, which loses most of its color and proportions in the pressing and drying, or parts of the flower, may be copied while fresh on a portion of the sheet on which the plant is mounted, or the root may be delineated if too tough or thick to press, and thus the entire character of the plant may be preserved. I had a sister in the East Indies, who is now in England, and the wife of one of the local civil judges. When the courts were not in session, she and her family retired to their country-seat in the Neilgherry Hills, where they had little society outside of occasional visits from army officers, or other officials, *en route* to various parts of the country, time would have hung very heavy, unless they had had some resources within themselves. She began to paint the wild flowers flourishing so luxuriantly around them. This led to the idea of delineating the flora of India, and she commenced the work many years ago. She met with encouragement and assistance in having plants sent to her from all quarters, and she has now nearly completed her task, in two large folio volumes. As the cost of reproduction would be very great, I doubt whether it will ever reach publication, but it is, I believe, the first elaborate work on the magnificent flora of that country, and, without reference to its future destination, has been a continued source of enjoyment to its compiler. With-

out going into an extensive herbarium, a collection of the plants of any given neighborhood in which one might be residing would be sufficient to make a goodly show.

I think I have said that botany was not taught in the German school in which I spent over two years; nor was any other branch of natural history. Still, most of the teachers were lovers of nature, and encouraged in the boys any taste in that direction. Many of us had quite respectable collections of butterflies, hawk-moths, and beetles. Armed with suitable nets, pins, and specimen-boxes, there would be a lively scamper in all directions, when once out in the open country, affording abundant and healthy active exercise; and, should a caterpillar of unusual size or markings cross our path, it stood little chance of retaining its liberty after we had once spotted it. Such we would take home, find out what leaves it fed on, place it in a box with lace net-work covering, to afford light and air, and at the bottom put two or three inches of not too dry earth; then we would feed and watch it from time to time until it went below the surface; if it belonged to the hawk-moths, it spun its cocoon on the upper portion, if to the butterflies, there it entered the chrysalis or grub state. Our patience would be rewarded after a while by the appearance of the moth or butterfly in its most perfect state; and thus we obtained the rarest as well as the largest and handsomest specimens. Sometimes we raised it from the egg, as many raise the silk-worm.

Some persons derive great pleasure from observing the peculiar habits of insects. I can not say that I have done much in that way myself, but it may not be inappropriate to give one illustration of the interest that may attach to such pursuits—one so extraordinary that I should have scarcely credited it had I not been an eye-witness. A tolerably large spider had made a large web between two supports and a cross-beam of a coal-shed in Newport. The exposure was to the southwest, and the web, being large, was considerably swayed by the wind. This seemed to give considerable trouble to the spider, and the question was, how should it be remedied, as there was nothing outside to which it could attach the lower part of the web. Well, it let itself down to the ground and attached the

thread to a pebble about the size of a small bean, and began diligently to infold it. After getting round and round it several times, it went up to the cross-beam, fastening the thread to the web above and to the cross-beam, repeating this over and over again until quite a string was formed, and so the lower edge of the web was steadied; but it did not stop there. A cart passing into the shed would have destroyed the work, and now comes the most extraordinary part. Having made the rope sufficiently strong, the spider now began to shorten it, thereby gradually raising the stone until it elevated it to within two or three inches of the lower edge of the web, thus steadying the latter by its weight. It was while the raising process was progressing that I saw it. It continued for two days, during which time several had been watching the proceedings from time to time. A drawing was made, and it was intended to photograph the work when completed. Unfortunately, one of the laborers, just after the midday hour, when none of the observers was present, seeing the large web, swept the whole down.

There is still another source of recreation available, whether in town or country, namely, the microscope. This instrument has been brought to great perfection, as well as reduced to a cheapness which enables any one, who has a fancy for it, to obtain an instrument suitable for all the purposes of the amateur. Though the larger and more expensive ones may be better for the purposes of instruction, they are so inconvenient to carry around, so difficult to pack, that a lighter, smaller, and more portable instrument will be found more advantageous. And what a world does the microscope open to us in revealing the form and structure of the minutest objects, whether they be the foot of a fly, the down of a butterfly's wing, or the ultimate tissues of animal or vegetable substances! If by the seaside, our net will bring up objects of extraordinary variety and beauty. In a word, by the microscope, a world far beyond the limits of our ordinary vision is presented to us, and it will prove as entertaining as it is instructive. The preparation and mounting of objects for the microscope constitute in themselves a very pleasing occupation.

In thus cursorily wandering over the different fields of nat-

ural history, I do not suppose any one would wish to take up all its branches, or could take an equal interest in all. Some will be content with collecting the minerals, geological specimens, or plants of a single neighborhood. In doing this they acquire more or less familiarity with the whole subject. I believe that by coming in contact with the smaller private collections, such as we have here, a taste for the pursuit of natural history is more apt to be roused than by visiting the greater national museums, and for two reasons: First, with the former the attention is directed to and concentrated upon a group of objects which excite our admiration; and, secondly, we feel that it is a something within our own power to acquire for ourselves; whereas, when visiting a grand museum, the attention is spread over and divided among a great variety of objects, over which the eye wanders restlessly, without time for concentration upon any one class, and, though gratified curiosity may excite wonder as well as pleasure for a time, the result is simply—fatigue. If I may so express it, the smaller collections allure by their attractiveness, the larger frighten us by their very magnitude and completeness. It is well to become thoroughly acquainted with the commoner specimens in the former; we shall then be able to appreciate better those rarer forms in the latter which it is not in the power of the ordinary collector to procure for himself. As one of the smaller collections of minerals, that of the Mount is very complete, containing as it does not only abundant illustrations of the more common forms in good crystallizations, but also very many of the rarer class.

To many persons minerals are only stones, and in one sense it is true, even in more than one sense, inasmuch as they are the foundation-stones of our upward material progress. While crystalline forms in our cabinet collections arrest the attention by their beauty, there are many of less attractive features, which we cast away, which contain elements that have largely contributed to the wealth of nations, and to the happiness and comfort of the people.

I may add that, when the following talks were addressed to a newly-formed class of mineralogy, they were intended merely as a sort of running commentary, while exhibiting the choicer specimens, and without any idea that they would be likely to

find their way into print. That they do so I can only attribute to a continuance of that partial consideration and uniform kindness which have been ever manifested in recognition of my efforts from the time I had the honor to become connected with Mount St. Vincent, many years ago, as physician of the institution.

Finally, as this is intended as a sort of general guide to the choicer specimens of the mineral cabinet, I have appended two numbers, the first being that of the section in which they are to be found, the second that of the specimen itself.

E. S. F. A.

April, 1883

FIRST TALK.

IN the few addresses which I have promised to make, I do not intend to trench upon the department of mineralogy as contained in didactic treatises on the subject. I shall, therefore, say nothing concerning the laws of crystallization, or the scientific determination of the varied and often exquisitely beautiful forms in which the products of the mineral world present themselves to our view—forms, inorganic though they are, yet as unvarying and as determinate as are found in the most highly organized plants and animals. We may, accordingly, find, in considering a few of the uses of the mineral kingdom in reference to man's wants, much useful material for instruction and reflection, as well as evidences of the wisdom and beneficence of a bountiful Creator.

I shall first say a few words on the geology of the mineral kingdom; then, while briefly running over some of the most important mineral substances, I shall take a cursory glance at their usefulness to man in his progress up to the present stage of civilization and refinement.

A complete ignorance of the mineral kingdom would be equivalent to a state of barbarism and utter helplessness, for not a moment passes that we are not called upon to determine mineralogical differences with a view to supplying our commonest wants. It is not my purpose, in these familiar discourses, to deal with the subject exhaustively, but rather to suggest such reflections as may enkindle in your minds a love of natural science, and to point out to you the beneficent operation of Divine Providence in the wide realms of Nature.

Geology of the Subject.—As you are aware, the inorganic world, considered in its widest sense, includes all that portion of the universe unendowed with life, embracing not only our own world, but all the spheres, the sun, the planets, and the countless multitude of stars, that revolve in their appointed orbits through the immensity of space.

It furnishes, moreover, the actual material of all the forms of organic life from the lowest up to man, to whom it was said, "Dust thou art, and unto dust shalt thou return." Yet, while in the organic world there is an ever-recurring period of reproduction, growth, decay, and death, there is no destruction of material. We are assured that, "though death destroy this body, yet in the flesh we shall see God."

The mere material elements, whether gaseous, fluid, or solid, which compose all living bodies, may, under the controlling laws of life, either change their forms, or enter into and nourish living forms, or redistribute themselves into inorganic chemical compounds, and thus again constitute a portion of the mineral kingdom. Does it follow from this that we are altogether materially constituted? Far from it; and, as I think this part of my subject can not be too well understood by those who take an interest in scientific progress, I will dwell upon it for a few moments.

Science, as the name implies, is knowledge systematically arranged. Thus, through an intelligent observation of the motions of the planetary system, scholars have built up the noble science of astronomy, so that it is now possible to predict the time of a comet's reappearance, as well as the hour and minute of the commencement of an eclipse. Again, electricity, though an invisible and impalpable agent, has been harnessed to the wheels of science and humbly does its bidding. It is sometimes stored away for future use; it lights up the darkness of night, it has brought the uttermost parts of the earth within speaking distance, and has literally annihilated space and time. These are but a few among the triumphs of modern science. We know nothing of the essential nature of electricity; we know it only by certain ascertained properties and manifestations, by which it is made appreciable to our senses as a power in nature.

In like manner, though we are aware of the earth's move-

ments around the sun and the manifold courses of the stars, we are entirely unable to explain their nature or assign their cause. If, then, in the absence of facts, we resort to mere speculation in order to fathom the mysteries of nature or of life, we are no longer on the path of science, but struggling in the ruts of a false philosophy that leads to materialism. It is to be greatly deplored that a large proportion of the scientific theories of the day are infected with this debasing doctrine, often urged with so much boldness and zeal, and so great wealth of talent, that they tend not only to lead untrained reasoners into false channels, but even to stagger the faith of the believing.

What, then, is materialism? It is a system which endows matter with life, which identifies the laws of our spiritual nature with those that govern the body, and admits no life beyond the grave. Is it supported by proofs? No; on the contrary, reason and observation convince us that matter in itself is a mere inanimate thing, subject to vital or chemical laws. Now, the very term "laws" implies a law-maker or law-giver, and consequently a supreme and all-controlling living power. So long as we live, our physical organization obeys the laws of life; when we die, those laws lose control, the laws of chemistry enter into operation, and the materials of the body pass through decay into other combinations.

The spirit, or soul, of man is something higher and nobler than matter. Though inclosed, clothed with it as it were for the time being, it is no integral part of it, or of mere life; but when life ceases, and the material part perishes, the soul simply leaves it to enter upon another phase of existence. Revelation alone, and not natural science, must guide us here, for it alone deals with the problems of a future life and the nature of the destiny in store for us after death. God's inner workings in creation are in his own keeping, and are as far above our limited comprehension as the heavens are above the earth. So far shalt thou go and no farther, is the command; and when man, with his finite reasoning powers, endeavors to unravel the mysteries of life, and, failing to do so, ignores their source, he goes beyond the legitimate bounds of scientific research, and can at best substitute simple assertion or unfounded hypothesis for the light of eternal truth.

In its more restricted sense, and as we have to deal with it, the mineral world consists of a very small portion only of the earth's crust, extending at most a few thousand feet deep. Calculating from the highest mountain-tops to the lowest depths of the sea, this crust does not, according to Lyell, exceed ten miles, or one four-hundredth part of the earth's radius, whereas the lowest depth reached by mining processes does not amount to a mile.

From a newspaper paragraph I learn that the deepest perpendicular shaft so far is the Adalbert, in a silver-lead mine in Przibram, Bohemia, which has been perforated to the depth of 3,280 feet. In two other localities, however, a still greater depth has been reached, though not in a perpendicular line, viz., the rock-salt bore-hole near Sperenberg, Prussia, which has been driven to the depth of 4,175 feet, and the coal-mine of Viviers Bemas, in Belgium, where the miners, by shaft-sinking and boring, have reached a total depth of 3,542 feet. How thin a film of the earth's diameter is this!

Although our knowledge of the earth's interior is necessarily speculative, yet it involves the condition in which the crust is found to-day, together with all its irregularities, its various layers, its veins of mineral treasure, its crystalline formations; in a word, the general physical aspects of the world in which we live. The older geological writers divided the earth's constituents into soils and rocks; but, as these are identical in their essential parts, and, by insensible gradations, pass into each other, both are now spoken of as rocks. The richest soils consist of decomposed rocks, or of materials as yet unhardened and mingled with decaying organic matter. To an indifferent observer the various kinds of rock seem piled together in inextricable confusion; but to the experienced eye of the geologist they appear otherwise. By him it is perceived that they form definite layers, and exhibit a fixed order of arrangement.

He consequently divides them into four principal classes, viz., the Aqueous, or secondary; the Plutonic, or primary; the Metamorphic, or transitional, also called conglomerate series, lying between the two former; and the Volcanic. Between the primary and the metamorphic, we have a mediary or inter-

mediary series, consisting principally of coal-measures and metallic veins. Let me say a few words on each of these in the order most easily understood.

The *Plutonic*, primary, or underlying rocks, as they are called, include the granites. They are not found on the surface in course of formation, and are, therefore, regarded as primitive, i. e., the earliest formed, though not always so, as we shall discover when speaking of the second series. These granites, which are of igneous production, having been formed at great depths in the earth, have, it is supposed, cooled and crystallized slowly under immense pressure, and are consequently homogeneous and compact in structure.

Next to the last class the *Aqueous*, stratified, or secondary rocks form a larger portion of the surface of the globe than any others. In the changes that have taken place on the surface of the earth, owing to upheavals and other disturbing influences, seas have evidently altered their location and rivers and lakes their beds. Hence, the mud or sand, having mingled with organic remains, grew dry and hard, and formed a deep bed called a stratum. Thus, in Diagram 1, if we suppose A to represent the underlying or primitive rock, in that case B, C, and D are strata successively formed on its surface.

Owing to the frequent changes in the earth's surface, one stratum may contain only fresh-water shells, showing that the surface was at one time covered with fresh water; another may contain only marine shells, showing that at another period the same spot was covered by the sea. We see this process going on in the sand-bars that form at the mouths of rivers as they flow into the sea. These numerous strata are not all found at one given spot, but they are piled in layers, one upon another, and often extend to a great depth. They do not, however, as one might suppose, generally lie in horizontal sheets, but often follow the undulations of the surface or stretch up the sides of underlying strata. They are often penetrated by other materials; they assume at times a perpendicular direction, and not unfrequently they are carried by upheavals, hereafter to be mentioned, thousands of feet above the level of the valley, as is shown in Diagram 2, A. These secondary rocks are non-crys-

talline in structure, though they sometimes contain imbedded crystals.

The *Metamorphic* rocks constitute the next class. We are not to suppose that, because the granitic rocks are called primary, they were necessarily formed before the strata. The contrary is proved by the fact that granitic veins have been poured into rifts in the strata, and the alterations caused by the heat of the latter at the point of contact render it clear that the strata were first formed, and then penetrated by the granite A, as in Diagram 3. Fissures have been made in the strata by the action of subterranean forces, and into these the granite was poured in a state of fusion. The intense heat of this mass affected the adjacent portions of the stratified rocks, altering their character, so that they are in part crystalline and in part stratified. These constitute metamorphic rocks. Such are gneiss, mica schist, hornblende schist, hypogene or metamorphic limestone, of which Carrara marble and certain kinds of quartz are samples.

The *Metalliferous Veins* are mostly found where the plutonic rock is in contact with the metamorphic; they may, indeed, be said to lie between them.

The *Volcanic* is the fourth kind of rock to be mentioned. We have various evidences of intense heat extending far into the interior of the earth. For instance, in deep borings it is found that, as we proceed beyond a certain depth, the temperature of water perceptibly increases; we have still better evidences in certain hot springs; but, above all, in the molten lava poured out by volcanoes upon the surface, and constituting in some localities extensive mountain-chains with numerous craters still distinguishable in form, though their active eruption has long since ceased. To these rocks belong the lavas, tufa, and breccias, or conglomerate of various materials, and the volcanic ash, all joined together by a suitable cement. These rocks are called overlying because, thrown up from below, they spread over the surface of the other rocks, often, as I have said, constituting mountain-chains, which hide from view many a site of town or villa buried beneath them. Of these, Pompeii and Herculaneum are notable examples. By the action of earthquakes or erosion (wearing

away), fissures and ravines have occasionally been formed in these rocks, laying their interior open to view. Says Lyell: "We behold not only successive beds and masses of porous lava, sand, and scoriæ, but also perpendicular walls, or dikes as they are called, butting through the other materials. Such dikes are observed in Vesuvius and other volcanoes." There are, besides, in some countries, rocks which, although without cones or craters, we believe, on account of their columnar form, as well as their identity with streams of lava, to be of volcanic origin. Such are the basaltic rocks of Staffa, in Scotland, and the Giant's Causeway, in Ireland, both of which are supposed to have been thrown up by submarine action. Masses of volcanic material are, however, not the only results of active forces beneath.

We have also *Upheavals*, by which land may rise or sink gradually, or violently as in earthquakes, and by which the relative positions of the various rocks toward one another are greatly modified, being curved or twisted, or sometimes even forced into upright positions. Knowing this, it is easy to understand how a metal like gold, for instance, with its metamorphic gangue, may have been thrown on the surface. The gangue being more perishable than the inclosed ore, and yielding to the influence of the elements, the liberated grains of gold are carried to the bottom of streams, where they are found imbedded in the sand. This statement, however, requires some modification, as we shall see when we come to speak of gold.

The faults in metallic veins, so troublesome to miners, arise from this cause. By a fault, we mean the interruption of a vein, which destroys its continuity, and causes a portion to be carried to a distance on a higher level, as represented in Diagram 4. A and B represent mineral veins, C and D the strata in which they are contained. By upheaval the strata have been split, and a portion of A has been carried above its level to E. The portion at A comes to a sudden termination, and the vein must be recovered by a knowledge of the different strata, and of the amount of dip.

By upheavals, masses may be forced up to an immense height, so that aqueous strata located in beds of considerable

thickness, and consisting almost exclusively of marine shells, have been found on granite at a height of three thousand feet above the level of the sea. These subterranean forces seem to have been much more active in former ages than they are now, though sufficiently alarming shocks of earthquake continue to occur from time to time.

In 1755, by the great earthquake at Lisbon, Portugal, almost the entire city, together with fifty thousand inhabitants, was swallowed up, and this is but a minor portion of the total ruin and devastation caused in various places by the same convulsion. Within a few years, the loss of nearly as many lives and the destruction of several towns on the South Pacific coast have been recorded as the result of earthquakes and tidal waves, the latter being the result of similar submarine perturbations.

We have now briefly described various rocks constituting the earth's crust, viz.: the aqueous, or stratified; the plutonic, or crystalline, beneath those; the metamorphic, situated between the two, and partaking of some of the characters of both; and the volcanic, or overlying, which were thrown from beneath the former by convulsions, that have greatly modified the positions of all toward one another. Wherever the metamorphic series are in contact with the plutonic, the metalliferous veins are most abundant.

Crystallization.—To form a crystal, it is necessary that mineral matter pass from a gaseous or fluid into a solid state, space being allowed for the proper aggregation of the constituent particles into the characteristic form of the individual species. As a rule, any substance occupies less space in a solid than in a fluid form, and less in a fluid than in a gaseous. This is due to the particles being more widely separated from one another in the two latter forms, whereby they are allowed to ride more easily over one another. Water, in freezing, would seem to form an exception to this rule, but the exception is apparent rather than real, for the crystals themselves are more loosely aggregated, and lock up large quantities of air between them.

For the purpose of crystallization, then, a substance must primarily be in a state of vapor or fluidity, either by solution or by igneous fusion. Very pretty exemplifications of the latter

are to be seen disseminated in brilliant though small crystals through the lavas that are found in mineralogical collections. Crystals are often formed in the slags of furnaces. We have already heard that the crystalline character of granite is probably due to fusion of the materials by intense heat and enormous superincumbent pressure, to which it owes its compactness. Of the intensity of heat required to pour out in liquid streams mountains of the most infusible of mineral substances, it is impossible for us to form a definite conception.

Why may not carbon in such a laboratory, and shut off from all substances with which it might combine by combustion, have found its fusing or vaporizing point, and have crystallized into the diamond, the hardest of minerals and the least affected by surrounding influences? It may then have been thrown to the surface, leaving behind it the softer matrix, or gangue, in which it was formed, and which would become disintegrated and perish. Carbon is utterly infusible, and, as we can not produce the conditions under which the diamond may be formed, we have so far failed to make it by any known process. This is not the theory usually held, but none of those which are entertained is more satisfactory. The same may be said of the other gems next in value to the diamond, as the sapphire, which is composed of pure alumina, the ruby, the Oriental topaz, etc.; also the emerald, which consists of silica and alumina, together with some glucina. A very large proportion of the crystals in cabinets have been found in or among igneous rocks.

There is another very interesting class of minerals called petrifications, which, although entirely in the form of organic substances, yet wholly consist of mineral matter. They were, in fact, originally organic substances, the component parts of which having been replaced, particle by particle, by silicious or other mineral matter, eventually disappeared, and a real stone of the exact appearance of the original was produced. There are some very beautiful specimens of this class, such as silicified and opalized woods,¹ and wood barytes.² Turning again to Lyell, he says that the process by which this change is effected is not thoroughly understood.

¹ Sections 38 and 39.

² 74, 72.

Some springs appear to possess antiseptic properties, which will preserve organic substances for a very long time, causing disintegration or decomposition, by which, through a very slow process, they are resolved into their gaseous elements. As this result, however, finally takes place, and as the organic particles disappear, mineral matters, with which the water is charged to saturation, having been deposited, take the place of the former, without altering the form of the original substance, and thus the substitution goes on until the whole results in a purely mineral mass.

The decomposition of woody fiber naturally takes place, in the majority of cases, more slowly than that of animal matter, and hence vegetable productions are more common. Springs containing free carbonic acid hold in solution more silica and similar compounds, usually insoluble, than others, while hot springs hold more than cold. Be that as it may, some are said to possess petrifying powers, under favorable conditions, and to convert into stone organic substances that find their way into them.

Of course, you know all about the formation of rivers; that waters falling on high ground, and not absorbed by the earth, seek a lower level in rills, afterward in brooks, and that these again, meeting and combining with others, expand into rivers. If, in their course, they meet with insuperable barriers, ponds or lakes result. A great amount of water, however, sinks deep into the earth, and, the more deeply it penetrates, the greater will be the pressure on it. If it can not escape in a lateral direction, it will begin to rise, so that if you pour water slowly, at A (see diagram), into a curved tube open at both ends and fill it up to C, the water will rise on the opposite side to B. But if one should try to fill the portion between A and C, the water will run over at B, and remain at the level of C. Water entering the earth at a high level, if it can not escape laterally, seeks, at a lower point, some crevice by which it may rise to its former level, and thus bubbles up in springs. This is one of the numerous beneficent arrangements of Divine Providence which enable man, when not living in the vicinity of ponds, rivers, or of surface springs, to provide himself with an abundance of pure and wholesome water, by simply sinking wells. In localities in which the population is large, and ordi-

nary wells are insufficient to meet the demand, or where the water-supply is more or less polluted by surface-drainage, by factories, or general refuse, man turns his scientific knowledge still further to account by sinking what are called artesian wells.

An *Artesian Well* is defined as a cylindrical perforation carried in a vertical direction, through one or more geological strata, down to a porous gravel-bed containing water, which, under the superincumbent pressure, is forced up through the perforation until it reaches the surface, or to a convenient height for pumping. Such waters find their way down along the edges of the strata till they reach a suitable place of storage. Let A, B, and C be rivers finding their way down to the strata E, F, G; in that case H, H, H are borings that extend down to the respective levels. Water thus obtained is of the purest kind: first, on account of the nature of the source from which it springs; and, secondly, because, no matter how polluted it may be at the surface, it is thoroughly purified by its filtration through the earth. At Reid's brewery, in London, there is a well of this kind, about 300 feet deep, I think, which furnishes an unlimited quantity of water. There is one at Passy, near Paris, over 1,900 feet deep, capable of furnishing 4,000,000 gallons daily, an adequate supply for a population of 500,000.

I can not better conclude this part of my subject than by quoting the journal "Nature," in relation to an artesian well now in progress at Pesth. This well, which, at the time of writing, had reached a depth of 951 metres (or over 3,000 feet), "was undertaken with the intention of obtaining an unlimited supply of warm water for the municipal establishments and the public. A temperature of 161° Fahr. is shown by the water at present issuing from the well, and the work will be prosecuted until water of 178° is obtained. About 175,000 gallons of warm water stream out daily, rising to a height of thirty-five feet. This amount will not only supply all the wants of the city, but will also convert the surrounding region into a tropical garden."

Having thus generally alluded to the distribution of the materials composing the earth's substance, I shall next speak of the materials themselves.

SECOND TALK.

IN my last address I spoke of the general arrangement of the materials constituting the earth's crust.

I shall now speak of them with such reference to their utility as the purpose I have in view may demand. It would be impossible to trace step by step the gradual employment of the different minerals in the progress of civilization. I shall therefore confine myself to a few general remarks. When the edict went forth to man that henceforward he should live by the sweat of his brow, his wants became greatly multiplied. In the genial clime of paradise, the fruits of the earth sufficed for all his wants. He was from the time of his expulsion to be subject, in the same locality, to changes of season, differences of climate, and marked alternations of temperature. He would need shelter from the inclemencies of the weather, pelts to protect him from the rigors of winter, materials for the hunt, weapons to guard himself against wild beasts, and even—as with sin came in all evil passions—to protect him from the assaults of his fellow-men. He needed now not only the fruits of the earth, but also its mineral treasures, either hidden beneath his feet or liberally scattered on its surface; and, thus equipped, he went forth to the battle of life, enabled by his intelligence and reasoning powers to make the brute creation as well as the mineral subservient to his wishes and his wants. He was henceforth to be a free and responsible agent.

As Prescott has beautifully said in his "History of Mexico": Since then, "ever on the advance, he passed on from discovery to discovery, from truth to truth. New facilities are devised for subsistence. Personal comforts of every kind are incon-

ceivably multiplied, until they are brought within the reach of the poorest. Secure of these, the thoughts travel into a nobler region than that of the senses, and the appliances of art are made to the demands of an elegant taste and a higher moral culture." The development of the mineral resources of the earth has been the most potent material agent in the progress of civilization. Among the rudest people the first weapons were made of bone, and subsequently of the harder kinds of stone, as in the arrow-heads of flint; the first building materials were of clay, hardened in the sun, and constituting unburned brick.

The earliest actual information we have on the subject is contained in Holy Writ (fourth chapter of Genesis), where Tubal-cain is spoken of as an instructor of artificers in brass and iron. The original meaning of these words may not be the same as that which we now attach to them, since iron, though the most useful and abundant of metals, did not come into use till a later period. It was employed, however, as early as the times of the Pharaohs, iron clamps having been used in the obelisk now in the Central Park. It is possibly owing to its liability to perish by oxidation that we find so few evidences of its use among the products of the earlier civilizations. Be that as it may, we have proof that man became acquainted with the use of metals at a very early period of his history. The first employed were undoubtedly such as were found in a metallic state upon the surface, and which, either in their elementary condition or altered by alloy, answered the purposes then required.

Alloys are not strictly chemical compounds; that is, although they unite in atomic proportions, they do not, however, unite indifferently, but are governed by their own particular affinities: thus, silver will not readily alloy with iron, but will do so with gold, copper, or lead. Dr. Ure remarks (and this is important) that, "in comparing alloys with their constituent materials, the following differences may be noted: in general, the ductility of the alloy is less than that of the separate metals, and sometimes remarkably so; on the other hand, the alloy is usually harder than the mean hardness of its constituents. To this, mercurials or amalgams would seem to form an exception."

While on this subject, I will allude to a singular alloy known as *Wood's Fusible Metal*. Cadmium is a metal rarely found, and mostly with ores of zinc. It is like tin in appearance, but melts and boils at a somewhat lower point than zinc, and burns with a brown smoke. Its use is mainly limited to making alloys that have low melting-points, which may be graduated to different degrees of heat, according to the proportions of the materials used. Wood's alloy consists of cadmium, two or three parts; tin, four parts; bismuth, fifteen parts; and lead, eight or ten parts. This melts at 70° Cent., or about 157° Fahr. A spoon made of it would melt like wax in boiling water. It is used for molds, for making impressions, etc. Dentists sometimes use an amalgam of cadmium as a temporary filling for the teeth.

There is a rare mineral called greenockite, which is a sulphuret of cadmium.¹ Gold is so soft a metal as to be unfit, by itself, for the uses to which we apply it, but, by alloying a very small portion of silver or copper with it, it acquires sufficient hardness to stand the necessary wear and tear of use without losing any of its more valuable qualities.

There are several native alloys, as, for instance, *native amalgam*, an alloy of silver and mercury (alloys with mercury are called amalgams), and in that rich mineral called *sylvanite*,² or graphitic tellurium, we have a natural alloy containing tellurium, 55.8; gold, 28.5; and silver, 15.7=100.

We are told that toward the close of the last century a metallic vein of supposed extraordinary richness was discovered in Transylvania, but nothing could be made of it. Analytical chemistry was not as well understood as it is now, and ultimately the disappointing ore was employed for paving the streets of a neighboring town.

A few years later a regiment of Uhlans were stationed in the place, the inhabitants were ordered not to leave their homes, and a gang of workmen was set to work to take up every stone. It seems that a specimen had fallen into the hands of the celebrated chemist Wöhler, who found it to be the alloy above mentioned. The inhabitants lost their pave-

¹ 87, 1331.

² 110, 429.

ment, but they can boast, at least, of a traditional respectability, for their streets were once paved with gold.

Tetradymite may also be mentioned, an alloy of bismuth and tellurium, with or without sulphur and selenium. Considerable knowledge and skill are required for the formation of the best alloys, of which bronze, brass, German silver, and Britannia-metal may be cited as our most useful utilitarian articles. Tin, though not actually found in the metallic state, is so easily converted into it, that, alloyed with copper in bronze, we find it among the earliest metallic substances in use.

We learn that the Peruvians, a people who had reached a high degree of civilization in the remotest times, possessed the art of hardening such an alloy of copper and tin as to render it equal in temper to steel, with which they were unacquainted. The process is not now known, but the loss of it is not important, since it has been superseded by a hundred others of greater value. As further evidence that very ancient peoples used bronze alike for tools and weapons I will again quote Ure. He says that "an antique sword, found in 1799 in the peat-moss of the Somme, contained 87.47 parts of copper and 19.53 of tin; hard and brittle nails contained 92.6 of copper and 7.4 of tin in 100 parts."

The wonderful monuments of Egypt, and later those of Nineveh, of which such perfect remains have come down to us with their engraved stones, and their hieroglyphic records, as deeply cut and as sharp in outline as when they were cut in the hardest of granite nearly four thousand years ago, are evidences of an acquaintance even then with excellent metallic tools. Again, as regards building materials, we read in the eleventh chapter of Genesis, with reference to the building of the tower of Babel, "Let us make brick and burn them thoroughly, and they had brick for stone and slime for mortar." Thus we see that, in the earliest times, man had learned to value and utilize the products of the mineral kingdom.

We shall now take a long step forward, and discuss our relations to the inorganic world at the present time. In alluding to mineral substances we speak of earths and metals, although the former are to a great extent oxides or combinations of the oxides of metals. Thus, silica is an oxide

of silicium, though this is not now classed among the metals, alumina of aluminium, and lime of calcium, facts revealed by chemistry in comparatively modern times. The earlier division, however, is still retained, the one class being utilized in their earthy state or state of oxides only, the other principally in their reduced condition; not wholly so, however, as many metallic salts are largely used in the arts and in medicine. The stratified and fossil-bearing rocks may be divided into the *Arenaceous* or *Silicious*, the *Argillaceous* or *Aluminous*, and the *Calcareous* or *Lime* formations.

I will first say a few words on each of the two former, after which, as a majority of the silicious minerals contain some alumina, I will allude to silicates in general—not, however, including the metals.

The *Silicious* formation largely predominates in the earth's crust. The granites, sandstones, igneous rocks, as lava, etc., and the metamorphic rocks, consist wholly of silicious compounds. Granite and basaltic rocks, as you know, constitute the most durable materials for building and paving stones. Lava also may be used for the same purpose, but some specimens¹ are very porous, and others again quite compact in structure. Many kinds of small ornaments, such as ear-rings, brooches, bracelets, and other articles, are cut out of lava of the latter by Neapolitans, who sell them to tourists.

A great number of beautiful crystals, usually small and of many different kinds, are to be found imbedded in the Vesuvian lavas.² Beds of loose sand consist of flinty grains, and flint itself is silica. The flint found in the nodules of chalk-beds is supposed to consist of the silicious remains of infusoria. Sand, as you are aware, is one of the components of mortar. Sandstone is merely an aggregate of grains bound together, sometimes without any visible cement, but more commonly by a slight quantity of calcareous matter, or by iron and clay. Many varieties of sandstone are highly valued for building purposes.

The purest form of silica is usually met with in the beautifully transparent and colorless crystallizations of quartz. The smaller crystals have sometimes been called St. Lawrence

¹ 58-60.

² 61-63.

diamonds, on account of the great perfection in which they exist near that river.¹ The California diamond is of the same kind.² In larger masses it is called Brazilian pebble.³ Some of these crystals, without losing their transparency, are beautifully colored. Amethyst is one of them.

The Cairngorm stone⁴ is a smoky quartz, of which there is a beautiful variety tinged copper-red, from the Lake Superior copper-region, which, together with variegated specimens, such as amethystine with red tips and others, may at some future time be employed in the manufacture of jewelry.⁵ The common amethyst, of which there is a very beautiful specimen from Canada,⁶ must not be confounded with the Oriental, to be mentioned hereafter.

Among the non-transparent varieties of quartz, colored by various metallic oxides, I may enumerate the variously colored agates, also chalcedony, onyx, jasper, chrysoprase, carnelian, and cat's-eye, all of more or less value to the jeweler. The precious opal is essentially a quartz with a different aggregation of its particles, and, as Dana observes, apparently incapable of crystallization. He further says that water is usually present, but is regarded as unessential. It would appear, however, that the presence of moisture is desirable to a certain extent, since I have been told that, when the cut gem has been kept in a very dry place for a length of time, the play of colors will be lessened, and that if, under such circumstances, you hold the gem for a while in the moist, warm palm of the hand, the brilliancy will be perceptibly increased.⁷

¹ 31, 514.

² 29, 107.

³ 30, 90.

⁴ 32, 95.

⁵ 32.

⁶ 33, 92.

⁷ 37, 464; 37, 716.

THIRD TALK.

I HAVE next to speak of the metals individually and their compounds.

Osmium, *rhodium*, *iridium*, and *platinum* are usually more or less associated with each other in platiniridium, 110, 962, and osmiridium, or iridosmene, 110, 604, with which latter rhodium is sometimes found, and exist in alluvial soils containing small quantities of gold. The three first named are not of much importance to the mineralogist, owing to their scarcity and consequent expensiveness, as well as from their hardness, infusibility, and general intractability. They exist in steel-like metallic grains or scales. If you ask me to point out to you the difference between these minerals, I can only answer that they resemble each other so closely that no description can sufficiently discriminate between them. Iridium, however, owing to the qualities above named, has been used for making the points of gold pens.

*Platinum*¹ is somewhat more abundantly found, rarely in crystals, but mostly in grains or small lumps, 110, 603. Occasionally, but very rarely, pieces of considerable size are ob-

¹ *Platinum*.—Cubical. $H = 4.5$; $g = 17$ to 19 ; opaque; luster metallic, but often dull; color, steel-gray. Malleable. Crystals very rare—occurs more usually in rounded grains. *Composition*.—Metallic platinum, usually containing small proportions of iridium, osmium, palladium, and other rare metals. *B.*, etc.—Infusible except in very minute grains. Insoluble in HCl or HNO₃; soluble in *aqua regia*, but not so readily as gold, forming a red solution. *Localities*.—It occurs in alluvial deposits in several parts of South America, especially in Colombia and Brazil. Also in the Ural Mountains and in the sands of many of its eastern valleys. To the chemist platinum is of greater value than even gold itself, on account of its great power of resisting the action of acids. The largest piece ever found was in the Ural Mountains, and weighed about eighteen pounds.

tained. In the window of Seymour's agency I saw a model of a mass from the Ural Mountains weighing 252 ounces Troy, or 21 pounds. Platinum comes to us mostly from Russia, which furnishes about 800 cwt. annually. South America and a few other countries yield it also in less quantity. The whole annual yield is probably less than 50 tons. It is very apt to be associated with iridium as platiniridium. It is the heaviest of metals, with a luster something between silver and iron, and is distinguished by its infusibility and hardness, a white heat not affecting it. We can readily account for its being found only in the metallic state when we consider that it does not oxidize when in contact with the air or with other substances, and that it remains unaffected by the strongest acids except the nitromuriatic. This metal is very malleable, and may be beaten out into leaves, says Ure, "so thin as to be blown about by the breath." From the qualities above enumerated it is a very valuable article alike to the manufacturing and analytical chemist, in the form of stills for distilling strong acids, of crucibles for reducing other substances by heat, or of wire or foil for holding substances exposed to the flame of the blow-pipe. I have seen at Tiffany's very beautiful breast-pins, sleeve-buttons, and similar articles of platinum, or platinum with gold, which contrast prettily, and do not tarnish as silver would do with gold. Such articles, however, are necessarily expensive, owing to the difficulty of working the material.

Gold comes next on our list, a metal which, in the thirst for it, works so much mischief in the civilized world; rightly employed, so great an amount of good; withal, so necessary (or its value) to provide us with the luxuries, comforts, and even necessities of life. Hear what Tom Hood says about it:

“Gold! gold! gold! gold!
Bright and yellow, hard and cold,
Molten, graven, hammered and rolled,
Heavy to get, and light to hold;
Stolen, borrowed, squandered, doled,
Spurned by the young, but hugged by the old
To the very verge of the churchyard mold;
Price of many a crime untold.

Gold! gold! gold! gold!
To save, to ruin, to bless, to curse,
How widely its agencies vary!"

Turn to Dana and you will find that, though one of the scarcer metals, its native abodes are numerous in every continent. Its primary localities, Ure observes, are among the trap-rocks of igneous formation, implanted in the sides of the fissures or disseminated in the veins, and with them heaved often to the surface. I stated before that metalliferous veins were mostly found at the junction of metamorphic and primary rock. Gold, however, does not form actual veins, but is found simply in grains or masses. Our principal supply is, as you know, obtained by digging deep in the sands of rivers in certain places, panning the sand, and washing out the gold. It might be supposed that this had been washed out from the various igneous rocks, carried down into the rivers, and there deposited. Such, however, does not appear to be the case, but rather that it actually belongs to the grounds washed by the waters. So says Ure, and quotes several authorities to show: 1. "That the soil of such plains contains frequently at a certain depth spangles of gold separable by washing. 2. The beds of the auriferous rivers and streamlets contain more gold after storms of rain upon the plains than at any other time. 3. It is found that gold occurs in the sands of rivers only in very circumscribed spaces. 4. On ascending those rivers their sands cease to afford gold, though, did the metal come from the rocks above, it should be found more abundantly near the source of the rivers." Of the latter fact numerous instances are cited, of which I shall only quote one or two. "The Ticino affords gold only below Lago Maggiore, and consequently far from the primitive mountains, and after traversing a lake, where its flow is slackened, and in which whatever was carried down from the mountains must have been deposited. The Rhine gives more gold near Strasburg than near Basle, though the latter is much nearer to the mountains; so in other localities. Gold, nevertheless, is not found in the secondary rocks. The greater part of the auriferous sands are ferruginous, and blackish or reddish in color, hence the gold is supposed to be derived from the decomposition of auriferous pyrites." In the cabi-

net, 111, 421, there are two or three small pieces of quartz covered with a thick iron-rust. This oxide of iron is a result of the decomposition of highly auriferous pyrite. The grains of gold are distinctly visible with a glass, and were formerly so to the naked eye; but many have been shaken out by handling. To return from this digression, Ure continues: "Moreover, the alluvial soils containing gold exhibit basaltic characters, or those of disintegrated trap, and the gold is often in the neighborhood of beds of lignite and fossil wood. Lastly, it has been remarked that the gold of alluvial formations is purer than that extracted from rocks." From all this you will justly infer, that although gold is found in so many localities, yet that uncertainty as to the quantity a given spot will yield, and the great irregularity in its distribution, entail much labor and hardship on the miner, and that the total yield is trifling in quantity compared with that of metals found in regular veins of ore.

Gold, then, is found in masses of various sizes—nuggets, as they are called—or in scales or grains, 111, 417; farther, in auriferous pyrites among various metallic sulphurets, and in the sands of rivers, as well as disseminated in veins of quartz. (See sections 110 and 111.) Nuggets of gold are seldom large, though occasionally considerable masses have been found. The largest, of which there is a model in the British Museum, and of which there is a copy on the top of one of the cases in our own, was obtained in Australia, weighing 2,166 ounces Troy, or 180½ pounds, its value being somewhat over \$41,000. Another, of 1,200 ounces, was found in the Ural Mountains. They are exceedingly irregular in shape, though said to be internally crystalline. Regular crystals of gold are very rare, but when found are usually in octahedral or dodecahedral forms. The Australian gold is more pure than the Californian, the average proportion of gold in the native specimens being in the former between .900 and .960, in the latter about .880. The Australian gold is also somewhat lighter in color. There is a very pretty, small specimen in the cabinet of this, 111, 1059, for which I am indebted to the kindness of Professor H. Morton. Total weight, 2.19 ounces; specific gravity, 3.52; weight of gold, 0.652; fine-

ness, .960. It will be seen that this quartz specimen is not only particularly rich in gold, but that the latter is of the highest purity. The gold in the pyrites or mixed sulphurets is not itself combined with sulphur, but is simply mingled with them in its native state.

You are, of course, familiar with the process of washing gold out of the sands by stirring the whole with water, thus allowing the lighter particles to be carried off, while the gold sinks to the bottom, then mixing in mercury, which amalgamates with the gold and retains it. When, by repeated washing, the whole of the extraneous matter is got rid of, the amalgam is subjected to heat in proper vessels, and the mercury thereby distilled off and collected for further use. When obtained from quartz rock, the rock is crushed, and the same process pursued. The proceeding is more complicated when the gold has to be separated from the metallic sulphurets or from other metals. Of late years a system of hydraulic mining, as it is called, has been largely carried on. Many of the hillsides where this course is pursued were in ages long past the beds of rivers. Streams of water of great power are made to play upon these dried up channels and bring down the gold deposited in them. The material thus washed down being conveyed in suitable channels to lower levels, the gold is gradually washed out. Of course, no effect of this kind could be produced on solid rock, but from the manner of its formation the material is comparatively loose and friable where this process is adopted.

Although gold is found on all the continents, its quantity in many places is not sufficient to pay for the working. According to Ure, the average quantity taken into the European market per annum from 1790 to 1802 was, from the old continent, 8,800 pounds; from the new, 40,260 pounds. This has been immensely increased since the gold discoveries in California and Australia, from each of which the quantities, estimated in dollars, amount to many millions annually; but, as I do not intend to burden my subject with statistics, I will merely say that the total estimated value of gold extant in the world in 1875 was about five thousand million dollars.

A large proportion of this is, of course, absorbed for trink-

ets and ornaments of various kinds, or in vases and similar articles of luxury; some, too, in gilding processes; the balance, in coin or bullion, goes to constitute the standard money of the civilized world. The interests of trade and commerce requiring that there should be a certain standard by which all other values may be relatively estimated, gold affords an excellent medium for the purpose. Its quantity has not thus far increased so rapidly as to exceed the needs of the monetary world, while, as it does not tarnish nor oxidize and thereby waste by exposure to the atmosphere, it makes an excellent coinage. True, it is too soft to use in its perfectly pure state, but, by alloying it with a very small proportion of silver or copper, it acquires the necessary hardness without losing any of its valuable qualities, though not without some loss through wear and tear, amounting to from one half to one per cent per annum, by circulation. When we speak of a gold chain, bracelet, or other article, as of so many carats fine, say twenty, it would mean twenty parts of gold, with four of alloy—pure gold being twenty-four. Eighteen carats fine is usually as high as the best gold articles in jewelry are made. Gold, like platinum, is exceedingly malleable, so much so that an ounce of it is beaten out to cover a surface of one hundred and fifty square feet, and might be farther attenuated, though not profitably.

Silver, next to gold, is the most valuable of our metals, being, like it, largely employed for ornamental and useful purposes, and, like it, converted into coin. It now constitutes a subject of peculiar interest, owing to the question as to whether it shall be made a standard for money as well as gold. Silver differs from gold in this, that it is found in various combinations, forming veins and beds of ore, as well as in its native state. Its supply is being so largely increased, but is so variable, that its relative value in comparison with gold is constantly changing, with a tendency to permanent depreciation. To-day the silver dollar is worth less than a greenback; and, though it may be made a standard in the United States, other countries will not accept it otherwise than at its commercial value.

Silver is the brightest, and, as such, when burnished, the most brilliant of metals, but, unfortunately, has a peculiar

affinity for sulphur, which, found in the form of sulphureted hydrogen in most houses where coal and gas are burned, causes it to tarnish readily; hence, in the cabinet, it is almost impossible to keep specimens bright (112, 393, and 1226). It melts at a good red heat, or about $1,280^{\circ}$ Fahr., and, like gold and platinum, is exceedingly malleable, admitting of being beaten into leaves of not more than one hundredth of an inch in thickness; at the same time, it is so ductile that it may be drawn out finer than a human hair. It is found native, more or less alloyed, sometimes crystallizing in cubes or octahedrons, in those countries which produce it most largely; also in disseminated grains, sometimes in masses of many pounds, likewise also in fibrous form. There are many specimens of these different kinds of native silver in section 112. The greater portion, however, of our silver is obtained from its ores; such are:

1. *Native amalgam*, a compound of silver with mercury in the proportion of about one third or one fourth of the former to two thirds or three fourths of the latter. This is confined to a few localities, and is rare.

2. *Antimonial silver*, or dyscrasite, 106, 842, consisting of 76 to 84 per cent of silver, the rest antimony.

3. *Mixed antimonial silver*, of the Hartz, containing silver, antimony, arsenic, and iron. The above are basic compounds, or alloys. The four following are compounds with sulphur.

4. *Argentite*, 106, 401, 402, 995, vitreous silver, or silver glance, a sulphuret of silver, dark-gray or leaden in color, and cutting with a metallic luster, said to occur in most silver mines.

5. *Black sulphuret*, acanthite.

6. *Proustite*, or light-red silver ore, consisting of silver, sulphur, and arsenic (107, 410, 887). Crystals of this ore are rare and very expensive. I am told, however, that they have recently been found in the mines in Nevada and elsewhere in the United States. Though small, they will, however, probably be found sooner or later of a fine quality and size, and disposable at a price enabling the ordinary collector to purchase them.

7. *Pyrrargyrite*, a dark-red silver ore, a compound of silver, sulphur, and antimony, in rhombohedral crystals, also massive. Of this there is a superb specimen in fine crystals, 107, 880, in the cabinet, another semicrystalline from Nevada, and others in 106 and 107.

8. *Huntelite*, a new mineral. It is an arsenical silver, and there are two kinds of it, viz., the hard, or crystalline, and the soft, or amorphous. They correspond to the domeykites of the copper series. The hard, 106, 1227, contains 44.67 per cent of silver, and 23.99 of arsenic; the soft, 59 per cent of silver, and 21.10 of arsenic, with other metals in smaller proportions. It will be seen that huntelite is a very valuable mineral, found only so far in the Silver Islet mine, Lake Superior. An analysis of the two huntelites is given in the catalogue.

9. *Yellow silver ore*, 101, 576, is not mentioned in Dana. On submitting it, however, to Professor Brush, he considered it an antimonial sulphuret converted into sulphates by oxygenation. It is considered a valuable ore in Mexico.

10. *Stromeyerite*, the Silberkupferglanz of the Germans, might be included among the silver ores, containing as it does 53.1 parts of silver, 31.2 of copper, and 15.7 of sulphur, a mixed sulphuret therefore. It is too scarce to require prolonged description.

11. *Hornsilver*, or cerargyrite. A chloride of silver and an exceedingly valuable ore. It is largely yielded by the mines in Leadville, Colorado, which are among the richest in the world. 108, 1289, and 1313.

12. *Selbite*, Plata azul, or negrilla, a black earthy carbonate of silver. It is not abundant, gives sulphur reactions according to Dana, who considers it a mixture. There is another mineral called petanque, or blue silver ore, 102, 416, an argenterous erubescite, but, as it does not contain more than about one per cent of silver, is not of much account as a silver ore, though very pretty.

In addition to the yield from the above, large quantities of silver are obtained from the so-called silver-lead ores, or argenterous galenas, the silver often imparting great brilliancy to the otherwise dull sulphuret of lead. The specimen 103, 356, is extraordinarily rich in silver, and there are other fine exam-

ples in 102 and 103. The manner of separating the silver from the lead is at once simple and interesting. The ore is first crushed and the extraneous matters picked out or thrown off by centrifugal force in the crushing process. It is next freed from the sulphur by roasting. It is then melted in large open pans, and a powerful current of air kept playing on the molten mass; by this means the lead is oxidized, forming a scum, which consists of litharge, on the surface. This is skimmed off and the litharge laid aside. When all the lead has by this means been removed, and the silver remains in its purity, the contents of the pan assume a blinding brilliancy. Nothing now remains but to draw off the pure silver, run it into bars, and stamp it. The litharge is afterward collected, smelted, and run into pig-lead. The value of the lead pays for the whole process, the value of the silver is profit. In Cumberland, where I saw the process carried on, about five per cent was considered about a fair average profit, the ore yielding sometimes more, sometimes less.

I need not enlarge upon the uses of silver. That they are manifold, and minister rather to our luxury than to our comfort, is well known. Burglars, however, have a peculiar affection for it, and it behooves us, if we have any silverware, to be especially careful not to leave it exposed to nocturnal marauders. For small currency, silver is certainly a most valuable medium.

Mercury, also a scarce metal, is found in countries where gold and silver usually abound. It is remarkable as being the only metal fluid at common temperatures, solidifying at 41° Fahr. below zero, while at a heat of about 656° Fahr. it becomes converted into vapor without oxidizing, so that on its condensation metallic mercury is again obtained. It is remarkable, too, for its great weight. It is sometimes found, disseminated in grains, with other metallic ores; the principal ore, however, from which it is obtained is the cinnabar or sulphuret, and the two principal localities whence it is obtained are Idria, in Austria, where it is found as a dark bituminous sulphuret, the idriate, or inflammable quicksilver, 3, 499, 109, 499, and 390, and New Almaden (from Almaden, a place in Spain), California, whence we have it of a beautiful bright-vermilion color,

109, 497. There is also a specimen of stream cinnabar in the cabinet, 109, 829. It is found also, as already stated, in native amalgam, and as a chloride, or horn mercury. The metal is altogether a rare one, the latter ores particularly so. Mercury has been spoken of as an amalgam for extracting gold, one or two pounds being lost for every ton of gold realized. It is used as a solvent of gold for gilding, and, alloyed with tin, as a coating for the backs of looking-glasses. The nitrate of mercury, says Ure, is employed for the secretage (or fixing) of rabbit and hare skins; that is, for communicating to the fur of these and other animals the faculty of felting. Its greatest utility in every-day life is in supplying us with fluid for the thermometer. The regularity and evenness of its expansion or contraction, under different degrees of heat, render it particularly valuable for determining temperature. It affords us, too, in its chemical combinations, some of our most valuable medicines, though like most good things it is apt to be abused. In the time of Queen Anne, in England, the notion prevailed that mercury beautified the complexion, and considerable quantities of metallic mercury were swallowed by the court ladies. Fortunately, metallic mercury is innocuous, and, as it was not taken up by the system, it did as little harm as it did good. Of the whole quantity of mercury obtained annually since the opening of the California mines I have not heard, the previous average probably not exceeding five hundred tons, though the mines at Carniola (Idria) at one time produced as much as 1,200 tons.

FOURTH TALK.

COPPER, one of the most valuable of metals, was among the earliest used, being found native in considerable quantities on the surface. It yields to gold, silver, and platinum in ductility, but is superior to them in tenacity, in which respect, however, it is in turn inferior to iron. It is not only valuable in its pure state for culinary vessels, as well as boilers, faucets, stills, etc., but also of the greatest utility when alloyed. Thus brass is an alloy with zinc, bronze and bell-metal alloys in different proportions with tin, German silver or white copper, a compound consisting of copper, nickel, zinc, and iron. What a multitude of uses do these names suggest! I have already alluded to the fact that a very small quantity of it alloyed with gold or silver gives them hardness and durability without altering their prominent qualities. I may mention the fact that copper wire, owing to its oxidizing less easily than iron, and possessing at the same time great tenacity, is the best material for bell-wires, and is further employed as a conductor of currents of electricity.

Its utility as an electric conductor is to be measured by the vast importance which telegraphic communication between the remotest parts possesses for the commercial and social world.

The ores of copper are numerous, and afford some of the choicest specimens in the cabinet of the mineralogist. Here, however, let me digress again for a moment to speak of ores in general, inasmuch as nowhere is the wisdom or beneficence of the Creator toward mankind more signally exhibited than in this class of minerals.

First, with regard to *ores*. We have now arrived at those

most useful of metals, the production of which we reckon by tens and hundreds of thousands of tons, nay, by millions often; metals in themselves of far more practical use to man, in aiding his advancement up to the present high standard of civilization, than all the gems and gold and silver of the world. It is necessary that they should be characterized by a very high degree of tenacity, and this quality would make it difficult to work them out in their respective fields of production in a metallic state. Suppose, for instance, we had to deal with veins of pure copper in the mine. We could not blast it with powder, we could not split it with an axe, we could not get it to our furnaces otherwise than by chiseling it out painfully in small pieces, involving an amount of time and labor and expense so great as would render it practically almost useless to us. In fact, there are very large masses of native copper on the surface in the Lake Superior region which can not be utilized on this account. Here comes in that beautiful provision for our wants, whereby, stored in abundant veins of ore, metals the most useful, in their various combinations with sulphur, or oxidized and combined with acids as salts, assume more or less of a soft or brittle character, that deprives them of their tenacity; and so they are readily broken up by blast or pick into convenient quantities for transport to the furnaces, where, crushed, smelted, and reduced by processes often complicated enough, they are separated and reduced to the metallic state at comparatively little cost.

It would be both tedious and unprofitable to enter upon those processes here. A single illustration will suffice for all. It must be remembered that, in smelting the ore of any given metal, we have not only itself and its compounds to deal with, but numerous other matters besides, as with other metallic substances, siliceous or earthy matters, sulphur and various acids. To obtain pure copper from its ores, Dr. Ure thus sums up the processes: 1. Calcination of the ore; 2. Melting of the calcined ore; 3. Calcination of the coarse metal; 4. Melting of the calcined coarse metal; 5. Calcination of the fine metal; 6. Melting of the calcined fine metal; 7. Roasting of the coarse copper: this sometimes is repeated four times, in which case a calcination and melting are omitted; 8. Refining the copper.

When all this has been done, copper may be purchased at comparatively few cents per pound. At first sight it might seem very nice to have a full description of all the proceedings in the reduction of metals, but one such summing up, not to mention the minor details, will be sufficient, I am sure, to elicit a cry of "Spare us!" which I intend to do, merely remarking that these processes are determined by the chemical qualities and different behavior of the various substances composing the ore under the influences of heat, oxygen or air, fluxes, etc.

To return to the ores of copper. We have—

1. *Native copper*, sometimes massive, 117, sometimes crystalline and assuming various fantastic forms, the crystals being twinned, as it is called—117, 371.

2. *Chalcocite*, or vitreous copper, sulphuret of copper, 118. One specimen in the cabinet has nice crystals, 117, 1104.

3. *Erubescite*, or purple copper, also called bornite or variegated copper, a sulphuret with iron. From the variety and beauty of its colors it is sometimes called peacock copper, 118.

4. *Gray copper*, sulphurets of copper, iron, and antimony.

5. *Chalcopyrite*, or copper pyrites, sulphurets of copper and iron; containing, however, much less copper and more iron than the erubescite, 118. It is a very common ore. Crystals tetrahedral.

The next two are oxides, viz.:

6. *Cuprite*, or red copper-ore, a protoxide of copper. This is a very beautiful mineral when in crystals, as in the handsome Redruth specimen, 113, 888; also in the fibrous chalcotrichite, 113, 561. Interesting crystals of oxidulated copper are found in Chessy, France, 120, 764. We have it also in an earthy form, massive, as in tile-ore, 120, 489.

7. *Melaconite*, a black peroxide of copper, 113, 488, common in the earthy form, and resulting often from decomposition of chalcopyrite and other copper-ores.

8. *Chrysocolla*, a hydrous silicate, often opal-like or enamel-like in texture and of various colors; a beautiful mineral. Sometimes it is earthy and massive; of this we possess a specimen.

9. *Diopase*, or emerald copper, an anhydrous silicate, of which we have a very beautiful specimen, 113, 379. It crystal-

lizes in rhombohedral form. Were the crystals harder, they would constitute a brilliant gem, and are used as such by the people among whom they are found.

10. *Malachite*, the blue and green carbonates, 114 and 115. There are good crystals of the former, the azurite, and one a very brilliant specimen presented by Job Lawrence, Esq., 114, 997. There are also in the cabinet many fine specimens of malachite proper, polished and unpolished. Malachite is, as you know, cut into various beautiful ornaments.

11. *Chalcanthite*, or blue vitriol, the sulphate of copper.

12. *Muriate of copper*, or oxychloride. The atacamite, 113, 591, from Chili, is a specimen containing nearly 60 per cent of copper, with chlorine, oxygen, and water.

13. *Liebethenite*, phosphate of copper.

14. *Chalcophyllite*, arseniate of copper.

There are some other rare forms in 120.¹ *Linarite*, another very handsome mineral, 92, 563, is a sulphate of copper and lead.

Tin has already been spoken of in connection with valuable alloys. It was among the earliest metals so employed. The Phœnicians are said to have traded with Cornwall for it three thousand years ago, and the mines there are now among the deepest in the world. Its localities are not numerous, and of its ores there are but two :

1. *Cassiterite*, 85, tin-ore, a deutoxide crystallizing tetragonally. It is found also massive as tin-stone, or in the sands of rivers as stream-tin.

2. *Stannite*, or sulphuret, containing also more or less copper, iron, and zinc.

Copper and iron vessels are often lined with tin, and indeed the tinned iron known as tinware serves a hundred useful purposes in every kitchen from the highest to the lowest. In addition to alloys of tin already alluded to, others of great value may be mentioned here : thus, the speculum-metal of telescopes consists of about one hundred parts of tin with two hundred and fifteen parts of copper. This of all the alloys is the whitest, the hardest, and most brilliant, and at the same time the most brittle. Cannon-metal is a variety of bronze. Of still more

¹ The beautiful Fahlerz specimens, in 119, are worthy of especial notice.

general utility is the Britannia-metal, said to consist of equal parts of tin, brass, antimony, and bismuth, furnishing in the houses of the poor the tea-pot, spoons, forks, and other useful domestic articles at an exceedingly cheap rate; while for higher-class goods of a similar description there is the plate-pewter, having when polished a silvery luster, and composed of one hundred parts of tin, eight of antimony, two of bismuth, and two of copper.

A great deal of care and skill are required in the processes of making the above, owing to the strong tendency of tin to oxidize at a high temperature, a fact which would interfere with the union and spoil the product. Gold-purple, or the purple of Cassius, is a vitreous pigment, by which glass and porcelain may be stained of a beautiful red or purple hue. It consists of oxide of tin with gold.

Antimony and *bismuth* are both found native, the former sometimes containing a small portion of arsenic, silver, or iron, the latter traces of tellurium, arsenic, or iron. Of the native antimony we have a very nice specimen in 85, 1315; the bismuth specimen, 84, 584, is artificially crystallized.

Allemontite, 86, 845, is an arsenical antimony; the principal ore, however, is the *stibnite*, or sulphuret of antimony, which is found often in beautiful needle-like crystallizations, sections 85 and 86.

Bismuth is found native, but not often in crystalline forms. Both of the above metals are found associated with other minerals: thus in grunauite, 86, 856, we have bismuth nickel, containing about 41 per cent of bismuth and between 46 and 47 per cent of nickel, and the bismuth copper or tannenite, 84, 838, with sixty-two parts of bismuth, eighteen of copper, and nineteen of sulphur, in round numbers. So, again, we have antimonial silver, and the antimonial nickel or breithauptite, 87, 854, with sixty-seven parts of antimony and thirty-two of nickel.

Type-metal is an alloy of lead and antimony. This alloy possesses the property of expanding on cooling and solidifying, hence gives a very sharp impression of the mold. I need not insist upon the immense importance of type, as an aid of civilization, recording as it does and infinitely multiply-

ing the results of investigation, the progress of thought, the sums total of human knowledge.

Titanium is a rare metal, discovered in 1794. There is a specimen of artificial production, 82, 691, in the collection. I do not know of any use of it in the arts. Sphene, 82, 701, is a titanic oxide with silica and lime; rutile, 82, a deutoxide; iserine, a titanic iron, 79, 1011, and 302. Octahedrite and brookite, 83, 1043, are pure deutoxides of titanium.

Lead is one of our most valuable metals, of which the use is very ancient. There are many very pretty specimens afforded by the numerous ores of lead, the most abundant of which is the galena, or sulphuret, 92. Galena is sometimes worked for the silver only, of which it often contains a portion, and of this about two parts in a thousand will pay for the process of separation. I have already described it. Pure galena is dull in color; those having silver associated with them, the argentiferous galenas, 102, as they are called, are often brilliant and generally of a finer grain. Of the other ores of lead may be enumerated *minium*, or red lead, very rare; the *melano-chroite*, oxide of lead with oxide of chromium; *crocoisite*, a chromate, of which we have a superb specimen with topaz, 95, 370; *cerussite*, 94, a carbonate; *anglesite*, 95, a sulphate in tabular and pyramidal crystals; *pyromorphite*, a phosphate, 94, varying in color from a yellow to a deep green, the lighter colors usually indicating the presence of arsenic; *stolzite*, 95, tungstate of lead; *vanadinite*, 96, a vanadate; *wulfenite*, 96, the molybdate, of which there are several fine specimens in the cabinet, one small specimen vanadinous, 275, and some others. The last three enumerated are quite rare, and have acids formed of metallic oxides.

Of the many useful ways in which lead is employed it seems almost superfluous to speak. For many purposes in the household, where it was formerly used, its alloys of pewter or others are now employed. It is still used for covering roofs, lining cisterns and baths, and above all for lead pipes, owing to its durability, tenacity, and flexibility. Such pipes are readily corroded by pure water, such as cistern or rain water. Well or river water, on the other hand, usually holding carbonates or sulphates in solution, deposits on the inner surface

a layer of carbonate or sulphate of lead, which being absolutely insoluble, prevents the lead from doing any injury. There is another interesting commercial application of lead, known as the making of shot. An alloy with arsenic is first made, which in a melted state is passed through a perforated skimmer and allowed to fall from a great height in a shot-tower into water below. This allows the globules in their passage through the air to cool thoroughly. If they do not round off well, a little arsenic is added and the process is repeated.

Zinc is another exceedingly valuable metal. Its ores are: 1. *Zincite*, or red zinc-ore, an oxide of zinc, the red color of which, in the opinion of Dana, is due to manganese, an unessential ingredient, 90 and 91. There are two very pretty specimens of zinc oxide in 90, 1056 and 1057. 2. *Blende*, sulphuret, the black-jack of English miners, 91. It is usually called sphalerite, and crystallizes in the garnet dodecahedron; 3. *Prismatic or electric calamine*, a silicate, pearly in character; and, 4. *Rhomboidal or sparry calamine*, smithsonite, a carbonate in botryoidal or stalactitic shapes, with generally a rough surface. There are a number of interesting smithsonites in section 90, including pseudomorphs after other minerals, for which I am indebted to William T. Henry, Esq., the mine-owner at Mineral Point; also some very fine crystallized calamines in 89, which I owe to the liberality of Professor Leeds. There is also a very large specimen of the latter on the mantel.

The above are the principal ores from which the zinc is obtained; but there are other zinc minerals, such as the franklinite, willemite, etc., 91, 1178, and 46, 348.

Apart from its use in alloys, already spoken of, zinc is used extensively for lining water-cisterns and baths, for spouts, pipes and plates for the zincographer, for voltaic battery plates, for the covering of roofs, and for architectural ornamentations, such as house-cornices, in the place of wood or stone, as being much lighter. It possesses, however, one disadvantage in case of fire, viz., that at a little over 700°, when in contact with air, it burns with a brilliant, bluish-white flame. This is a disadvantage in relation to the last two uses named. Its filings are used in the manufacture of fire-works. The purified white ox-

ide of zinc makes a far better white paint than carbonate of lead, retaining its color, while the latter is apt to turn yellow from contact with sulphurous fumes in the atmosphere. Painters object to its use, because it is somewhat more expensive. Finally, zinc is also of much value for medicinal purposes.

Arsenic, though not actually classed with the metals, may with propriety be alluded to here. It is often mingled with antimony and traces of other metals, as iron, silver, or bismuth, when found native, 84, 1067. *Arsenolite*, 84, 283, is an oxide of arsenic sometimes found in small stalactitic form. The principal ores are the red and yellow sulphurets, *realgar* and *orpiment*. Much is obtained from other ores, more particularly those of cobalt.

Common arsenic is a powerful poison when taken in any quantity, although a valuable remedy in medicine in minute doses. Even in medicinal doses its effects must be closely watched, as they are apt to be cumulative; that is to say, to accumulate in the system until poisonous effects are produced; yet, strange to say, there are people in Styria and Lower Austria who, commencing arsenic-eating early in life, become so habituated to its use as to consume it in considerable quantities, with the effect of adding to their strength and vigor. In cases of poisoning, the viscera containing it have been found in a perfect state of preservation months, even years, after. At the same time it can be detected by the chemist in less than one ten-thousandth of a grain. Thus, while from its cheapness and tastelessness it has formerly been sometimes used for criminal purposes, it is fortunately one of the most readily detected poisons, alike from the peculiar symptoms it produces, and from the ease with which its presence is ascertained. There seems to be a certain volatility in arsenical salts, and serious effects have resulted from the use of green wall-papers in which arsenical preparations have been used as a coloring agent.

To the taxidermist it is invaluable, owing to its peculiar preserving powers, and he largely avails himself of these in preparing stuffed animals and birds for our museums.

Of the two following metals, cobalt and nickel, I have not much to say.

Cobalt is largely associated with arsenic—indeed, in the only two principal ores of it we have; viz., *cobaltite*, or cobalt-glance, of which there are very nice specimens in 88, is an arsenical sulphuret; and *erythrite*, or cobalt-bloom, 88, 337, is an arseniate. The prismatic red cobalt, 88, 338, is very beautiful.

Cobalt is used in the painting of porcelain and in the manufacture of blue glass. It is often associated with other minerals in a minor quantity. The same may be said of

Nickel, but the special ores of this mineral are also mainly combinations with arsenic or sulphur, or both; thus we have: 1. *Nickelite*, or Kupfernichel, so called from its color, but in reality consisting of 56·4 of arsenic and 43·6 of nickel. 2. *Milnerite*, a sulphuret (see capillary pyrites), 86, 855; and, 3. *Gersdorffite*, an arsenical sulphuret.

Smaltite consists mainly of arsenic, as Dana says, having, when of the typical kind, about 72 of arsenic and 9 each of cobalt, nickel, and iron. The smaltite proper, however, has little iron or nickel and more cobalt, while the variety called *chloanthite*, 87, 555, is mainly nickeliferous, having more nickel and less cobalt. There is a third variety in which the iron preponderates over the cobalt and nickel, called *safflorite*.

The greatest value of nickel is as an ingredient of German-silver; indeed, it is the principal one. To some extent it has been used also for minor coinage.

Manganese, the next metal of which I have to speak, is of some importance in the arts and in chemistry. It enters into the composition of numerous other mineral substances, as well as being the principal metal in the following ores: 1. *Manganite*, 82, 324, a hydrated sesquioxide. 2. *Hausmannite*, a brownish-black deutoxide. 3. *Wad*, or bog-manganese, 81, 323, a name given to the hydrated peroxide, mixed more or less with other oxides, consequently having no definite composition, and found in masses, also in various imitative shapes, or as a coating on other minerals. 4. *Psilomelane*, 82, 325, or fibrous wad, or deutoxide with peroxide and some baryta. 5. *Pyrolusite*, 82, 321, of which *polianite*, 82, 322, is a variety, is a deutoxide, and one of its most common and valuable ores. It is also called the gray oxide. 6. *Braunite*, a silicate. 7. *Diallogite*,

called also rhodocroisite, 81, 840, is a sulphuret. It will be seen that the oxides preponderate.

Manganese is used in the manufacture of flint-glass, in calico-printing, and in making the black enamel of pottery, etc. It is also one of the best materials from which to obtain oxygen gas. By mixing strong sulphuric acid with the peroxide, the latter is converted into a protoxide, which unites with the acid to form a sulphate, while the surplus oxygen passes off, and may be collected.

Iron, of all the metals one of the most beneficent gifts of God to man, is the last I shall speak of. As it is one of the most useful, so is it also one of the most abundant, especially in Great Britain and the United States, to the prosperity and growth of both of which countries it has contributed enormously. The ores of iron are numerous, but with a few exceptions are not very attractive objects in the mineral cabinet.

Owing to the tendency iron has to oxidize, we do not find it in a metallic state, except in those mysterious objects the meteorites, which do not seem to belong to our sphere. They contain iron and nickel in a metallic state, the latter more or less crystalline, and olivine, a volcanic product; occasionally also other materials. In the cabinet there is a very beautiful specimen of *meteoric iron*, 78, 1082. It weighs about three pounds thirteen ounces, being about one fifth or one sixth of the whole mass found by Indians in the desert of Meyellanos. The imbedded olivine is seen in rectangular lines, showing crystallization (prisms). The slender crystals, like small hairs, and the minute tuft on the broken portion, best seen with a glass, are the mineral *schreibersite*—phosphorus, iron, and nickel—found only in meteoric stones. There is another cut and polished piece of meteorite, 78, 286, showing on one side Wiedmannstaedt figures (lines of crystallization brought out by treating the specimen with strong acid). Although I have mentioned the meteorite here, it is not enumerated among the ores of iron, nor is it to be regarded as such. It is altogether an outsider. Of iron-ores we have: 1. *Magnetite*, or magnetic iron, a black oxide, 72, 73, and 74, consisting partly of protoxide and partly of sesquioxide, and containing about seventy-two per cent of metallic iron. It crystallizes in octahedrons and

dodecahedrons, and is one of the most valuable ores. It is found abundantly in the United States. 2. *Hematite*, a sesquioxide. This includes several varieties, among them the brilliant specular iron of which we have some very beautiful specimens in 78, the red-ochreous iron, clay iron-stone, and others. 3. *Limonite*, 73 to 76, a hydrous sesquioxide, sometimes compact, sometimes botryoidal. It includes also bog-ore, yellow ochre, 80, 617, brown clay, iron-stone, etc. The last two ores, viz., hematite and limonite, are both very valuable ores. 4. *Titaniferous* (or iron) *sand*, which is magnetic. 5. *Ilmenite*, or *menaccanite*, 79, 302, and 1011, a rare mineral, consisting of the oxides of iron and titanium, with a little magnesia and manganese. 6. *Mispickel*, or arsenical iron, of which we have some fine specimens in 79. This is a very pretty mineral. 7. *White* and *yellow sulphurets*, the former called *marcasite*, fibrous or radiated, the other *pyrite*, of which the commonest form of crystallization is the cube; but there is great variety in this respect. Of these too we have a variety of exceedingly beautiful specimens in 77 and 78. In gold countries pyrite is often associated with gold and worked for it. Both varieties are employed to obtain sulphur, sulphuric acid, and sulphate of iron. *Marcasite*, I may observe, is one of the meanest of cabinet minerals, inasmuch as it is apt to disintegrate when in contact with atmospheric air. Two really handsome specimens of other minerals in the cabinet have gone to pieces in consequence of association with it. 8. *Goethite*, or brown hematite, 80, called also *needle iron-stone* or *wood-iron*, from its fibrous or acicular character. Sometimes it is stalactitic. It is a hydrous sesquioxide. 9. *Siderite*, *spathic iron*, 76 and 77, a carbonate. 10. *Vivianite*, 80, 319, 755, phosphate of iron, rare. 11. *Chromite*, 77, 1015, chromic iron. 12. *Copiapite*, 80, 318, or *yellow copperas*, sulphate of the sesquioxide of iron, also a very rare mineral; and, lastly, 13. *Humboldtine*, an oxalate of the protoxide, also rare, and, like several of those enumerated, not a working ore. In the west of England, where the manufacture of iron has long been one of the great leading industries, the large beds of iron-ore are contiguous to others of coal and lime; thus the ore and the materials for smelting may be said to be together. The coal is apt to contain some sulphur, and it is exceedingly difficult to

separate the sulphur from the iron; on the other hand, the smallest quantity of the former associated with the latter makes it brittle and granular in structure, as we find it in common pig-iron. The pure iron, as we find it in the best Swedish iron, is charcoal-made, and is fibrous in texture. Its purity may be tested by bending double, without breaking, a bar, say an inch square, in a cold state. When this is done, the fibrous character is well shown.

Steel is a carburet of iron. Colange informs us that the best steel contains about one and a half per cent of carbon; when it has less than this, that it approaches in its properties to wrought-iron; while in proportion as it has more, it becomes more like pig-iron.

Iron furnishes us not only with the material of stoves and grates and cooking-utensils, of table cutlery and hard tools of every description, but, further utilized by the inventive genius of modern times, in the construction of machinery, it presides over the largest industries in the world, affording profitable employment to millions, cheapening articles of utility until they are brought into the homes of the poorest. Iron affords material for houses, as also for the largest ships, for the ponderous machinery which propels them, and for the needle of the compass by which their course is steered over the waste of waters; it gives us the common sewing-needle, and the Nasmyth hammer, so admirably balanced and controlled that, capable of striking with a ton force, it can equally be made to forge an eighty-ton gun or to barely crack an egg-shell; it affords the material for that inestimable article of domestic use the sewing-machine, as for the huge Corliss engine in the Pennsylvania Centennial Exhibition, which, controlled by a single lever, stopped or set in motion simultaneously a hundred or more different industries, all doing their work with a delicacy and precision, a rapidity and a uniformity, that could never be achieved by simple hand-labor. Dr. Ure thus sums up the merits of iron: "Every person knows the uses of this precious metal; it is capable of being cast in molds of every form; of being drawn out in wires of any desirable strength or fineness; of being extended in plates or sheets; of being bent in every direction; of being hardened, sharpened, or softened at pleas-

ure ; it accommodates itself to all our wants, desires, and even caprices ; it is equally serviceable to the arts, the sciences, to agriculture, and to war ; the same ore furnishes the sword, the plowshare, the scythe, the pruning-hook, the needle, the graver, the spring of a watch or of a carriage, the chisel and the chain, the anchor or the compass, the cannon or the bomb. It is a medicine of much power, and the only metal favorable to the human frame."

FIFTH TALK.

HAVING disposed of the principal metals, I shall next say a few words on the alkalies and earths, which are, however, as we have already learned, themselves oxides of metals, with the one exception of ammonia.

The *Alkalies* are the oxides of cæsium, rubidium, lithium, potassium, sodium, and the non-metallic ammonia. They are all characterized by strong alkaline and powerful electro-positive qualities, and possess many chemical properties in common, as regards solubility and the efflorescence or deliquescence of their corresponding salts. The carbonate and phosphate of lithia are of difficult solubility, and thus, as Bloxam observes, seem to constitute a link between the alkalies and the alkaline earths. Potash, soda, and ammonia are the only alkalies of sufficient importance to need mention here. They find few representatives in our mineral cabinets. The general solubility of their salts in water, the tendency of some to effloresce, parting with their water of crystallization when exposed to the atmosphere, and so losing their crystalline character; of others to deliquesce, thereby dissolving by absorption of water and so melting, prevent their being often found in nature, or, when found, make their preservation difficult. I have what was once a crystal of borax, or borate of soda, 10, 16, a beautiful one when it first came into my possession, translucent, greenish in color, and fine in shape, every plane and angle being perfect. I covered it with gum to preserve it; yet now, after long exposure, having effloresced, it is a swollen, shapeless, pulverulent mass, ready to fall to pieces with a touch. Borax must not be confounded with boracite, 26, 75, which is a borate of magne-

sia. Halite, NaCl , or common salt, in cubic crystals, if kept dry may be preserved, but if exposed to much dampness will deliquesce and spoil. There are large beds of halite in Prussia, in Nova Scotia, and some other localities; the larger portion of the salt of commerce, however, is obtained by evaporation from sea-water, or from salt-springs, such as those at Syracuse, in this State, or from salt-lakes. The quantity required is very large, it being not only one of the great necessities of life, both to man and beast, but from it most of the other salts of soda are obtained by chemical manufacturing processes, such as the carbonate of soda, the sulphate or Glauber's salt, etc. Some might say, Do not forget soda-water; but the name is a misnomer, this drink being ordinarily nothing more than water highly charged with carbonic-acid gas. This is done by decomposing carbonate of lime or marble-dust, by means of sulphuric acid, thereby forming a sulphate of lime, and liberating the carbonic-acid gas, which passing off is collected and forced into the water. Then what should we do without saltpeter, or nitrate of potash, to assist in salting down meats? How carry on blasting without the aid of gunpowder, of which it is an essential ingredient? Further, as it is said "cleanliness is next to godliness," how would the civilized world, without the aid of potash or soda, manage to obtain that very important article, soap?

The principles of soap-manufacture are very simple. When a solution of caustic potash or soda, alkaline lye as it is called, is boiled with oils or fats, a certain decomposition takes place, oleic and stearic acids resulting therefrom, and these in their turn, entering into combination with the alkali, form a saponaceous compound—soap, in fact. The lye may be prepared by boiling fresh hydrate of lime—made by slacking quicklime—with a solution of carbonate of soda or potash. The lime takes the carbonic acid from the alkali, forming an insoluble carbonate of lime which sinks to the bottom, while the supernatant lye may be drawn off. The fat or oil is boiled sometimes with successive portions of this lye, for three or four hours each time, until no more soap is formed, and the superfluous liquor after cooling is allowed to drain away below. By treating the residue with a strong solution of salt, with which the soap will

not dissolve, neutral soluble salts and any excess of lye will be taken up, while the soap floats to the surface and may be skimmed off. It may when cool be cut into cakes and allowed to dry and harden.

Soda-lye forms a hydrated soap, which takes up considerable water but hardens nevertheless, hence, makes hard soap. With potash-lye a more deliquescent material is formed, and the result is soft soap. These are the simplest forms, but, as there are a great many varieties, of course the processes will vary accordingly; the general principles, however, are the same. We hardly realize what a blessing soap is to us until we happen to be placed in circumstances where we are deprived of it for a length of time.

I have, I think, mentioned the fact that beds of nitre are formed; the principal supply of potash, however, is derived from wood-ashes. Plants contain a large amount of potash; hence, when the former are burned, a considerable part of the ash consists of the latter. By lixiviation and evaporation we obtain a carbonate of potassa with some sulphate—the common potash of commerce. By further purification it becomes pearlsh.

The *Alkaline Earths* constitute the next group, and are equally well defined. Bloxam, in summing up their qualities, says: "Barium, strontium, calcium, and magnesium, form a highly interesting natural group of metals, related to each other in a remarkable manner. They exhibit a marked gradation in their attraction for oxygen. The first three decompose water at the ordinary temperature, uniting with the oxygen and liberating the hydrogen, but magnesium requires the aid of heat to effect this decomposition. The oxides of the metals exhibit a similar gradation in properties: baryta, strontia, and lime combine with water very energetically, with great evolution of heat, while in the case of magnesia no rise of temperature is observed. The hydrate of baryta does not lose its water, however strongly it may be heated, whereas the hydrates of strontia and lime are decomposed at a red heat, and hydrate of magnesia at a lower temperature even. The hydrate of baryta and hydrate of strontia are far more soluble than hydrate of lime, which requires seven hundred parts of water to dissolve it, but

hydrate of magnesia requires three thousand parts of water to dissolve it, and is so feebly alkaline that it might even be fairly classed among the earths proper. The sulphates of the four metals present a gradation of a similar description, that of baryta being almost absolutely insoluble, that of strontia soluble to a slight extent, sulphate of lime somewhat more so, and the sulphate of magnesia readily soluble, a property in which it again approaches the earths proper, the sulphates of which are remarkably soluble in water. The manner in which these metals are associated in nature is also not without significance; for, if two of them are found in the same mineral, they will be usually those which stand next to each other in the group; thus, carbonate of strontia is found with carbonate of baryta in Witherite, 8, 806, while carbonate of lime is associated with sulphate of strontia in celestine, 8 and 9. Again, carbonate of strontia is often found with carbonate of lime in aragonite, 19, and the carbonate of lime occurs with the carbonate of magnesia in dolomite, 18." I have quoted thus extensively from Bloxam, as this is a very interesting matter. Somewhat similar affinities and graduation of properties may be observed among some of the true metals.

While the sulphates and carbonates of the alkalies are all perishable, those of the alkaline earths, with the exception of sulphate of magnesia, from their insolubility and resistance to ordinary external influences, furnish a great variety of choice specimens for the mineralogical cabinet. Witness the wonderful variety of form in the crystallized calcites, 14 to 17, the graceful and often fantastic stalactites, 13, the various richly colored marbles, 11, all carbonate of lime; gypsum, 20 and 21, satin-spar, and alabaster, sulphate of lime; apatite, 21 and 22, and phosphate of lime, so valuable as a fertilizer. Then we have mixed carbonates in the dolomites, 18, and aragonites, 19; brucite, 9, native magnesia; and the carbonates and sulphates of barytes and strontian already alluded to. These alkaline earths have their uses in the arts and manufactures, especially lime and magnesia, but time will not allow us to dwell upon them.

The *Earths* proper are the oxides of aluminum, glucinum, yttrium, thorium, zirconium, erbium, terbium, cerium, lan-

thanum, and didymium. Of these the only one of any importance is the oxide of aluminum, or alumina.

I have on a former occasion, in speaking of argillaceous or aluminous rocks, adverted to the great abundance of alumina in combination with silica, forming as it does a very large portion of the primary rocks; also as a material element of clay or aluminous earth, to the peculiar properties of which I have also alluded, especially in relation to the potter's art. I shall now speak more particularly of clay.

Clay, then, consists essentially of silica and alumina sometimes tinged with iron; lime and magnesia with other coloring oxide are generally present. Clays are readily diffusible through water and capable of being formed into a plastic, ductile mass, which may be kneaded into any shape by hand. This plasticity is not equal, however, in all clays. They congregate into a hard mass when dried, and assume upon exposure to ignition a hardness sometimes sufficient to give sparks with steel. Under such circumstances they lose their plasticity, even when pulverized. Tolerably pure clays, though infusible in the furnace, readily become so when mixed with lime, iron, manganese, etc. All clays, however free from moisture previously, shrink in the fire, owing to the reciprocal affinity of their particles for each other, and hence crack and split, but will remain solid if intimately mixed with some equally durable material not liable to contract. The above qualities of clay render them peculiarly adapted to the manufacture of ceramics. Clays, moreover, when dry, absorb water, produce a peculiarly styptic effect upon the tongue, and have often when impure a disagreeable odor. Ure divides the clays into—

1. *Fire-Clays*, found in greatest abundance in slate-clay. Such are used in making fire-bricks.

2. *Common Clay*, or *Loam*, an impure ochreous clay with some iron and sometimes mica. It is used for making bricks, tiles, and coarse earthenware.

3. *Potter's Clay*, plastic clay, or pipe-clay, compact, soft, and unctuous. If gray at first, it becomes white in the porcelain-kiln.

4. *Porcelain Clay*, or *Kaolin*. This consists of silica and alumina in nearly equal proportions. It is derived from the

decomposition of the feldspars, granites, and principally those rocks of feldspar and quartz called graphic granite.

Ceramics include pottery of every kind, from the coarsest earthenware up to the finest porcelain, and, wide apart as these two appear, they approach each other so gradually through the different forms of stone-ware, biscuit, faïence, etc., that it would be difficult to draw an exact line of demarkation between pottery and porcelain. The manufacture of ceramics, in one form or other, has been understood from the most primitive times.

You are all no doubt familiar with ancient Egyptian earthenware vessels in museums, as old as or older than the pyramids, and those beautiful brown and black Etruscan vases of a later period; and you have seen at home or among your friends those dainty little real china cups or china dishes that have been treasured, perhaps, in the family for a century or two. Perhaps you have even come across one of those rare antique china vases of a peculiar blue, and of fabulous value, the art of coloring which was lost centuries ago, for the manufacture of chinese porcelain antedates our modern European civilization, going even beyond the commencement of the Christian era. How many things of utility and beauty are embraced in the terms earthenware, crockery, and china, including as they do a very large proportion of necessary, or at least highly desirable and convenient articles, and yet how apparently worthless the materials from which all their varieties are primarily produced—clay decomposed, rotten feldspar, ground flint, ashes, and similar substances!

In England, up to the middle of the last century, common white or brown glazed stone-ware alone was manufactured, finer qualities being imported. In 1763, however, the largest English manufacturer of his day, Josiah Wedgwood, produced the celebrated ware named after him. It is said that traveling on horseback, as was common in those days, his horse hurt his foot, and he stopped at a blacksmith's shop to have it attended to. The blacksmith took some flint, burned it in the forge, and ground it to the consistency of powder. The beautiful, white, siliceous material immediately arrested the attention of the manufacturer, and he commenced experimenting with it,

with the result of producing a species of pottery that has since borne his name. This material is now largely employed in all the higher branches of the art. From that time the manufacture of fine stone-ware and porcelain in England has been a large and increasing industry, and already begins to rival that of the most celebrated foreign establishments.

Stone-ware consists of an infusible mixture of earths, which is refractory in the kiln, continuing opaque, and comprises common earthenware, delft, ironstone china, faïence, etc.; while porcelain consists of a fusible earthy mixture with an infusible, which, when combined, become semi-vitrified and translucent in the kiln.

In the manufacture of stone-ware the clay, having had stone and similar impurities removed as far as possible, is worked and ground down to the consistence of a smooth, creamy paste, the coarser particles, which are subsequently ground again, being removed by passing the mixture through fine sieves. Flint powder is treated in the same way. To obtain this, flint, which is extensively found in nodules in the chalk-beds, is calcined in the furnace and thrown while hot into water, which makes it very brittle, and in this state it may be readily ground. For the coarser kinds of earthenware, fine sand or ground ashes are sometimes used in the place of flint. Then the flinty mixture, being reduced to the same smooth, creamy consistence as the clay, the two are mixed together, and the water is allowed to evaporate until the mass acquires the consistence of dough. This is cut into lumps, piled in heaps, and allowed to remain for some months in damp cellars. Here disintegration of the argillaceous and siliceous particles occurs, apparently by a sort of fermentative process, and the material made from the paste so resulting is found to be finer grained, more homogeneous, and less liable to crack, than that made from the fresh admixture. Such is the stone-ware paste, which is now ready for throwing, as it is called, or turning on the lathe, molding into various forms, and baking into stone-ware.

Porcelain is of two kinds—hard and tender.

Hard porcelain consists essentially, says Ure: “First, of a natural clay containing some silica, infusible, and retaining its whiteness at a great heat—such a clay is kaolin; and, second-

ly, of a flux consisting of silica and lime, such as the Cornish stone, or Pe-tunt-se of the Chinese, a disintegrated feldspar. With these materials the first processes are much the same as those for making stone-ware."

Tender porcelain, though made on similar principles, requires a longer and more delicate process. A vitreous frit, as it is called, is first prepared. This is made at Sèvres with niter, a little sea-salt, barilla, alum, gypsum, and much sand or ground flint. The mixture is subjected to an incipient, pasty fusion in a furnace, where it is stirred to blend the materials well, and thus a white, spongy mass is obtained. This is pulverized, and to every three parts of it one of the white marl of Argenteuil (a peculiarly fine clay) is added, and when the whole are well ground together, the paste of tender porcelain is formed. It is less cohesive and firm than the other pastes, and will not retain its shape in the furnace unsupported by molds; even then it will sometimes curl or crack, and so the whole process is rendered more difficult and expensive. Ure says that some advantages are claimed for this kind of porcelain in the matter of painting, and "that it may be made so gaudy and brilliant in its decoration as to captivate the vulgar eye." He further says: "It is always yellow and more transparent, at the same time more incapable of bearing rapid transitions of temperature, so that the heat even of boiling water will frequently crack it." Servants, I should say, will be found capable of breaking enough, without providing articles that will break of themselves. Such, then, are the materials, such the essential processes, in the manufacture of earthenware and china. Of course, numerous others are required for painting, glazing, gilding, and decorating, but these lie beyond our present scope. When we consider the fire-brick necessary for our stoves and furnaces and grates, or the millions of brick of various kinds annually turned out for building purposes, it must be conceded that even despised clay should be reckoned among the truly valuable aids to the comfort of human existence.

I have already spoken of silica as performing the part of an acid, and combining only with other bases to form silicates; thus we have no such thing as a carbonate or sulphate or ni-

trate of silica, but we have silicates of lime, potash, alumina, iron, and other bases. I have spoken also of the great variety and numerous subdivisions of the siliceous minerals.

Now there is another important class of manufactures, which comes appropriately under the immediate head of silica. While silica in the production of ceramic wares plays an important though secondary part, in the manufacture of glass-ware it takes the leading place, from the property it possesses of fusing with various alkaline bases into the different kinds of transparent material which we call glass. Very comfortless our homes would be without it. A knowledge of this material is also of very ancient date, the Egyptians having been acquainted with it. In ancient Tyre it is said by Pliny to have been a staple manufacture, houses even being built of it. It was known to the Romans, windows having been made of it in Pompeii. I do not recollect reading, however, that the belles of that day enjoyed the pleasure of seeing themselves reflected in glass mirrors, polished metal being the substitute; but I may be wrong. It was first imported into England for windows in 1177, in the reign of Henry II. Among the rudest peoples a hut with a hole at the top to let out smoke, and an open space in the side, or an only partially closed doorway, afford the only means of admitting light. In some of the semi-barbarous civilizations of the present day, as in Persia, we learn from the modern tour of Arthur Arnold that, in the majority of houses, there is only a blank wall adjacent to the street, with an arched entrance into an inner court-yard, toward which the rooms with unglazed windows and ill-fitting doors open; and where it became necessary, in the severely cold weather, to shelter himself from the biting air, he was compelled to cover every aperture with all the rugs and carpet he could muster, of course at the expense of light. No one, who has experienced an approach even to such a mode of life, can fail to appreciate the blessing we enjoy in our glass windows, which, while they protect us from winds and storms, and from entrance of chilling airs, allow the full light of day to stream through every part of our dwellings. Then, again, with how many articles of comfort and luxury does this same material supply us, from the readiness with which when fused it may

be blown or cast into any desired form, as well as from its hardness, durability, cleanliness, and capability of resisting ordinary external influences, when once converted into one or other of the many valuable articles of utility made of it?

The manufacture of glass is simple enough, consisting only, as I said before, of the fusion of silica with an alkali or earth, other materials being occasionally added, thus:

Common window-glass consists of silica fused with lime and soda; *Bohemian* or *crown-glass*, of silica with lime and potash; *bottle-glass*, a mixture of silica with soda, lime, alumina and iron; *crystal-glass*, of silica with potash and lead; *strap*, the material of factitious gems, the same but richer in lead, the desired colors being given by various metallic admixtures; *enamel* consists of a silicate and stannate (or antimonate) of potash or soda and lead.

All these are prepared by fusion of the other materials with silica or sand, resulting in the formation of vitreous silicates. There is one other vitreous silicate to which I shall especially allude, viz., the *soluble glass* or silicate of soda, a material of considerable interest, if only on account of Pettenkoffer's valuable discovery, namely, that of protecting inflammable substances by a coating of it from the action of fire. It is not very long since one of the Brooklyn theatres was burnt, with a fearful destruction of human life. From the first alarm, the whole work of death was done in half an hour or less. The quantity of canvass, paint, and varnish of the scenery, with their light frame-work, as well as the inflammable character of the light materials of which the general decorations and roofs of theatres are usually made, aided by strong draughts of air on the more open stage, cause a fire once enkindled to spread with great rapidity. The occurrence of accidents of this kind, from time to time, aroused the attention of the European Governments, and Pettenkoffer was commissioned to find a remedy. Now the salts of soda are all more or less highly soluble, and the silicate of soda, of which soluble glass consists, forms no exception. He found that by coating scenery or other light materials with this transparent substance, laid on in solution and allowed to dry, they could thereby resist the action of fire. A weak solution is employed first to make a groundwork, and

afterward a more concentrated one. Experiments have been tried in New York with entire success, and this will, no doubt, in a variety of ways, prove to be a valuable discovery, the bounds of which will be widely extended. A solution of tungstate of soda, it is said, which possesses the same property, may be applied more advantageously to textile fabrics for the same purpose.

SIXTH TALK.

HAVING now run over a few of the most important uses of the metallic compounds, I shall conclude with some remarks on the value to man of some of the non-metallic, of which, however, sulphur and carbon, with the hydrocarbons, will alone claim our attention.

Sulphur enters into combination with numerous metals to form sulphides or sulphurets, or, in combination with oxygen, constituting sulphuric acid, it unites with oxides of metals as sulphates. The sulphurets include some of the most valuable ores, both sulphur and metal being obtained from them. Many of them are very beautiful objects in the mineral cabinet, such as peacock-copper, 118; the petanque, 102, 416; some of the iron pyrites, 78, especially the rich and varied mixed pyrites of Colorado and other gold countries, 97 and 98, or the brilliant argentiferous galenas, 102. Sulphur, 3, is also found native in the vicinity of some volcanoes, notably at Girghenti in Sicily, whence the finest crystals are obtained, often with celestite; also in minute crystals at Solfatara; in the vicinity of hot springs in California, Nevada, the Chilian Andes, and other volcanic localities; indeed, in the common mind it is often associated with visions of a very hot place, where we would hardly wish to go to collect it.

Sulphur is used in the manufacture of cinnabar or vermilion, of gunpowder, and of sulphuric acid or oil of vitriol, a material of considerable value in chemistry and the arts. It is also employed in the process of hardening vulcanized rubber, which furnishes so many useful articles. The sulphurous acid produced by its combustion in the atmosphere, in addition to

being useful in many ways in the arts, is employed in the destruction of noxious insects, says Ure ; and he says, moreover, "that from its property of checking and destroying flame, a handful of sulphur thrown on the fire is often sufficient to quench a burning chimney." Such practical facts are worth recording.

Carbon is a far more important element, being one of the essential elements of all organic substances. When from these latter the other essential elements are withdrawn, the residue is charcoal, with which all are familiar.

In nature, the purest free carbon is the *diamond* ; in a less pure, mostly uncrystalline form, we have it in *graphite* or *plumbago*, 4 ; and, in a more mixed condition, it occurs in large beds in the form of coal. Carbon, combined with oxygen, unites with various oxides to form a large class of mineral carbonates.

It is to that inestimable blessing to the human race, *coal*, with a few words subsequently on coal-oil and gas, that I shall now direct your attention. Turn in imagination back to England, as she was six or seven centuries ago, and compare her with the England of the present day. Then it was a land well covered with forests and woods, interspersed with cleared patches ; exhibiting now and then a more widely cultivated district, with the tall spires of an abbey, convent, or town in the midst of it, varying occasionally with the embattled mansion or castle of some feudal noble.

The towns were few, at any rate comparatively small, and a middle class could scarcely be said to exist. By degrees, as the population increased, towns grew more populous, to supply which more land was required for farming purposes, and forests began to diminish and slowly disappear. Let us suppose that things had gone on thus up to the present time, and how would it be with her now ? Her boundaries are limited by the sea and can not be enlarged ; her forests would long ere this have been exhausted, her mineral resources have remained largely undeveloped, her wealth, her manufactures, marine and commerce comparatively small. She relies even now for building purposes, to some extent, on foreign timber ; then she must have done so even for a sufficient supply of fuel, while much

of her metallic ore must have been exported for smelting. She might at most have filled the position of a thriving and industrious nation, though, perhaps, owing to her isolated position, somewhat behind her continental neighbors in advancement. But she was to fill a much larger niche than this in modern history, and the means for developing her energies to the utmost lay from the first hidden beneath her own soil, bountifully provided for use whenever her necessities should call them forth. Coal has been a mighty factor in the development of England's commanding position. This, we are told, was first discovered at Newcastle-upon-Tyne, in or about A. D. 1234. Its gradual introduction into use was slow, and in 1273 the use of sea-coal was prohibited in or near London as being prejudicial to human health. A century later, however, viz., in 1381, coals were made an article of commerce from Newcastle to London, and by the commencement of the following century began to be generally burned in London. The consumption now in England is said to be about 25,000,000 tons annually. In the United States, Lehigh coal from Mauch Chunk, in Pennsylvania, was first mined and used in 1806; and in 1870 there were mined in the United States, of anthracite 20,654,500 tons, of bituminous coal 26,031,726 tons, or in all 46,686,235 tons. These figures will perhaps give the best idea of the importance of coal for manufacturing, domestic, and other purposes.

We may next inquire how it is found and what it is. The coal-measures, as they are called, are found between the conglomerate (or transition) and secondary series. They are in basin form, and alternate with parallel beds of sandstone, slate, clay ironstone, and occasionally limestone. Some geologists have called these a medial formation. The coal-beds are of immense extent, and often of great thickness. To give some idea of the supply of this truly valuable material stored up in the bowels of the earth, it may be stated that the coal-fields of Durham and Northumberland extend over an area of 723 square miles. Those of Newcastle, Sunderland, Whitehaven, and other places, are also of vast magnitude, and there are exhaustless beds of coal in Yorkshire. That in South Wales alone would, at the present rate of consumption in England,

supply the country for two thousand years. I quote from Putnam's "Dates." The whole area includes many thousand square miles. In the United States, according to Lyell, the coal strata in Pennsylvania and Ohio, etc., extend 700 miles. Add other extensive fields, and according to Dana the workable area may be estimated at 125,000 square miles. There are also extensive beds in Nova Scotia, estimated at 18,000 more. To all those enumerated may be added large coal-fields actively worked in Belgium, France, Rhenish Prussia, Silesia, Bohemia, Russia, and Spain. It will be seen how little chance there is of the failure of this material, which, were it only used for domestic fuel, must be regarded as one of the richest gifts of the Almighty to mankind, from the occupant of the palace to the tenant of the hovel.

And what is coal—so different in its composition and qualities from ordinary mineral substances? It is simply a result of the alteration of vegetable matter, associated with some mineral substances, which constitute the ash. Dana says of it, "that it is made up of different kinds of hydrocarbons (of which I shall speak presently), with perhaps some free carbon, at any rate carbon in excess." He further says that, "in distillation most kinds afford more or less oily and tarry substances, which are mixtures of hydrocarbons and paraffine." As we shall see, they are just such compounds as are afforded by the destructive distillation of wood. On analyzing coal, it is found to consist of carbon, hydrogen, nitrogen, and oxygen, with some mineral ash and a little sulphur, and it will be seen that the essential elements are precisely those which constitute animal and vegetable, in other words, organic tissues. In fact, coal consists of huge buried forests, partly decomposed, at the same time compressed, solidified, and altered by superincumbent pressure and heat into the condition in which we find them as coal. This may be demonstrated by the fact that we can follow its formation from the fibrous vegetable peat almost to the solid coal; further, that in the shale associated with the coal we have often distinct and beautiful impressions of leaves and stems, sometimes even in the coal itself; and lastly, in the coal we find often the appearance of wood still retained. In the fibrous peat, 1, 448, we have disintegrated wood, somewhat

changed, yet still possessing the entire appearance of woody fiber. We find it on the surface of peat-beds. As we go down deeper we find it more and more compressed into a solid mass, 1, 453. In the artificially compressed peat, 1, 454, representing an immense pressure, we have it entirely solid. Now compare this with lignite (or brown coal), 1, 433, the latest of coal formations, and you will see how closely they resemble each other. But the process does not end here. I have already observed that the coal is found between the conglomerate and secondary series. It is, therefore, not only deeply buried, and under great superficial pressure, but the woody fiber has been subjected to considerable heat, corresponding with a partial destructive distillation when carried on at the surface, and so the entire surface becomes changed, and we have as a result bituminous or non-bituminous coals, mixtures of hydrocarbons, in which the woody appearance sometimes remains unobliterated, while in the shales immediately adjacent we have the impressions, made while they were yet soft, of leaves and stems of ferns and other genera. We have, further, other hydrocarbons, distilled off from the woody elements of coal in its conversion, such as petroleum, mineral rubber, and the like, also closely resembling in their elements the hydrocarbons procured by ordinary destructive distillation of wood. Cannel coal is the most highly bituminous variety. Of this, *jet*, so much used for ornamental purposes, is a harder variety.

The *hydrocarbons* are, as the name implies, compounds of carbon and hydrogen, in various proportions, mixed with more or less of impurities. Some are oxygenated, that is, contain oxygen, others not. The latter, the simple hydrocarbons, are the more numerous. They are all of ligneous origin, and, as before observed, very similar in composition to some of the products of the destructive distillation of wood. Indeed, the paraffine yielded by the latter, and the paraffine contained in crude petroleum, are identical. Coal-tar and wood-tar are very similar, not differing more than might be expected from the difference of the conditions under which they are produced. There is a curious mineral belonging to this group of which I once had a specimen, namely, the *mineral rubber* or *elaterite*, found in considerable quantity at Castleton, in Derbyshire,

England, and closely resembling ordinary vegetable rubber. It has much the same appearance, is like it quite flexible and elastic, burns like it, and with a similar smell. The specimen we possess, 2, 1,317, is not quite so characteristic. The hydrocarbons, as stated, are divided into the simple hydrocarbons and the oxygenated.

The simple hydrocarbons, or compounds of hydrogen and carbon, only include—

1. The *Marsh-Gas Series*. Bloxam states that “this is found wherever vegetable decomposition takes place in presence of moisture; hence we find it bubbling up in conjunction with carbonic acid from stagnant pools.” These gases, he farther says, are just what might be expected to be given off in the process of conversion of wood into coal. Such, in fact, is the terrible *fire-damp* of the miners, which, issuing from the crevices between the coal-layers, becomes very explosive when mingled with a certain quantity of atmospheric air, and leads to the catastrophes we occasionally read of. The result of the combustion is carbonic acid, known by miners as *after-damp*, and almost as fatal in its effects as the former. The *petroleum*, or mineral oil, belongs to this series.

2. The *Olefant Series*, including mineral-tar and the waxy paraffine.

3. The *Camphene Series*.

4. The *Benzole Series*, known as benzine when purified.

5. The *Napthaline Series*, of which *idrialite* is a variety, 3, 499. This, though crystalline in a pure state and white, is only found in an impure condition, mixed with cinnabar, and from its combustibility is called inflammable quicksilver. It is a brownish-black earthy mineral, containing mercury, with generally some clay, pyrite, and gypsum, from the quicksilver mines of Idria, in Austria.

The oxygenated hydrocarbon compounds are mostly found in the brown-coal deposits. *Amber*, 1, 1,209, or succinite, comes under this class, being evidently a fossilized resin found nearer the surface. This may be seen by the insects which we often find entangled and inclosed within it. The acid oxygenated hydrocarbons find a representative in bog-butter.

Lastly, I may mention *asphaltum*, or mineral-pitch, a mixt-

ure of hydrocarbons, which seems to hold an intermediate position between them and coal, 3, 431.

At the commencement of the present century the streets of London and Paris—New York was not then of much account comparatively—were so poorly and dimly lighted with oil that it scarcely served to make darkness visible. Up to that period, although gas had begun to be experimentally tried, whale-oil and other fish-oils, together with wax or tallow candles, according to the means of the consumer, afforded the only methods of lighting streets and houses. As the energy with which the whale-fishery was prosecuted began to make the fish more scarce, and consequently the oil more expensive, the resources of chemistry were called in, and various other expressed or manufactured oils, such as lard-oil, etc., came into use. At the same time paraffine, stearine, and similar candles were introduced as a substitute for the more expensive wax. But a great revolution was at hand in the matter of lighting.

Coal-gas was first evolved from coal by Dr. Clayton in 1739. It was tried for the purposes of illumination by Mr. Murdoch in Cornwall in 1792. The first display of gas-lights was made at Boulton and Watts foundry, in Birmingham, in 1802. It was permanently used, to the exclusion of lamps and candles, in the cotton mills of Phillips and Lee, of Manchester, where 1,000 burners were lighted, in 1805. Gas-lamps were not in general use in London until about 1814, although individual districts had enjoyed the benefit of it experimentally. Such were some of the most important proceedings attending the discovery and introduction of coal-gas as a lighting material. Its use to-day is uncommon in private dwellings in England, although almost universal in the better class of city houses in the United States. It is not without some disadvantages as to houses, but as to streets and factories, in no country in the world are these better lighted than in England.

Coal-gas consists essentially of light carburetted hydrogen (marsh-gas), of heavy bicarburetted hydrogen (olefiant gas), free hydrogen, carbonic oxide, and some other matters. It is made by the destructive distillation of the more highly bituminous coals in retorts heated to a cherry-red heat, and kept at the same during the distilling process, seven or eight hours.

In addition to the coal-gas, carbonic acid, tar, and various refuse hydrocarbons pass over, and are separated, the carbonic acid and sulphur by being passed through lime, the others by deposition. In coal there is always a little sulphur; accordingly, more or less sulphuretted hydrogen and bisulphide of carbon are apt to be generated with the gas during the process, and are exceedingly difficult to be entirely got rid of. If these remain, and they do often to some extent, as impurities in the gas, they are converted by combustion into sulphurous acid, which is not only injurious to respiration, but quickly tarnishes silverware, and acts detrimentally upon articles of furniture, pictures, etc.

Chemistry, some fifty years ago, was beginning to make rapid strides in its application to the purposes of our daily life, and camphene and naphtha were introduced, by which domestic illumination was improved, still farther cheapened, and brought within reach of all but the poorest. I can remember when the farthing rush-light and common tallow dips were in vogue among the last mentioned, and supplied about as dreary a light in their dwellings as the old oil-lamps gave in the streets. But the revolution was to be completed, and the poor also supplied. Be it remembered that the paraffine, camphene, naphtha, etc., were all hydrocarbons, differing only in the proportions of their constituent parts.

Petroleum, or mineral oil, has long been an article of commerce. Ure mentions that at Baku, near the Caspian, where wells have been dug, the oil there collected is used for lighting and domestic purposes. Rangoon is also a well-known locality. In Burmah, near the Irawaddy, there are said to be no less than 520 springs, each spring yielding annually 170 casks of 950 pounds each. There are also many localities in southern Europe. The largest supply, however, to the market was from Trinidad, whence also the greatest amount of asphaltum is obtained. But it was not yet cheap enough to become an article of universal consumption. However, just previous to 1860, oil was struck, as the saying is, in Pennsylvania, and from that time the quantity supplied has so steadily and rapidly increased that it would seem to be inexhaustible. The export in 1860 amounted to 1,500,000 gallons. Allowing

twenty cents a gallon as the value of the crude oil, and supposing about half as much to be consumed at home as exported, the total value of oil raised in 1870, when the amount exported had already reached 141,208,155 gallons, would exceed \$42,000,000. The low price of the refined oil brings it within the reach of all classes, and the dwellings of the poor may now boast of as good illumination as those of their well-to-do neighbors.

But the march of improvement still goes on, and a still more brilliant light threatens largely to supersede that of gas. Such is the electric light, which is already being employed to light streets and public places, halls and even stores, and a few private dwellings. The light is so pure, white, and brilliant, that the best of gas-light looks of a dull yellow by its side, and the photographer can make use of it even in place of sunlight.

And now my task is done. In going over a few of the beautiful forms assumed by inorganic substances, I have alluded very cursorily to some of those more striking properties of different minerals, specially adapting them to the varied wants of man, of which he has accordingly availed himself. I shall feel abundantly satisfied if, on the one hand, I have been enabled to point out any new line of thought in regard to the many collateral subjects of interest connected with the study of minerals; or if, on the other, I have succeeded in keeping your attention directed to the abundant evidence, displayed alike in the distribution and varied properties of the different minerals, of the wisdom and forethought of a benevolent Creator in thus providing for us, in the mineral as in the organic world, not only whatever is necessary for our actual wants, but all that can add to our comfort and enjoyment, all that can aid in the advancement of our efforts toward a higher grade of general civilization.

SEVENTH TALK.

BY CORNELIUS M. O'LEARY, M. D., LL. D.

In the following remarks upon crystals the writer lays no claim to originality, as he has merely culled the materials of his work from the latest authentic sources of information, and notably from the learned and able article on "Crystallography" in Appletons' American Cyclopædia.

MANHATTANVILLE, *December 10, 1884.*

C. M. O'L.

JUST as chemistry discloses to us the molecular elements which render material substances mutually distinct, so does the science of crystallography reveal to us the laws in accordance with which those molecular elements combine to produce this distinction. Molecules give rise to crystals, and crystals unite to produce most of the simple elements with which we are acquainted. The importance of knowing the laws in obedience to which crystals are formed, may be inferred from the fact that such knowledge supplies us with the means of determining the specific differences between many various kinds of matter. Thus the specific difference which exists between common table salt or chloride of sodium, and Epsom salt or sulphate of magnesia, is clearly attributable to the different forms of the elementary or primary crystals which constitute them respectively. And this is true likewise with respect to all the other crystalline shapes which most commonly fall under our observation. The most familiar form of crystal is ice, and there are few who have not watched with interest surface water gradually assuming needle-like shapes under the influence of cold. Indeed, the very name itself is derived from the Greek word (*κρύσταλλος*) signifying ice. The unvarying regularity with which water is converted into those beautiful shafts that sparkle in the sunshine, producing what Poe has so happily termed

“crystalline delight,” and the admirable symmetry which characterizes the delicate snow-flake, indicate at once the superiority of Nature’s processes over those of man, and proclaim the grandeur and stability of those laws which the Creator has established for the government of the universe. But there are crystals which we can not see with the naked eye, and the commonest substances that we handle, which seemingly possess nothing attractive to enlist our admiration, are made up of the most beautiful and varied crystalline shapes. Thus one of the most ordinary crystals we are acquainted with—limestone—is in reality the result of the union of the most resplendent and varied minute crystals that we know of. The diamond, which is crystallized carbon, surpasses all others in brilliancy only for the reason that its molecules cohere with more tenacity, and thus, in the form in which it is usually found, exhibits a power of refraction which other crystals of the same magnitude do not possess. The commonest clay we handle is an aggregate of crystals which, if they were but to cohere more closely, would exhibit the most beautiful effects. All the solid materials which constitute the inorganic kingdom are so many crystalline structures, the vast variety and beautiful arrangement of which we might observe if our physical vision were keener and more piercing. The lava that flows down the mountain side, carrying ruin and desolation in its headlong course, is a beautiful crystal, and has been slowly shaped in the great laboratory of Nature. As the lightning-flash, that deals destruction where it strikes, also illumines with dazzling light the face of the earth, and discloses its beauties more vividly than the sunshine, so the upheavals of the land and the eruptions of volcanic mountains, though carrying ruin in their track, leave behind them most beautiful and diversified effects in the shape of crystalline formations. The very foundations of the earth are crystal, and would show forth to the eye unsuspected beauties, could we but see deep enough down to behold them. The air we breathe is filled with materials suited for crystallization, and if we could bring sufficient pressure to bear upon the oxygen of the atmosphere we would produce a crystal gem before the brilliancy of which even the diamond would pale its fire.

Every metal is a crystal, and though gold may be hammered into leaves of incredible thinness, and platinum be drawn into threads of impalpable fineness, neither loses its crystalline character in the operation. Silica and alumina, when united with some of the alkalis, go to constitute the choicest and most abundant crystals we possess; of these, the varieties known as tourmaline, feldspar, and garnet, are the most prized. The plan which Nature has pursued in the structure of crystals has long puzzled the most ingenious minds, and many elaborate attempts have been made to unfold it; but experiment can not deal with the matter, and so the science of crystallography may be regarded in the main as a speculative one.

The leading property of crystals, by virtue of which we are enabled to classify them, is what is known as cleavage. By cleavage we understand the tendency of certain crystals to exhibit the same respective position of the faces, no matter how we may subdivide them. Thus, if we gently break a piece of fluor-spar with the hammer, we will find a constant symmetry of arrangement, from which there is no departure, even in the minutest subdivisions. So, also, in mica or isinglass we may tear off with the fingers laminae, or sheets, which always follow the same direction. But cleavage can not reveal to us the internal structure of crystals, and we are, therefore, compelled to have recourse to imaginary lines, or axes and planes, in order to determine crystalline groups. The introduction of these imaginary lines and planes opened the door at first to numberless theories which were more fanciful than well founded, and the scientific annals of two hundred years ago are replete with unsuccessful attempts to solve the problem of crystallization.

During the middle ages much interest was evinced by scholars in the marvelous phenomena of crystallization, and many efforts were made to explain them, which reflect more credit on the learning and scientific zeal of those times than many are disposed to give them credit for. Albertus Magnus, in the thirteenth century, strove to fathom the mystery of ice-formation, and, though he failed for want of scientific data on which to proceed in his inquiry, his remarks are both curious and ingenious. The first who struck the true key-note of the best theory of crystallization was René Just Haüy (died 1822),

whose attention to the matter was first drawn by an accident. He noticed that a hexahedral prism of calc-spar (a cube) developed by continued cleavings into a rhomboid (an elongated rhomb—the latter a figure of four equal sides but unequal angles), and that this was not an isolated instance of the kind. The theory which he based on these facts was to the following effect: He maintained that in every crystal there are what he called integrant molecules, on the action and play of which the resultant form of the crystal depended. These molecules he held to be solid bodies that allow no further subdivision, and so invariable in form that their angles and dimensions can be accurately determined by calculation. He regarded them as primitive crystals, and their resultants secondary, or such crystals as we are acquainted with through observation. He held, however, that six of the primitive forms have reached their full development in the known orders, and consequently fall under observation. In order to the production of what he calls the secondary crystals, which enveloped the primary forms, he supposed the enveloping matter to consist of a series of laminae, each decreasing in extent either equally in all directions or only at certain points.

This decrease he supposed to take place by the regular subtraction of one or several ranges of integrant molecules in each successive layer, and thus he held that we are enabled to account for not only all known forms of crystal, but to forecast, hypothetically, forms as yet undiscovered. Much was assumed in the theory of Haüy, and many facts have been arrayed in opposition to his views, but this invaluable result has been obtained from his inquiries and speculations, viz.: that there exists a law or set of laws in obedience to which the process of crystallization goes on, and that there is nothing capricious about it. Thus, though later investigations have demonstrated the inadequacy of Haüy's system to explain all the facts of crystallography, enough at least was accomplished by him to set the science on a thoroughly scientific basis, and to stimulate the ardor of subsequent inquirers. But even those inquirers have failed to satisfy us on all points, and their views necessarily partake more of the character of speculations than of scientifically demonstrated conclusions, so that the words of the

late learned Sir David Brewster still possess a melancholy meaning for us. "In whatever way crystallography shall succeed," says he, "in accounting for the various secondary forms of crystal, they are then only on the threshold of their subject. The real constitution of crystals would be still unknown, and, though the examination of these bodies has been pretty diligently pursued, we can at this moment form no adequate idea of the complex and beautiful organization of these apparently simple bodies."

Armand Levy, in France (1841), accepted the theory of Haüy, and lent additional weight to it by his improved mathematical calculations. The system is substantially identical with that of Haüy, and has been adopted by the well-known Des Cloizeaux in his "Manuel" (Paris, 1874). We will now sum up the leading characters of crystals, so far as they have been discovered, and so far, consequently, as they are calculated to affect the future of the science. We have already remarked that crystals are bounded by plane surfaces symmetrically arranged around imaginary lines called axes, and that the internal structure, so far as it can be ascertained by ocular observation, is revealed to us by cleavage. Cleavage is not the same for all crystals, for, though the majority of specimens split in a direction parallel to one or more of the axial planes, many of them cleave diagonally, but in all cases these directions are fixed as regards species.

The various forms of crystals belong, as regards their mathematical properties, to six systems of crystallization: the isometric, or those whose measurements are equal; the tetragonal, or those having four angles and sides; the orthorhombic, or those having the three axes unequal, as in the rectangular and rhombic prisms. In the above-mentioned forms the axes intersect at right angles. Then there are the monoclinic, or crystals that have one of the intersections oblique, as in the oblique rhombic prism; the triclinic, having all three of the intersections oblique; and the hexagonal, also called the rhombohedral, in which there are three equal lateral axes. The greater number of crystalline forms are those that are based on the four-sided prism and the regular six-sided prism. Four-sided prisms have three fundamental axes cross-

ing at the center, one vertical axis connecting the centers of the opposite bases, and two lateral, connecting the centers of either the opposite lateral faces, or the opposite lateral edges. The four-sided prism may be either right or oblique. The six-sided prism is always right, and has four axes, one vertical and four lateral. In the right four sided prism the intersections of the axes are all at right angles, whereas in oblique four-sided prisms one or all of them are oblique angles.

There are two chief systems of crystals, which are called (I) orthometric and (II) clinometric, according as the angles are right or oblique. The orthometric system contains the following sub-systems: (1) the isometric; (2) the tetragonal, or dimetric; (3) the orthorhombic, or trimetric. (1) The isometric sub-system—three axes equal—is represented by the cube

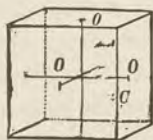


FIG. 1.



FIG. 2.



FIG. 3.

(Fig. 1), containing six equal square faces; the regular octahedron, containing eight equal triangular faces (Fig. 2); and the dodecahedron, containing twelve equal rhombic faces (Fig. 3). Examples of these are the *garnet*, the *diamond*, *gold*, *lead*, and *alum*. (2) The tetragonal, or dimetric sub-system—one axis,



FIG. 4.

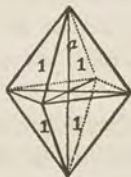


FIG. 5.



FIG. 6.

called the vertical, unequal to the other two, or lateral, and the lateral, thus of two varieties. The square prism is an example (Fig. 4). There are, besides, the square octahedron, or the equilateral eight-sided prism (Fig. 5), and the eight-sided

double pyramid (Fig. 6), besides others. Examples of this formation are *idocrase*, *zircon*, and *tin*. (3) The orthorhombic or trimetric sub-system—the vertical axis unequal to the lateral, and the two lateral mutually unequal. The rectangu-

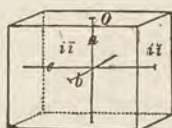


FIG. 7.

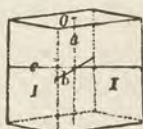


FIG. 8.

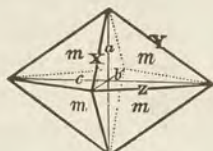


FIG. 9.

lar prism is an example (Fig. 7). There are, besides, the right rhombic prism (Fig. 8), in which the vertical axis connects the centers of the bases. Another form of this sub-system is the rhombic octahedron (Fig. 9). Examples of this are *sulphur*, *heavy spar*, *Epsom salt*, and *topaz*. We now come to the oblique or clinometric (II) system, which embraces two sub-systems: (1) The monoclinic sub-system—one only of the intersections oblique. The oblique rhombic prism is an example (Figs. 10 and 11), which is converted from the right rhombic prism by making the vertical axis oblique to one of the lateral. Examples of this crystal are *Glauber salt*, *sugar*, and *pyroxene*. (2) The second sub-system is the tri-

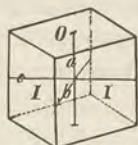


FIG. 10.

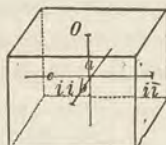


FIG. 11.

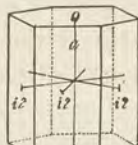


FIG. 12.

clinic—all three intersections oblique, and the axes unequal. Its forms are oblique prisms, with rhomboidal faces. Examples of this crystal are *blue vitriol* and *axinite*. There are some crystals that have four axes. Of these are the regular hexagonal prism (Figs. 12 and 13). In this crystal the vertical axis connects the centers of the bases, and the three lateral the centers of the opposite lateral faces. Another form is the double six-sided pyramid (Fig. 14). Examples of these are the

beryl, or *emerald*, and *apatite*. The rhombohedron is said to belong to the same system as the regular hexagonal prism, for the reason that its symmetry is hexagonal. The rhombohedron (Fig. 15) is a solid bounded by six equal faces equally in-

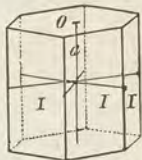


FIG. 13.

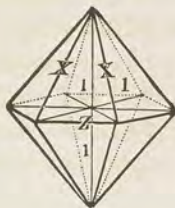


FIG. 14.



FIG. 15.

clined to one another, but the faces are rhombic, and the inclinations are acute. A fuller idea of the rhombohedron may be gained by comparing it with a cube. If a cube be placed on one solid angle, with the diagonal from that angle to the opposite solid angle vertical, it will have three edges and three faces meeting at the top angle, and as many edges and faces in alternate positions meeting at the opposite angles below. The cube, in this position, is a rhombohedron of 90° which, by elongation, would become an acute rhombohedron of less than 90° , or by pressure would become an obtuse rhombohedron with an angle of more than 90° . Examples of this mode of formation are the *calcite*, the *sapphire*, and *quartz*. The relative value of the axes in any species may be ascertained from the angles of inclination of the planes on one another. The proof of this statement involves mathematical calculations which it would be out of place to introduce here, but it contains a proposition to the truth of which crystallography owes its mathematical basis. It is by the application of this law that crystals are classified, and that specific modifications do not exclude different orders of crystal from the same family. It is also in accordance with this law that abnormal and new forms, which are apparently unclassified, may be reduced to their proper rank. In this fact we observe an instructive instance of the infinite variety of Nature's works, consisting with remarkable unity. Thus, the *diamond*, which belongs to the isometric sub-system, occurs in octahedrons, in dodecahedrons, and in

solids that are like octahedrons, but have low pyramids of three or six faces. So, in the dimetric species, *idocrase* occurs at times in simple square prisms, or in square prisms with the edges beveled, or in eight-sided prisms, or in square octahedrons. In *calcite* the number of these derivative forms amounts to several hundreds. In all cases of derivative or secondary forms, either all similar parts are modified alike, or only half, alternate in position, are modified. This may be observed by reference to Figs. 16, 17, and 18. Hence we may distinguish a cube modified on the edges, however much it may be dis-

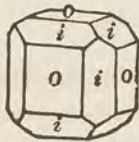


FIG. 16.

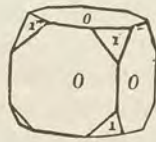


FIG. 17.

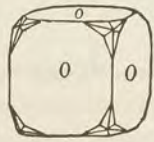


FIG. 18.

torted, by finding the same planes on the twelve edges of the solid. The eight angles of a cube are similar, and hence they will all have similar modifications, either one plane, as in Fig. 19, or three planes, as in Fig. 18. Again, the eight angles of a square prism are similar, and are, therefore, modified alike. The difference between the square prism and cube is this, that in the cube, when there is one plane on each angle, that plane will incline equally to each of the three faces adjoining, because these faces are equal, while in the square prism the plane will incline equally to the two lateral planes, and at a different angle to the base. This is the general law of "similar parts

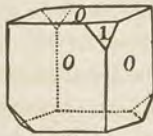


FIG. 19.

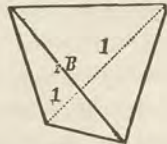


FIG. 20.

similarly modified," and accounts for the symmetry of the parts thus modified. Half the parts only are modified in *boracite* (Fig. 19), in which half of the eight solid angles have planes unlike those of the other half, a combination whence is pro-

duced the tetrahedron (Fig. 20). The same condition exists in *tourmaline*, in which the planes at one end of the crystal differ from those of the other. Fig. 21 represents a holohedral, that is a cube having as many faces as possible, the excess being the result of beveled edges. Then there is the hemihedral, in which only half of the edges are beveled (Fig. 22).

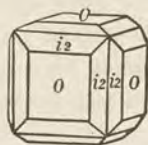


FIG. 21.



FIG. 22.

The physical characters of crystals have a direct relation to their forms and axes. Thus cleavage, color, hardness, elasticity, expansibility, and conductivity, differ in the direction of different axial lines, and are similar in the direction of similar axes. An interesting fact in connection with axial lines is that the light transmitted along the vertical and lateral axes of a prism is often very different, and thus, by refraction, the phenomenon known as pleochroism—parti-coloring—is produced. The curving of crystals, which gives rise to a vast deal of irregularity in their form, is a result due either to abrupt changes of temperature, or to the presence of foreign agents, which change the direction of axial lines. Thus the unequal expansion of inequiaxial crystals along different axial directions, occasions a change of angle with a change of temperature. A familiar instance of curving forms is afforded by ice, or frost, as it covers window-panes, or is met with near the covering of sewers. Two factors enter into the irregular formation of ice-crystals on windows, viz.: the unequal reduction of temperature, and the presence of impurities chemically different, both of which determine the fantastic and irregular pictures which so please us by their perfect symmetry and marked departure from severe mathematical outlines. It is strange that this arborescence, as it is called, which makes midwinter panes supply the beauty which at other times the glass enables us to see in the landscape, is the type and embodiment of almost every crystalline shape. Here the diamond, the garnet, and the

emerald find their counterpart, and by their combination present to the eye the perfect picture of Nature's handiwork in the production of crystals. Rhombohedrons of *dolomite* and spathic iron (carbonate of iron having a leaf-like shape) often exhibit this curving twist, half the faces being concave and the other half convex. Other deviations from the normal type are the result of an oscillating tendency to the formation of two planes, which ends in a striated, or striped, curving surface. In addition to the simple crystals, hitherto spoken of, we have also twin, or compound crystals. The six-rayed stars of snow (Fig. 23), and the arrow headed forms of gypsum, are examples of compound crystals. In the stars of snow there are three crystals crossing at the middle; in gypsum two crystals are so united as to form a perfect twin. These crystals may be imitated by cutting a model of the form in two, inverting one part, and again uniting the cut surfaces. Thus Fig. 24 represents an octahedron placed on one of its faces, with a plane intersecting at the middle, and Fig. 25 is the same form with the upper half revolved 60° . This reversion of position is sup-

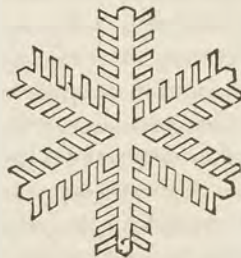


FIG. 23.

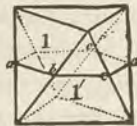


FIG. 24.



FIG. 25.

posed to be due to opposite polar forces, with which crystalline molecules are endowed. By virtue of this force the molecules act in different directions, under the influence of minute electric currents, and so produce opposite effects on opposite sides of a crystal. The conditions necessary for the formation of perfect crystals rarely exist in nature; for perfect rest, accompanied by a slow cooling, is requisite for this result, and we know that natural forces most frequently act with great violence and irregularity. Hence it is that those immense columnar masses that line the banks of the Hudson for miles, and

are known as the Palisades, present to the eye an attempt at regularity, marred and broken at intervals. The center or axis of each column is the center of a concretionary structure, and this was, therefore, the position of the first solidifying point of the cooling mass. The distance between these points determines the size of the column, as the interval is filled in with concretions. Thus, given the distance between any two individual columns of the Palisades, their diameters may be calculated. Dimorphism is an interesting property of some substances, by virtue of which, under varying conditions, they assume different crystalline shapes. Thus carbonate of lime usually crystallizes in rhombohedrons, when it is called *calcite*, and again it crystallizes in trimetric prisms, and is called *aragonite*. Besides difference of form, there is also in such cases difference in the degree of hardness, and in specific gravity. When carbon crystallizes isometrically we have the diamond, when it crystallizes as a hexagon we have what is known as graphite, or the black-lead of pencils.

We will now consider the various ways in which crystallization takes place. The first and commonest way is by solution, when the solvent disunites the molecules of a solid, and gives them the freedom of movement necessary for a reunion in the crystalline shape. Thus a saturated solution of sugar or alum will furnish by evaporation a mass of crystals, and when evaporation is carried on slowly and cautiously, the same solution will yield a variety of crystals. Sea-water may be made to deposit first gypsum, afterward crystals of common salt, and lastly the salts of magnesia. The second mode of crystallization is by fusion. In this case heat dissevers the molecules, which slowly reunite in crystalline shapes as cooling goes on. It is thus water crystallizes into ice, and aqueous vapor into snow. So, also, if a mass of molten sulphur be allowed to partially cool, be then tapped, and the still molten contents run off, the interior of the cavity will be found lined with beautiful crystals. The third way in which crystals are produced is by the application of heat, short of melting. It is in this manner that temper is imparted to steel, for, though the heat does not reach the fusing point, the molecules assume new relations, and so change their crystalline shape. This is the

mode of crystallization by which metamorphic rocks are formed. The long-continued application of a low degree of heat changes beds of earthy sediment into gneiss and mica schist, and the finest marble is produced in the same way from fossiliferous limestone. The slower the process by which Nature works out her designs, the more perfect the result, and it is for this reason that those crystals which exhibit the most regularity and symmetry, together with great cohesiveness of parts, are those which have been developed by low and slow heat. Nearly all the gems with which we are acquainted, and rocks possessing the highest power of refraction, are the result of metamorphic formation.

When the same substance assumes different crystalline shapes, the modification is usually due to the presence of some disturbing agent in the solution. When common salt crystallizes from a solution of pure water, the result is a cube, but if boracic acid should be present, the cube exhibits truncated angles. Carbonate of copper changes the form of its crystals on the addition of ammonia, and undergoes an additional change when sulphuric acid is present. This fact may account for many of those apparently capricious formations in nature, for it is only on the supposition of the presence of some additional agent that we can account for the variety of forms under which substances chemically different often crystallize. Thus calcite or common limestone crystallizes in certain places under the form of scalenohedron—a pyramid with six sides, and the faces scalene triangles—and is elsewhere found in the shape of short hexagonal prisms.

In massive aggregate crystalline rocks there is a tendency to parallelism, and hence, in a granite quarry, it is easier to split the rocks in one direction than in another, owing to an approximate parallelism in the cleavage planes of the feldspar. (Feldspar is one of the essential constituents of granite, gneiss, mica slate, and porphyry, and enters into the constitution of nearly all volcanic rocks.) This peculiarity of cleavage is attended with consequences of great practical interest, for not only does a knowledge of it facilitate the work of the quarryman, but we possess therein the means of determining the duration of geological periods, when the formation is either com-

paratively recent or begins to undergo disintegration. It may be that in the recent columnar formations of volcanic districts, where the lines of cleavage are more distinct, and the feldspar is not in so cohesive a state, the internal forces operating along these loose lines of cleavage rend them asunder, and produce those dreaded disturbances of the earth's surface known as earthquakes. This, of course, is only a conjecture, but we often witness an analogous proceeding in melting ice. Ice forms in columns, as any one may perceive by viewing the longitudinal lines of thick ice-cakes. When the sun becomes strong enough to melt the surface, these columns become loosened, and, long before the ice has become thin enough to yield to the pressure of a superincumbent weight, a sharp blow with a hammer will drive a considerable mass into the water beneath. And if loosely cohering columns of ice will thus act from the application of external force, why not the comparatively non-cohering columns of volcanic rocks exhibit a similar tendency from the application of an internal force? Thus we see that the formation of crystals is a process which has been going on from the day on which the foundations of the universe were cast, and that its force is felt in the minutest particles of matter as in those giant masses that tower to the sky, and have built up the inaccessible heights of the Rocky Mountains and the Himalayas.

Brewster has shown that a close relation exists between crystallographic characters and the physical properties of the crystals themselves, so that the classification of crystals, according to their molecular proportions, can no longer be considered a mere matter of speculation, but is entirely confirmed by facts. A recent invention, made by the German *savant* Von Kobell, and known as the *stauroscope*, has wonderfully aided the investigation of the physical properties of crystals. The stauroscope enables us to determine the position of the planes of vibration in sections of crystals, and so to infer the proportion in which molecules are mutually arranged and act upon each other. The polarizing microscope of Nörremberg has also considerably helped to the same result. The optical, magnetic, and electrical properties of crystals are now being studied with great zeal, in Germany particularly, and crystallographers

are confident that, with the improved instruments which modern science has placed at their disposal, they will eventually be able to bring within the range of systematized knowledge most of those interesting facts of crystalline formation which fill us with wonder, but which we have not hitherto been able to account for.

THE DIAMOND.

We will here make a few observations concerning a crystal which, in point of brilliancy, value, and high refractive powers, as well by reason of the extraordinary histories which have been handed down to us concerning it, undoubtedly stands at the head of the whole family of minerals. We speak of the diamond. The commonest form in which the diamond is found is the octahedron, or double four-sided pyramid, next to which occur the rhombic dodecahedron with twelve faces, and those exhibiting twenty-four and forty-eight faces. The diamond has a perfect cleavage parallel to its faces, and readily breaks in this direction. It is, therefore, contrary to an old and still current opinion, brittle and easily broken by a blow or a fall. It surpasses in hardness all other substances, and it was by this quality that the ancients distinguished it from other gems. It was highly prized in olden times, even before the art of polishing it was understood. The old Jewish doctors believed that the third stone in the second row on the breast-plate of the high-priest was a diamond, and as such it is translated in the King James version, though it was more probably a jasper, as rendered in the Douay version, for, as the name of one of the tribes was inscribed on each stone, it is not easy to understand how this could have been done at a time when diamond-cutting was not understood. It was first known among the Greeks about B. C. 300, by whom it was called *ἀδάμας*, or the "unsubduable," from its supposed power of resisting the action of fire. Its present name is derived from this Greek word, and it was first called *diamas* by Albertus Magnus in the thirteenth century. Pliny says that it exceeded in value all human things, and so strange were the stories told of it that many, during the early part of the Middle Ages, believed that it could be reduced to a state of fusion only by being dipped

in the fresh and still warm blood of a goat. Pliny also assures us that the Indian and Arabian varieties of the stone were so hard that when struck with a hammer even the iron and anvil were frequently torn asunder. This unconquerable hardness had the effect of lowering the value of the diamond as an ornamental gem, and it was not till Ludwig van Berguen, in 1476, discovered the manner of cutting and polishing it, that it came to be highly esteemed as a precious stone. It was after this discovery also that the remarkable optical properties of the diamond came to be understood. The purest stones, or, as they are called, those of the first water, are highly transparent, though never completely so, and entirely colorless. Those that are not of the first water are said to be "off color," and exhibit various tints, such as white, gray, or brown; sometimes blue, red, yellow, or green, and, very seldom, black. The high refractive* power which it possesses, and the strong reflections which both surfaces produce, while interfering with its transparency, impart to the diamond the brilliancy for which it is so remarkable. Robert Boyle, in 1664, described another interesting property of the diamond, known as phosphorescence, or its power of emitting rays of light in the dark, immediately after having been exposed to the action of the sun. That the diamond is combustible was long a matter of doubt, and even of disbelief, till in 1695 members of the Florentine Academy reduced it to ashes by means of a powerful burning-glass, and so proved that, chemically, it is pure carbon crystallized. This discovery set many persons to making experiments with the view of crystallizing carbon, and so producing artificial diamonds. Notwithstanding that a few chemists claimed to have succeeded in the attempt, and to have produced artificial diamonds of very minute size, it may be said that all efforts at producing diamonds by artificial means have practically failed.

Many widely differing opinions are still entertained by chemists touching the origin of this gem, but, passing over the older and more fanciful views, we will here merely refer to the latest and most widely accepted opinion. The occurrence

* A ray of light is said to be refracted when it enters obliquely a medium of a different density from that through which it had previously moved, and so changes its direction.

of diamonds in mica slate, and near igneous rocks, tends to favor the view that it is of metamorphic origin, and its perfect mode of crystallization confirms this conclusion. The oldest home of the diamond is India, where it is still found in a wide district extending from the Pennar River, in 14° north latitude, to Bundelkund, 25° north latitude. The diamonds of Golconda, which have obtained such a wide celebrity throughout the world, were merely cut and polished, and not mined, in this old fortress and home of enormous mausolea. The diamonds of Golconda are the largest of Indian origin. The diamonds of India are chiefly found in recent deposits, in beds of sand and clay, and sometimes in ferruginous sandstone, though the real matrix of the crystal does not exist in these deposits. During the end of the last and the beginning of the present century, Brazil was the most fruitful source of the diamond. They were first recognized in 1727, in the province of Minas Geraes, where they had long been used by negroes as counters in playing cards. The Brazilian diamonds are chiefly obtained from the Cascalho, a loose, gravelly deposit mixed with red clay. The diamond mines of Brazil are government property, and are jealously watched by the crown officials. It is estimated that three million carats of diamonds, valued at about thirty-five million dollars, were taken from the Brazilian mines between the years 1772 and 1818. Brazilian stones are, for the most part, small, though exceedingly brilliant. The largest stone from Brazil was discovered in 1854, and weighed two hundred and fifty-four and a half carats in the rough. This was an irregular dodecahedron of brilliant lustre, and with no flaws. After having been cut, it weighed about one hundred and twenty-four carats, and is now known as the Star of the South.

Diamonds have also been found in old Mexico, Georgia, North Carolina, California, and Arizona, but these are for the most part small sized; the largest, discovered in the latter Territory, weighing but three carats. A few diamonds have been discovered in Europe, the largest of which, discovered in the Ural Mountains, weighed eight carats. Many diamonds have been found in Australia, but they are for the most part small, the largest Australian diamond hitherto discovered weighing

but six carats. In 1867 a Dutch farmer obtained from a Boer a bright stone which his children were using as a plaything, and which proved to be a valuable diamond, for which twenty-five thousand dollars was obtained at Paris during the Exposition of that year, though its intrinsic value was much greater. This circumstance gave a strong impetus to diamond-digging in South Africa, and before long a very great number of most valuable stones were brought to light. These discoveries were chiefly made near the Orange and Vaal Rivers in Griqualand West. Their favorite abode was a vein of peculiar igneous rock named *diabase*, or *gabbro*, by the natives. Throughout this rock, which has been explored to the depth of from one hundred to two hundred feet, diamonds were found scattered weighing from one hundred and fifty carats to the hundredth part thereof. It is estimated that about seventy-five million dollars worth of diamonds have been mined in the Cape territory since 1867. The largest Cape diamond, of a light blue yellow, since cut, is known as the Stewart, and weighed two hundred and eighty-eight and three eighths carats in the rough.

We have already remarked that Berghem (or Berguen), of Bruges, was the first, of whom we have any authentic information, who practiced the art of diamond-polishing. It was he who first made a diamond cut diamond, and for the purpose he used diamond-dust and a polishing-wheel. The process remains substantially the same to this day, and the finest cutting is done in England. The period required to reduce a stone of twenty-four carats formerly extended from seven to eight months, and in the case of larger diamonds it took a space of time proportionately longer. Since, however, the steam drill and polisher was introduced, the time required for polishing diamonds has been considerably lessened. The diamonds are cut chiefly in three shapes, viz.: the *brilliant*, the *rose*, and the *table*. The brilliant is the form most desired, since it gives the highest effect to the luster of the stone, and involves less reduction in weight. The reason of this is because it follows the outlines of the octahedron, which is the commonest shape of the diamond. The principal upper surface is called the *table*, the minor upper surfaces are called the *bezel*, while the

dividing line between the upper and lower surfaces is called the *girdle*, which is the common base of two pyramids. The portion below the *girdle* is called the *collet side*. Diamonds cut in the *brilliant* shape are usually set open, both the *table* side and the *collet side* being exposed to view. What is known as the *rose* cut is given to stones which have too little depth to be cut as brilliants, the whole upper surface being covered with equilateral triangles. The *table* cut, which is the least beautiful, is intended for broad and shallow stones, and shows a series of four-sided facets above and below the *girdle*. A recent style of cutting diamonds, common in France, is called the *star*, or *taille à étoile*, and involves still less reduction of weight than the ordinary brilliant cutting. In all forms the dividing line, or *girdle*, ought to be perfectly smooth, as any roughness here is apt to be mistaken for a flaw, and often interferes with the brilliancy of the stone. Diamonds are valued in proportion to their size, purity, color, freedom from flaws, and the skill with which they have been cut.

The weight of diamonds is reckoned by carats, a carat being the equivalent for 3.174 grains, troy weight. The rule for valuing diamonds is to rate them by the square of their weight in carats. Thus, if a good stone of one carat weight, faultless in shape and water, is worth one hundred dollars, a similar stone of two carats would be worth four hundred dollars, and so on. But this rule is not invariable, the state of the market, the rate of supply and demand, and even political events, having often much to do with determining their value. In the mineralogical cabinet of the Academy of Mount St. Vincent are to be seen fac-similes of the largest and most interesting diamonds in the world, the history of which is, in some instances, connected with the most stirring political and diplomatic events of the age. These diamonds are four in number, the largest undoubted one of which is the Orloff, now in the scepter of the Emperor of Russia. It is cut in rose form, with a flat face below, and resembles the half of a pigeon's egg. It is supposed to have been the eye of an Indian idol, and to have been stolen by a French deserter. Another story is to the effect that it once belonged to Nadir, Shah of Persia, whose life it cost him, and that it found its way into the hands of an Armenian mer-

chant, who brought it to Amsterdam. In 1772 it was sold to the Empress Catharine II for four hundred and fifty thousand dollars, together with an annuity of four thousand dollars and a nobility patent under the Russian crown. Next to the Orloff comes the Regent, or Pitt diamond, which weighs one hundred and thirty-six and three fourths carats, though before it was reduced to its present size it weighed four hundred and ten carats, and the fragments split from it when it was cut have been valued at more than a hundred thousand dollars. It was bought in 1702 by the Governor of Madras, Mr. Pitt, after whom it was named. It cost him at the time one hundred thousand dollars, which was then a virtually far greater sum than the same figures now represent. Mr. Pitt had it cut as a brilliant at a cost of fifteen thousand dollars, two years having been consumed in the process. It was sold in 1717 to Louis XV of France for six hundred and fifty thousand dollars, though it is reputed to-day to be worth considerably more than twice that sum, and is the finest and most perfect brilliant in Europe. The diamond next in weight to it is the Florentine, or Grand Duke (called in the Mount St. Vincent collection the *Toscaner*). It is a fine yellow stone, oblong in shape, and cut in rose. It is said to have been lost by Charles the Bold at the battle of Granson, and found by a Swiss soldier, who sold it for a few pennies as a piece of rock-crystal. It is now in the possession of the Emperor of Austria. Its exact weight is 133.16 Vienna carats. The Koh-i-noor, or Mountain of Light (called in the Mount St. Vincent collection the "*Gross Mogul*"), is the largest belonging to the British Crown. A common legend tells us that it was found in one of the Indian diamond mines, near the Kishna River, and had been worn five thousand years ago by one of the heroes celebrated in the Mahábhárata, the celebrated epic poem of the Hindoos. Its original weight is supposed to have been seven hundred and ninety-three and five eighths carats, but by injudicious cutting it lost a great part of its weight and size. Its adventures and vicissitudes, from the time that it served as a percussion flint for an Indian peasant to the moment that it fell into the possession of the Queen of England, are numerous, romantic, and often fabulous. When exhibited in the London Exhibition of 1851 it weighed

one hundred and eighty-six carats, but since that time it has been recut in the rose shape, and now weighs one hundred and six carats, and is no longer deemed a beautiful stone. It is conjectured that the Koh-i-noor, the Orloff, and a third diamond weighing four hundred and thirty-two carats, at present in the possession of some Indian potentate, formed originally the Grand Mogul, as their lines of cleavage marvelously agree. The other celebrated diamonds are the Sancy, of Russia, weighing fifty-three and a half carats; the Polar Star, also Russian, weighing forty carats; a diamond known as the Nassac, which weighs, in its recently recut shape, seventy-eight and five eighths carats; the Pasha of Egypt, which weighs forty carats, and cost one hundred and sixteen thousand dollars; and the "Cleveland Gem," which was completed on the 20th day of January, 1885, after eighty-one days of continuous polishing, and which weighs forty-two and a half carats. Red diamonds are very rare, and the most celebrated, weighing ten carats, is to be found among the crown jewels of Russia. Among the economic uses of the diamond the best known are glass-cutting and rock-boring, in both which industrial applications it has proved of great practical service.

QUESTIONS ON FAMILIAR TALKS.

FIRST TALK.

1. What would follow from a complete ignorance of the mineral kingdom?
2. What constitutes the inorganic world?
3. What is materialism?
4. Is the soul distinct from matter?
5. What is the depth of the earth's crust?
6. What is the greatest depth to which a perpendicular shaft has been sunk?
7. How are rocks divided?
8. Describe the Plutonic rocks.
9. Describe the aqueous rocks.
10. Describe the metamorphic rocks.
11. Where are metalliferous veins found?
12. Describe the volcanic rocks.
13. What is the effect of earthquakes on volcanic rocks?
14. What is the result of upheavals?
15. What is meant by a fault in metallic veins?
16. How is a crystal formed?
17. How is it probable that diamonds are formed?
18. What are petrifications?
19. What properties do some springs appear to possess?
20. How are rivers, lakes, and springs formed?
21. What is an artesian well?
22. What is the depth of the artesian well at Passy, and what quantity of water is it capable of supplying?
23. What is said of the artesian well now in progress at Pesth?

SECOND TALK.

1. What was the effect of man's expulsion from paradise as regards the physical world?

2. What does Prescott say on the matter?
3. What is said of the development of the mineral resources of the earth?
4. What is the earliest period at which we find iron employed?
5. What are alloys, and what is the law governing them?
6. What is *Wood's fusible metal*?
7. What is a native alloy, and what a native amalgam?
8. What is *sylvanite*?
9. What is the story told of Transylvania?
10. What is *tetradymite*?
11. What is said of the Peruvians?
12. What do the monuments of Egypt prove?
13. How are the stratified and fossil-bearing rocks divided?
14. Describe the siliceous rocks, and state the uses to which they are converted.
15. What is the St. Lawrence diamond?
16. What the California?
17. What is meant by the Cairngorm stone?
18. Enumerate some non-transparent varieties of quartz.
19. What is the effect of moisture on gems?

THIRD TALK.

1. Describe *osmium*, *rhodium*, *iridium*, and *platinum*.
2. What does Hood say of *gold*?
3. What are its primary localities?
4. How is it found?
5. What does Ure say of it?
6. Is it found in secondary rocks?
7. What is said of the pieces of quartz contained in the cabinet?
8. What are nuggets of gold?
9. Where is the largest nugget to be seen?
10. What is its weight and value?
11. In what shapes does gold crystallize?
12. How is gold separated from sand?
13. What is meant by hydraulic mining?
14. What was the average quantity of gold per annum taken into the European market from the old country between the years 1790 and 1802?
15. What was the estimated value of gold in the world in 1875?
16. Why is it not used in its perfectly pure state?
17. How many carats fine in jewelry?
18. What is said of silver?
19. Is a silver dollar of equal value with a greenback?
20. Why not so?
21. What is said of its affinity for sulphur?

22. At what degree of temperature does it melt?
23. How is it found?
24. Name the ores from which it is obtained.
25. How is silver separated from lead?
26. In what countries is mercury found?
27. At what degree does it solidify? Vaporize?
28. What is said of idrialite?
29. What are the uses of mercury?
30. How was it used in the time of Queen Anne?

FOURTH TALK.

1. Wherein does copper differ from gold and silver?
2. What is said of it as an electric conductor?
3. What is the consequence of copper being found in ores?
4. If it existed in its purity in mines could it be utilized?
5. How is pure copper obtained from the ore?
6. Name and describe the various ores of copper.
7. How long ago was tin known?
8. Name its ores.
9. Describe some of its purposes.
10. What is speculum metal?
11. What is britannia metal?
12. Why is great care required in its preparation?
13. Describe antimony and bismuth.
14. What is allemontite?
15. What is type-metal?

FIFTH TALK.

1. What does stone-ware consist of?
2. How is stone-ware manufactured?
3. How many kinds of porcelain are there?
4. What does hard porcelain consist of?
5. How is tender porcelain prepared?
6. What does Ure say of it?
7. How does common clay contribute to human comfort?
8. What important property does silica possess?
9. How far back does the knowledge of glass date?
10. When was it first imported into England?
11. How were houses lighted prior to that time?
12. Enumerate some of the advantages of glass.
13. What is common window-glass?
14. Bohemian or crown glass?
15. Bottle glass?
16. Crystal glass?
17. Strap? Enamel?

18. How are these prepared?
19. What is *soluble* glass?
20. What is Pettenkoffer's discovery?

SIXTH TALK.

1. What is the subject of this talk?
2. To what substances does sulphur give rise in combination with metals?
3. In combination with oxygen?
4. Enumerate some sulphurets.
5. Whence are the finest crystals of sulphur obtained?
6. In what manufactures is sulphur used?
7. How is sulphurous acid produced?
8. To what practical uses is it applied?
9. What is the important feature of carbon?
10. What is charcoal?
11. What is carbon in its purest state?
12. In its less pure states?
13. Point out the advantages of coal by a reference to England.
14. When and where was coal first discovered?
15. What is the annual consumption of coal in England?
16. When was coal first mined in the United States?
17. How many tons of coal were mined in the United States in 1870?
18. Between what series are the coal-measures found?
19. What is the extent of the coal-fields of Durham and Northumberland?
20. For how many years would South Wales supply England with coal, even at the present rate of consumption?
21. How far do the coal-fields of Ohio, Pennsylvania, etc., extend?
22. Is there a probability that the coal supply will ever give out?
23. What is the composition of coal?
24. What does Dana say of it?
25. What does the analysis of coal reveal?
26. In what condition are those buried forests found which have been converted into coal?
27. What is fibrous peat?
28. What is bituminous and non-bituminous coal?
29. What hydrocarbons are distilled from the woody elements of coal?
30. What is jet?
31. What are hydrocarbons, and how are they divided?
32. What is *mineral rubber* or *elaterite*?
33. Enumerate the simple hydrocarbons.
34. What is said of the *marsh-gas series*?
35. What is understood by *fire-damp*, and what by *after-damp*?
36. To what series is idrialite referred?

37. Describe it.
38. Where are the oxygenated hydrocarbon compounds chiefly found?
39. What is asphaltum?
40. How were the streets of London, Paris, and New York lighted at the beginning of the present century?
41. When and by whom was coal-gas first evolved from coal?
42. Whether is its use more common in the houses of England or those of the United States?
43. Of what does coal-gas consist?
44. How is it made?
45. What is petroleum?
46. Where was it first discovered?
47. When was it discovered in Pennsylvania?
48. What was the value of the petroleum taken from the springs in 1870?
49. What is the latest improvement in illumination of streets and buildings?
50. What thoughts does the study of mineralogy suggest?

SEVENTH TALK.

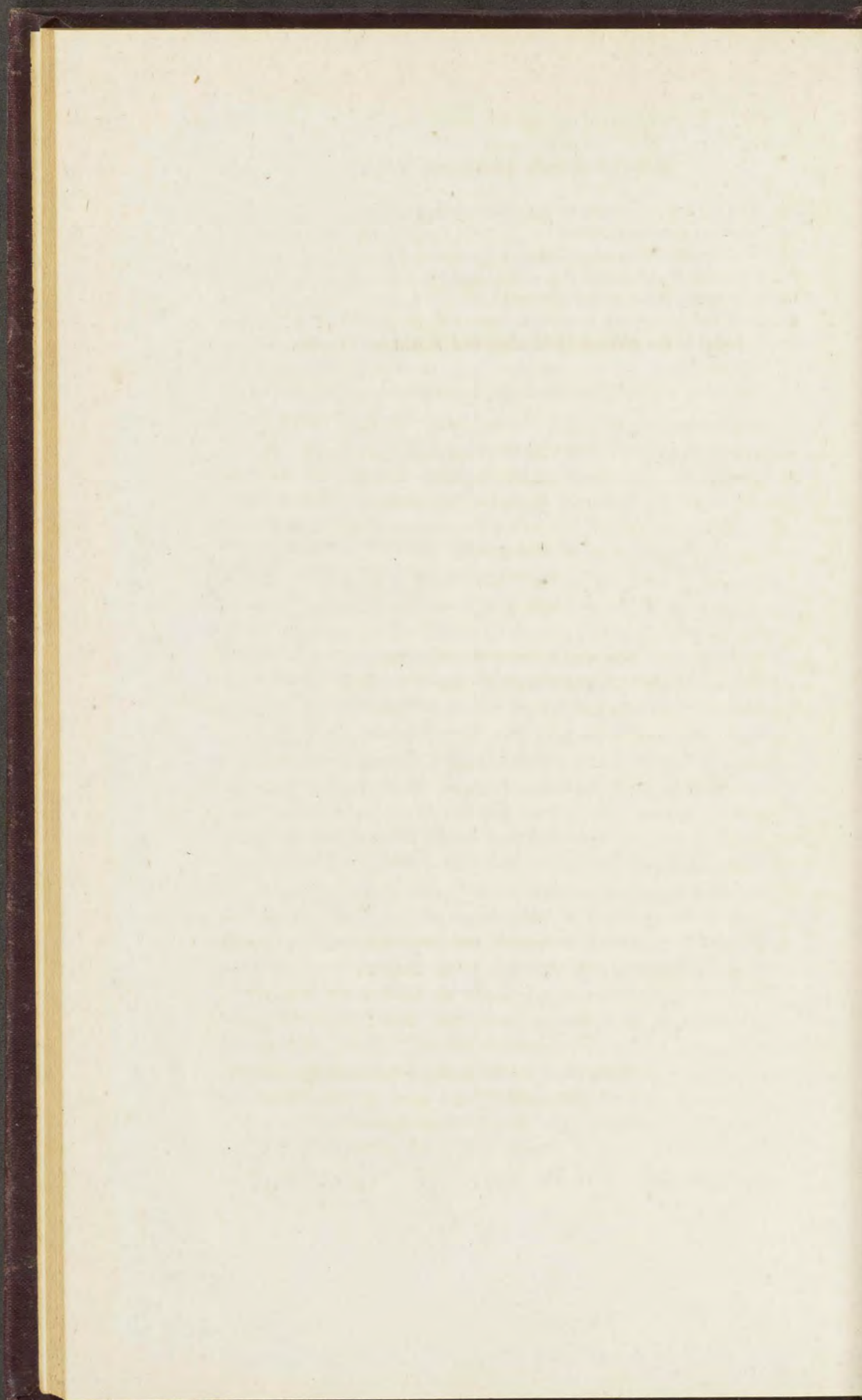
1. What does chemistry do for us with respect to the molecular elements of matter?
2. What crystallography?
3. State the importance of knowing the laws of crystallography.
4. What is the most familiar form of crystal, and why is it so called?
5. How does Poe designate the ice crystal?
6. Are all crystals visible to the naked eye?
7. What is said of common clay?
8. How may lava and lightning be compared?
9. What is said of the air we breathe?
10. Are metals crystals?
11. What is said of silica and alumina?
12. What is said of the plan which Nature has pursued in the formation of crystals?
13. How, consequently, may the science of crystallography be regarded?
14. What is the leading property of crystals?
15. What is understood by cleavage?
16. To what else besides cleavage must we have recourse in order to ascertain the laws of crystallography?
17. What is said of crystallography during the middle ages?
18. Who first struck the key-note of the soundest theory?
19. What had he noticed?
20. What did he maintain?
21. State the theory of Haüy?

22. Is the theory admissible?
23. What does Sir David Brewster say?
24. Who accepted and approved the theory of Haüy?
25. Is cleavage the same in all directions?
26. How many systems of crystallization are there.
27. State them.
28. What are the two chief systems of crystals?
29. What sub-systems does the orthometric contain?
30. What figures represent the isometric sub-system?
31. What the tetragonal or dimetric sub-system?
32. What the orthorhombic or trimetric sub-system?
33. Give names of crystals coming under the above sub-systems.
34. How many sub-systems come under the oblique or clinometric system?
35. Mention them.
36. What is said of the hexagonal prism?
37. Give names of crystals coming under these sub-systems.
38. What is a rhombohedron?
39. How may fuller idea of it be obtained?
40. Mention the names of crystals that present this shape.
41. To what sub-system does the diamond belong?
42. What is the difference between a square prism and a cube?
43. To what features of a crystal do its physical characters possess a relation?
44. What is pleochroism, and how is it produced?
45. What causes curving of crystals?
46. What factors enter into the formation of ice-crystals on windows?
47. Mention some crystals due to irregular action.
48. Do the conditions for the formation of perfect crystals commonly exist?
49. What are those conditions?
50. What is said of the Palisades?
51. In how many ways do crystals form?
52. When the same substance assumes different crystalline shapes, to what is this circumstance due?
53. What is meant by parallelism?
54. How may we by means of it account for earthquakes?
55. What is the stauroscope?
56. In what country is the study of crystallography most ardently pursued?

DIAMONDS.

57. In how many shapes does the diamond crystallize?
58. Is it easy to break, and why?
59. What is said of the precious stone on the breast-plate of the Jewish high-priest?

60. Who discovered the art of diamond-cutting?
61. What is phosphorescence?
62. Who proved the combustibility of the diamond?
63. Name the places where it is chiefly found?
64. How is the value of the diamond estimated?
65. Give the history of those diamonds the fac-similes of which are found in the mineralogical cabinet of Mount St. Vincent.



SUPPLEMENT.

THOSE who have seen something of the beauty and variety of form exhibited in the mineral world, and learned to appreciate the great utility to man of many of its materials, may be induced thereby, in order to know more about them, to take up the study of mineralogy: and a very fascinating pursuit they will find it.

It may not be amiss, therefore, by way of supplement to the foregoing talks, to add a few words on the science of mineralogy.

We say that the whole material inorganic world, including the solid earth's crust, is made up of mineral substances. This would include fluids and gases, as water and air, which play an important part in the formation of, and changes occurring in, minerals. I shall confine myself to solids only.

A *Mineral* may be described as an inorganic material body homogeneous in all its parts. If we break it into the smallest of pieces, we shall find every part of it presenting the same appearance and characters. We shall find sometimes whole mountain-masses composed of a single mineral, impure it is true, as in limestone or the chalk ranges in England; in general, however, we find different minerals aggregated together in dealing with masses, and then we term them *Rock*. Thus in granite or gneiss we can detect no less than three different minerals, namely, quartz, mica, and felspar, or, in the darker kinds, quartz, mica, and hornblende. The study of rocks is the province of *Geology*; thus the sciences of mineralogy and geology, as far as the material is concerned, are closely associated.

I have said that minerals are composed purely of inorganic matter. To this, coal, which is found in beds

of vast extent and often at great depths, may seem an exception, but it has become so altered by the influences around it as to possess the ordinary characters of a mineral, and so is spoken of as such. The same may be said of other hydro-carbon compounds.

Taking the definition of a mineral as given above, it may be observed that, though homogeneous in its structure, it may contain quite a number of elements; thus for instance, hornblende is made up of silica, alumina, magnesia, lime, and the oxides of iron and manganese, and these can only be separated by chemical decomposition and analysis.

The useful metals found native, and more particularly their compounds called *Ores*, distributed or running in veins, as they are called, through rock-masses, afford occupation to the miner and metallurgist.

Although the number of ultimate elements does not exceed sixty-two, their different combinations in the formation of species are so varied and numerous that there are probably not less than fifteen hundred different species and varieties described in works on mineralogy. Some of the elements exist in very small quantities, being found only in very rare minerals or being contained in some more abundant ones only in minute quantities; others again are exceedingly plentiful, as in silica and alumina. The silicates indeed are said to comprise more than half of the whole amount.

Many have an idea that a *Crystal* must be clear and transparent like glass. In point of fact, any piece of mineral that assumes a geometrical form, though it be black and opaque as a piece of coal, is a crystal. Indeed, with very slight exceptions under nature's laws of symmetry, the whole inorganic world is made up of crystals. Those bits of stone which to the naked eye seem to be utterly without shape are in fact made up of minute grains of crystals. The earth we tread upon, the sands of the ocean, the rocks and mountains, whether of chalk or granite or lava, are all built up of them. When, however, we speak of a crystalline formation, or of a crystal, we mean a mineral substance in geometrical form patent to the unassisted

vision or, at the most, by the aid of an ordinary magnifier.

We say, then, that a mineral is amorphous when there is no visible crystallization, subcrystalline when crystallization is imperfectly manifested, or crystalline when in more or less perfect crystals. Crystals of the same mineral, wherever found, usually have the same fundamental form, though they may be so greatly modified in appearance as at first sight to seem something entirely different. The study of crystallography, therefore, is essential to all who would be mineralogists, more especially as many minerals may be at once distinguished by the peculiar form of their crystals.

Crystals may often be split in certain directions more than in others, mostly parallel with the principal faces. This may be the more readily understood when we remember that larger crystals are made up of bundles of smaller ones, all similarly arranged. When they thus split uniformly in certain directions, this is called *Cleavage*. It may be perfect or imperfect. When a break occurs in any direction apart from a regular cleavage, it is called a *Fracture*.

Besides the above points there are many physical properties to be taken into consideration in the determination of minerals, such as hardness, tenacity, transparency or opacity. These are the most important. Taste, odor, electrical or magnetic properties are occasionally characteristic.

To determine the *Hardness* of a mineral a certain scale has been adopted, commencing with some very soft mineral and gradually rising to the hardest; thus Talc is 1, Gypsum 2, Calcite 3, Fluor Spar 4, Apatite 5, Orthoclase 6, Quartz 7, Topaz 8, Corundum 9, Diamond 10, the last being the hardest of all minerals. By the endeavor to scratch a mineral with others of known hardness we shall arrive at the hardness of any given specimen. By practice in scratching with a file or knife one may gradually acquire the amount of force requisite to scratch a mineral, to estimate pretty correctly the degree of its hardness.

As regards *Tenacity*, a mineral may be tough or brittle,

friable, malleable, sectile, flexible, elastic, etc. These terms readily explain themselves for the most part. By malleability we understand that it may be hammered out into plates—a property possessed by some native metals, such as copper or gold.

By *Specific Gravity* is meant the weight of a substance as compared with that of water, the latter being taken as a unit, and we obtain the former in the following manner: First weigh the specimen carefully, then suspend it by a horsehair or very fine silken thread from below the pan of the scale and let it sink into water; then again take the weight. It will be found to be less. Subtract the lesser from the greater weight and divide the latter by the difference. Thus, say the specimen weighs 50 grains in air and 30 in water: the difference will be 20. Divide 50 by 20, and it will give 2.5 as the specific gravity. There is another method, by the displacement of water in a bottle holding exactly say 500 grains of water. Having filled and dried the outside of the bottle, balance it carefully by counter-weights, then take the weight of the mineral in the air and add the two. Now put the mineral into the bottle, and of course it will displace some of the water. See that the bottle be exactly filled, and it then will be found to weigh so much less than the two separate ones did by the amount of water displaced. As in the other case, subtract the weight in water from the two weights in air combined, divide the greater weight by the difference and you obtain the specific gravity.

The *Color* of a mineral is also a matter to be noted, although it may vary considerably in the same species. The color of the surface may also differ from that obtained by scratching it, or by abrasion, and that shown by the denuded part is called the *Streak*.

In determining the character of a mineral, all the above points are usually noted; namely, form of crystal, hardness, specific gravity, color, and streak.

There are some other characters to be noted besides the above in minerals, such as lustre, transparency, opacity,

etc., given in all descriptive works, together with their chemical composition.

As a thorough knowledge of analytical chemistry, with the facilities afforded by a laboratory, are required for this last, of course the ordinary amateur is not expected to ascertain this for himself. It may be observed, however, that the best classification of minerals is for the most part based on chemical relations.

To one more feature I will allude in the examination and determination of minerals, namely, the assistance afforded by the *Blowpipe*. With a little practice this can be used readily by all, and it affords valuable aid to the student in his work.

In the foregoing, I have endeavored to point out simply a few of the many things the student will have to attend to in acquiring a knowledge of mineralogy, but can promise that once embarked in the pursuit he will be led on to follow it with ever-increasing interest. For the beginner, the little *First Book of Mineralogy*, by Collins, published by Putnam's Sons, will prove an excellent instructor. Dana's *Handbook of Mineralogy* will thereafter furnish a sufficient guide.

The author would like to call attention to the following circular of William H. Sadlier, 11 Barclay Street, New York. These collections are unique in character, very beautiful, and highly instructive, and familiarity with the specimens will give the student a considerable amount of practical knowledge at the start. The whole is contained within the space of an ordinary writing-desk, and the price is marvellously low.

ELMUND S. F. ARNOLD, M.D.

DIAGRAM 1.

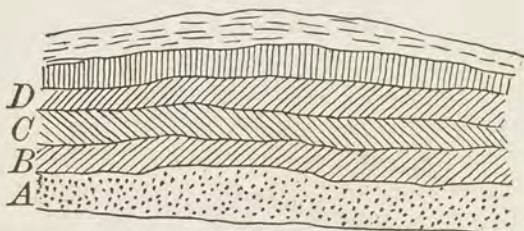


DIAGRAM 2.

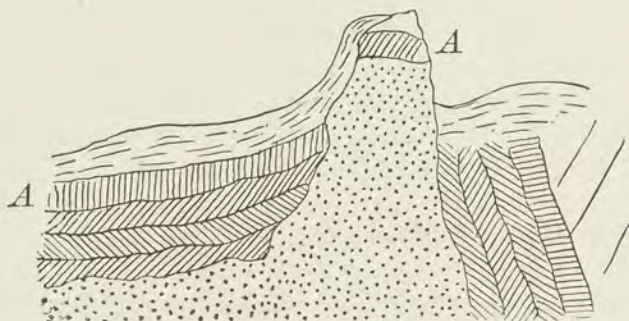


DIAGRAM 3.

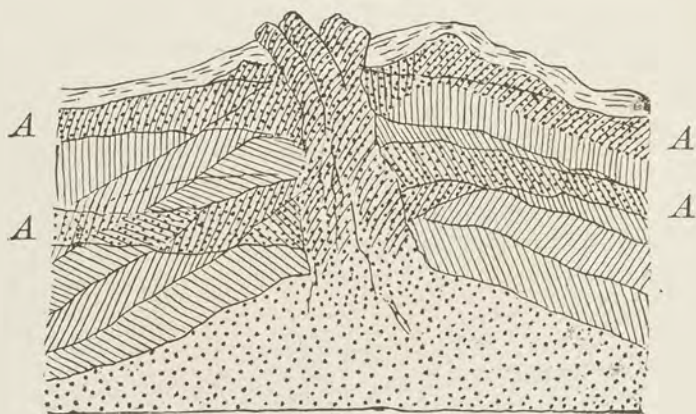


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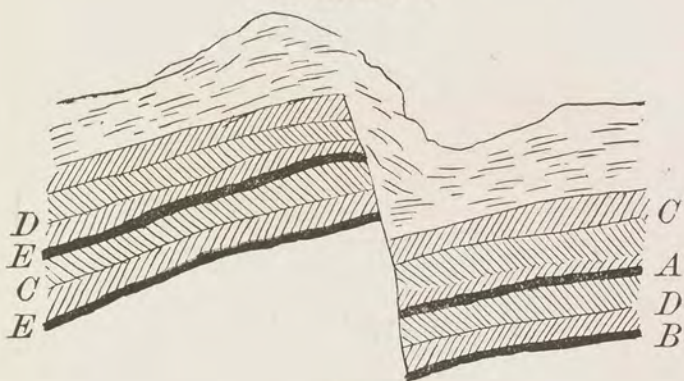


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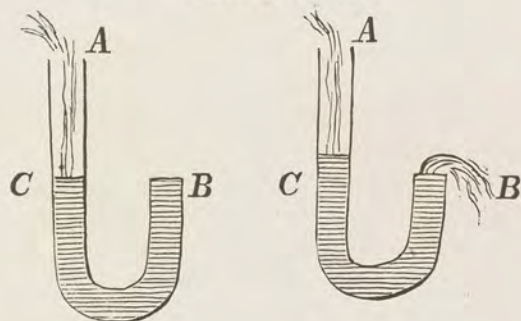
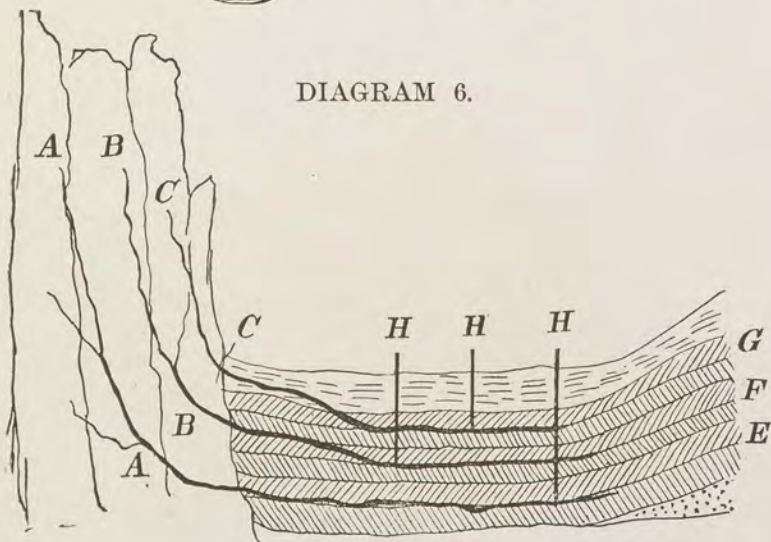
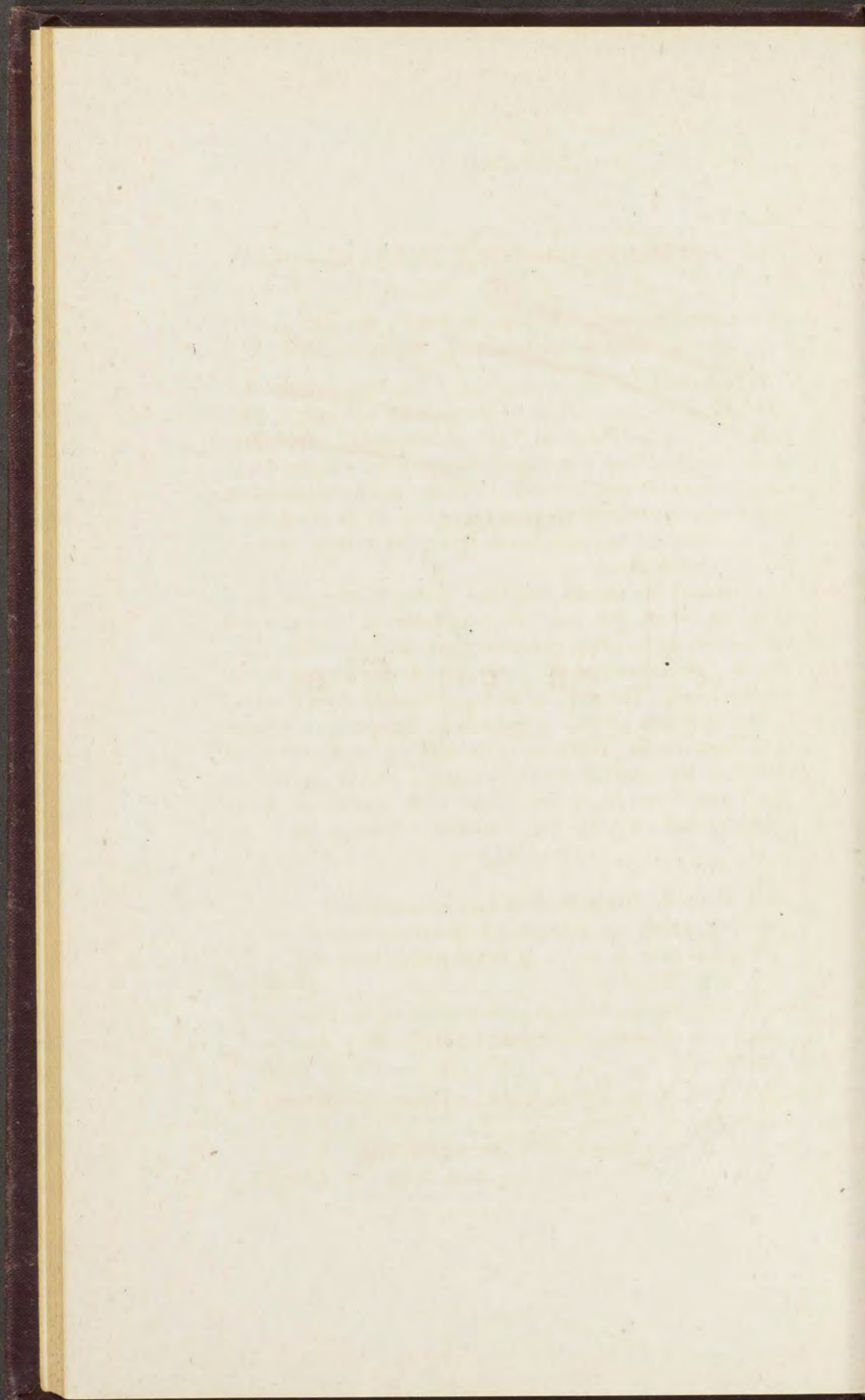


DIAGRAM 6.





THE "STUDENT'S COMPLETE MINERAL COLLECTION."

ACCOMPANIED BY DANA'S MANUAL OF MINERALOGY AND PETROGRAPHY; REVISED AND ENLARGED, 500 PAGES, 1887.

This collection, comprising three hundred species and sub-species, includes most of the salient and many of the rare minerals described in "Talks on Minerals." It contains cubes, octahedrons, dodecahedrons, trapezohedrons, cleavages of rhombic and hexagonal prisms, and crystallizations of the minerals which occur only, or mainly, in crystallized form. Many of the specimens illustrate to perfection the property of cleavage.

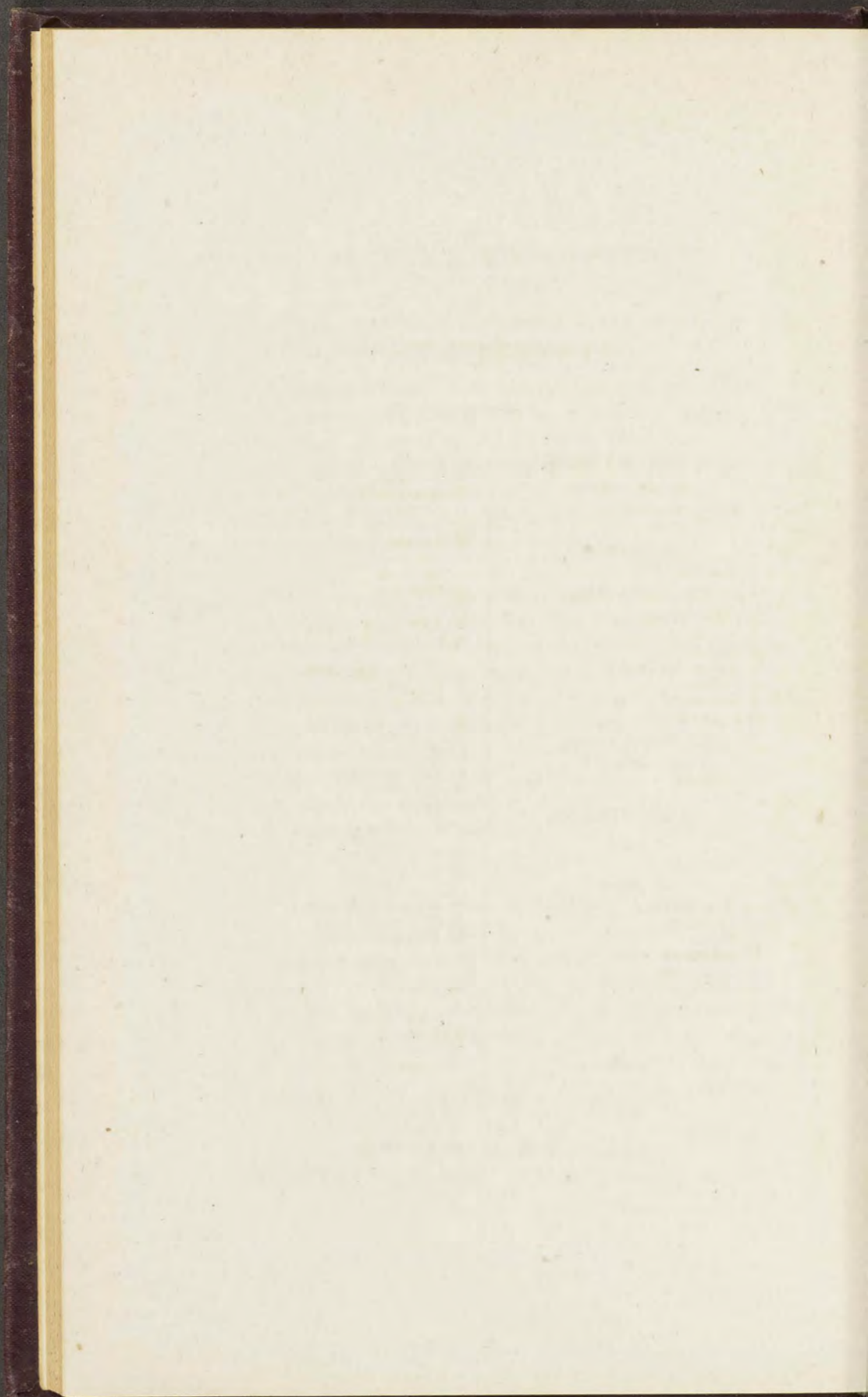
In massive specimens, numbers of the objects are duplicated, to show not only the contrasts in colors which the same mineral often possesses, but also other differences between individuals of the same species taken from different localities. The specimens are arranged as represented by the diagrams above. The name of the species is printed at the bottom, the numbers on the left are consecutive, and those on the right indicate the pages of the manual on which the descriptions are given. The specimens are of good size and are quite characteristic of the species.

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CONTENTS.

1. ACIDIC DIVISION.

I. Sulphur Group.

- 1 Native Sulphur
- 2 Molybdenite

II. Boron Group.

- 3 Sassolite

III. Arsenic Group.

- 4 Native Arsenic
- 5 Orpiment
- 6 Realgar
- 7 Native Antimony
- 8 Stibnite
- 9 Kermesite
- 10 Bismuthinite

IV. Carbon Group.

- 11 Diamond, octahedral
- 12 Graphite

2. BASIC DIVISION.

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- 13 Native Gold

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- 39 Chrysocolla

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- 40 Galenite
- 41 Minium
- 42 Anglesite
- 43 Crocoite
- 44 Wulfenite
- 45 Pyromorphite
- 46 Vanadinite
- 47 Cerussite

VII. Zinc.

- 48 Sphalerite
- 49 Zincite
- 50 Smithsonite
- 51 Hydrozincite
- 52 Willemite
- 53 Calamine

VIII. Cadmium

- 54 Greenockite

IX. Tin.

- 55 Stannite
- 56 Cassiterite
- 57 Stream Tin

X. Titanium.

- 58 Rutile
- 59 Brookite
- 60 Percfskite

XI. Cobalt and Nickel.

- 61 Linnæite
- 62 Millerite

- 63 Smaltite
64 Cobaltite
65 Niccolite
66 Erythrite
67 Zaratite
68 Garnierite

XII. Uranium

- 69 Uraninite
70 Autunite

XIII. Iron.

- 71 Meteoric Iron
72 Pyrite
73 Marcasite
74 Pyrrhotite
75 Arsenopyrite
76 Leucopyrite
77 Red Hematite
78 Specular Iron
79 Micaceous Iron
80 Oolitic Iron
81 Menaccanite
82 Magnetite
83 Lodestone
84 Franklinite
85 Chromite
86 Limonite
87 Limonite pseudomorp
88 Yellow Ochre
89 Bog Ore
90 Goethite
91 Wolframite
92 Columbite
93 Vivianite
94 Dufrenite
95 Siderite

XIV. Manganese.

- 96 Pyrolusite
97 Braunite
98 Manganite
99 Psilomelane
100 Chalcophanite
101 Wad
102 Lampadite
103 Triphylite
104 Triplite
105 Rhodochrosite

XV. Compounds of Aluminum.

- | | |
|-----------------|--------------------------|
| 106 Corundum | } <i>Corundum Group.</i> |
| 107 Sapphire | |
| 108 Emery | |
| 109 Ruby | |
| 110 Diaspore | |
| 111 Gibbsite | |
| 112 Spinel | |
| 113 Gahnite | |
| 114 Chrysoberyl | |
| 115 Cryolite | |

- 116 Alunite
117 Amblygonite
118 Lazulite
119 Variscite
120 Turquois
121 Wavellite

XVI. Compounds of Cerium, Yttrium, etc.

- 122 Yttrocerite
123 Samarskite

XVII. Compounds of Magnesium.

- 124 Brucite
125 Nematite
126 Hydromagnesite
127 Polyhalite
128 Magnesite

XVIII. Compounds of Calcium.

- 129 Fluorite
130 "
131 Snowy Gypsum
132 Selenite
133 Satin Spar
134 Alabaster
135 Rose Gypsum
136 Anhydrite
137 Ulexite
138 Pricelite
139 Scheelite
140 Apatite
141 Phosphorite
142 Calcite
143 "
144 "
145 Dog Tooth Spar
146 Iceland Spar
147 Calcareous Tufa
148 Stalactite
149 Oolite
150 Aragonite
151 Mexican Onyx
152 Dolomite
153 Pearl Spar
154 Gurhofite

XIX. Compounds of Barium and Strontium.

- 155 Barite
156 Witherite
157 Celestite
158 Strontianite

XX. Compounds of Sodium.

- 159 Halite

3. SILICA AND SILICATES.

I. Silica.

QUARTZ.

- 160 Rock Crystal
161 Amethyst

- 163 Rose Quartz
- 163 False Topaz
- 164 Smoky Quartz
- 165 Milky " "
- 166 Ferruginous Quartz
- 167 Chalcedony
- 168 Chrysoptase
- 169 Carnelian
- 170 Sard
- 171 Agate
- 172 Moss Agate
- 173 Onyx
- 174 Sardonyx
- 175 Jasper
- 176 Heliotrope
- 177 Basanite
- 178 Silicified Wood
- 179 Fleches d'amour

OPAL.

- 180 Precious Opal
- 181 Semiopal
- 182 Hyalite
- 183 Wood Opal
- 184 Geyselite
- 185 Tripolite

II. Silicates.

A. ANHYDROUS SILICATES.

I. Bisilicates.

- 186 Enstatite
 - 187 Wollastonite
 - 188 Malacolite
 - 189 Coccoilite
 - 190 Jeffersonite
 - 191 Rhodonite
 - 192 Spodumene
 - 193 Petalite
 - 194 Tremolite
 - 195 Actinolite
 - 196 Asbestos
 - 197 Nephrite
 - 198 Pargasite
 - 199 Hornblende
 - 200 Anthophyllite
 - 201 Crocidolite
 - 202 Beryl
 - 203 Emerald
 - 204 Aquamarine
- } *Pyroxene Group.*
- } *Hornblende Group.*
- } *Beryl Group.*

II. Unisilicates.

- 205 Chrysolite
 - 206 Tephroite
 - 207 Garnet
 - 208 Cinnamon Stone
 - 209 Pyrope
 - 210 Melanite
 - 211 Polyadelphite
 - 212 Ouvarovite
 - 213 Zircon
- } *Chrysolite Group.*
- } *Garnet Group.*

- 214 Vesuvianite
 - 215 Epidote
 - 216 Allanite
 - 217 Zoisite
 - 218 Axinite
 - 219 Danburite
 - 220 Iolite
 - 221 Muscovite
 - 222 Plumose Mica
 - 223 Lepidolite
 - 224 Phlogopite
 - 225 Lepidomelane
 - 226 Biotite
 - 227 Wernerite
 - 228 Nephelite
 - 229 Elæolite
 - 230 Cancrinite
 - 231 Sodalite
 - 232 Lapis Lazuli
 - 233 Leucite
 - 234 Anorthite
 - 235 Labradorite
 - 236 Oligoclase
 - 237 Sunstone
 - 238 Albite
 - 239 Cleavelandite
 - 240 Microcline
 - 241 Orthoclase
- } *Epidote Group.*
- } *Mica Group.*
- } *Feldspar Group.*

III. Subsilicates.

- 242 Chondrodite
 - 243 Tourmaline
 - 244 Rubellite
 - 245 Indicolite
 - 246 Andalusite
 - 247 Chiastolite
 - 248 Fibrolite
 - 249 Cyanite
 - 250 Topaz
 - 251 Datolite
 - 252 Titanite
 - 253 Staurolite
 - 254 Schorlomite
- } *Tourmaline Group.*

B. HYDROUS SILICATES.

I. General Section.

- 255 Radiated Pectolite
- 256 Fibrous Pectolite
- 257 Apophyllite
- 258 Prehnite
- 259 Chlorastrolite

II. Zeolite Section

- 260 Thomsonite
- 261 Natrolite
- 262 Analcite
- 263 Acadialite
- 264 Harmotome
- 265 Stilbite
- 266 Heulandite

<i>III. Margarophyllite Section.</i>		288 Margarite
267 Talc	} <i>Talc Group.</i>	289 Seybertite
268 Steatite		
269 Rensselaerite		
570 Pyrophyllite		
271 Sepiolite (Meerschaum)		4. HYDROCARBON COM- POUNDS.
272 Glauconite		<i>I. Simple Hydrocarbons.</i>
273 Serpentine	} <i>Serpentine Group</i>	290 Ozocerite
274 Amianthus		
275 Picrolite		
276 Deweylite		
277 Genthite		<i>II Oxygenated Hydrocarbons.</i>
278 Kaolinite		291 Amber
279 Margarodite	} <i>Hydro-mica Group.</i>	<i>III. Asphaltum and Mineral Coals</i>
280 Damourite		
281 Cookeite		
282 Chlorophyllite		
283 Vermiculite	} <i>Chlo- rite Group.</i>	292 Asphaltum
284 Jefferisite		
285 Protovermiculite		
286 Ripidolite		
287 Prochlorite		
		293 Albertite
		294 Anthracite
		295 Anthracite, iridescent
		296 Bituminous Coal
		297 Cannel Coal
		298 Lignite
		299 Jet
		300 Native Coke



