OUTLINE SKETCH OF THE MOST VALUABLE MINERALS OF INDIANA.

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The most valuable deposits found in the rock formations of Indiana may be described briefly as follows:

INDIANA KAOLIN.

In the Fifteenth Report of this Department, the State Geologist gave a clear and concise paper suggesting the origin and composition of the kaolin beds of this State. Since then the subject has received a careful re-examination from every point of view, and although the conclusions first arrived at have been very generally maintained, it has been considered proper to record briefly the best possible outline of the subject as it is now understood.

First, to those who have not made chemistry and geology, with their kindred sciences, the subject of careful study, it is necessary to give some cardinal rules governing the dissolution and rearrangement of sedimentary rock formations under the action of water and other natural agents.

Rain water is the greatest destroyer of rocks; the atmosphere comes next. The operation of these forces is two-fold chiefly. Mechanical destruction is brought about by mere gravitating motion; chemical destruction comes on by reason of a motion generated by the subtle action of one substance upon another tending to dissolve, disintegrate and dissipate. On the other hand mechanical reformation is by sedimentary deposit, while chemical reformation is through molecular re-arrangement by the laws of chemical affinity.

A practical example of the mechanical destruction of a rock would be the case of a limestone or a sandstone which, when exposed to the action of rain water, is slowly dissolved and washed away in the form of fine particles. If these particles be afterwards deposited and form themselves into a compact body by the force of their own weight we shall have a case of mechanical reformation.
A practical example of the chemical destruction of a rock would be where a limestone or a sandstone is acted upon by an acid agent causing molecular disintegration. Chemical reformation is the coming together of the ultimate molecules of disintegrated substances by the laws of affinity.

The salts of iron can be taken up in water which, when exposed to the oxygen of the atmosphere, deposits the iron in the form of oxide, as is witnessed by the yellowish sediment of all our chalybeate springs. In a similar way silica is solved by water and afterward deposited in the form of crystals, flint nodules, silicified wood, etc. Lime, alumina, magnesia and many other substances are subject to the same or kindred processes.

Chemically speaking, the kaolin of the Indiana deposits is a silicate of alumina, bearing but slight traces of iron, lime and other substances. For all practical purposes it is a pure silicate of alumina.

It is found underlying the conglomerate sandstone, and occupying the space which otherwise is filled with a stratum of limestone; in other words, it has usurped the place of the limestone. Professor E. T. Cox, formerly State Geologist of Indiana, was the first to suggest that the kaolin owes its origin to the destruction and the chemical reformation of the limestone; but this theory did not go far enough to account for all the elements of the problem. Under the conditions propounded the almost total absence of lime in the clay and the heavy per cent. of silica and alumina could not be explained. What went with the lime from the dissolved limestone stratum? Why was it not redeposited on the spot along with the silica and the alumina? Furthermore, whence came such a wonderful amount of the last two substances? In the first place, moreover, the fact arose that here was a deposit of clay entirely filling up the space formerly occupied by the limestone, and since a whole is greater than any of its parts, it was impossible that the limestone had furnished all the material for the clay with all its original lime and iron to spare.

With the above-stated questions in view, the whole problem has been analyzed, and every fact bearing upon it has been scrutinized with all the care possible, more particularly because no feature of Indiana geology has attracted wider attention or given rise to more curious inquiry.

To understand the matter at the outset, let us try to get a view of the local situation as it was before the kaolin beds had begun to be deposited, after which we shall be able to follow the process of deposition.

In the beginning, then, we have a stratum of limestone of a soft and destructible nature, immediately above which lies a massive sandstone formation of coarse grain and loose texture.

Everybody knows that rain-water will percolate easily through massive coarse sandstone, and in this case it did so percolate, and thus reach the underlying limestone which it slowly destroyed, the first step being the
bearing away of the lime and iron, these being the elements most readily
affected by the water. The residuum now left of the limestone is com-
posed of silica and alumina; meantime the water passing through the
sandstone has been taking therefrom silica and alumina, with a trace of
mica in a fine state of mechanical division, and bearing them down to the
cavity below, where by chemical action they combine with the silica and
alumina left over from the destruction of the limestone. Thus, in short,
was the kaolin of Indiana made.

The above theory is perfectly borne out by all the facts yet discovered
bearing upon it. If proof is asked for in justification of the assertion
that water passing through sandstone will take up silica and redeposit it
at a lower horizon, we may cite the flint beds found underlying the mas-
sive sandstones in so many places. In Tippecanoe County, and in War-
ren and Fountain counties, are notable examples of these flint deposits,
due to the action of water passing through the conglomerate sandstone.
In the southern part of the State such deposits lie below many of the
carboniferous sandstone strata. Chert or flint nodules and so-called veins
occur (in all our limestones) where the silica has been deposited in cavities
left by the previous solution and removal of easily destroyed substances.
In each of these cases if the alumina had been present we should have
had kaolin in the place of flint bodies. As has been shown in another
part of this report there are places in the drift formations where the silica
and alumina of the bowlder till has been taken out by water and deposed-
it in the form of a white kaolin-like clay often of great thickness. In
a gas well of Boone County a stratum of this white clay was found to be
over a hundred feet thick. In Kosciusko County a vast bed is reached
at a comparatively slight depth underlying the bowlder clay. These drift
deposits of so called kaolin bear a heavy per cent. of lime carbonate, and
are more or less touched with iron oxide. In some places carbonate of
magnesia is a large element of the clay. So it will be seen that wherever
water percolates through a formation it gradually removes a large amount
of the soluble constituents. Lime goes first, magnesia next, then alum-
ina, then silica, and whenever the two last mentioned come together they
blend chemically and form the silicate of alumina, which, in Indiana, has
been named kaolin.

In the case of lime taken up by water the redeposit is in the form of
chalk, like that which in the northern part of the State is known as lime
marl.

The kaolin of Indiana differs from that of many other districts of the
world in that it bears very little mica, and no discoverable evidences of
having been formed directly from the dissolution of granite or other
primitive rocks.

The deposits of kaolin in Lawrence County cannot be mentioned too
often. Here lies a practically exhaustless quantity of the most beautiful,
pure and desirable clay ever offered to the manufacturer of fine earthen wares, to say nothing of its value in various other branches of manufacture. Next to our coals our natural gas and our building stones these magnificent beds of kaolin will in the future be the greatest source of our mineral wealth.

The only way to build up the varied interests of Indiana is to make the world familiar with our resources. This is not the work of a day, a year, or a decade, but it must come of long, persistent, continuous advertising. It was many years after our coal fields were discovered before the commercial and manufacturing world could be made to believe that any paying coal mines could be opened in this State, and now, after years of reiterated statement the kaolin beds of Indiana are scarcely recognized, so timid is capital and so conservative and reticent are the owners of the valuable mines. It is, however, a mere question of time, patience and persistent energy; such resources are a mighty reserve of wealth.

INDIANA BUILDING STONE.

From Greencastle, in Putnam County, southward to the region of the Ohio River stretches a vast area under which lies the oolitic limestone whose fame as an incomparable building material is beginning to be known all over the country. Within a few years' time the quarrying interests have been developed to such an extent that the superb blocks of oolitic limestone are seen on nearly every railroad in the land, and an immense capital has found most profitable and permanent investment.

This rock is an element of the St. Louis group showing itself in a massive, evenly bedded stratum of homogeneous limestone, of a whitish gray color, whose grain, viewed casually, has the appearance of a rather coarse sand loosely cemented together. Upon careful examination with the glass, however, this grain proves to be infinitesimal shells and shell fragments all bound together by a firm and even setting of lime carbonate. No art of man could construct a mass at once so firm, even and workable, and at the same time so elastic and strong. The stone comes from the quarry soft, tough and easily cut. In a short time it hardens so that it rings with a musical note (like that from a steel bar) when struck with the hammer. A bar of it four feet in length and two inches square may be bent so as to deflect greatly, and when released will spring back to a right line with the promptness and energy of highly tempered steel. Upon being broken the stone parts with a smooth, direct fracture, showing a surprising evenness and continuity of texture with no trace whatever of laminous seams or changes of structure. The Capitol building at Indianapolis shows the wonderful qualities of this superb stone, and every passer-by may see how beautiful, how massive and how well suited to building purposes it is. Our quarries have made the building
one to be proud of, and in turn the building is an imperishable monument to the resources of our quarries.

Geologically the oolitic limestone is very interesting, and its existence is by no means a problem easy of solution. The more it is studied, however, the more it appears to be the result of calcareous sediment deposited at the bottom of a deep trough in an elsewhere shallow sea. The shells of which the greater portion of the rock is composed, are, as a rule, much smaller than the smallest ordinary pinhead; indeed, barely distinguishable under the most favorable circumstances by the unaided eye. These minute shells are cemented together with a cement composed of fine fragment-dust of other shells, and an intermediate setting of pure lime carbonate, which renders the whole mass perfectly homogeneous, elastic and resonant.

The name, oolitic, as applied to this element of the St. Louis group of rocks, is not technically a proper one, but it is sufficiently distinguishing for practical purposes. On the northern verge of the field the limestone loses the oolitic grain in a degree, but it remains, nevertheless, a building-stone of the highest value and beauty. There can be no favoring distinctions made in this report between the various quarries of the region; in every locality examined the stone is simply perfect in its qualities. Doubtless there are exceptions to this general rule, but the careful inquiries of the Department have failed to discover them. It is safe to say that the oolitic limestone quarries of Indiana can challenge boldly the competition of the world. Indeed, the challenge has gone forth already, and, in consequence, the beautiful and indestructible material is reaching all parts of the continent where permanent buildings are being erected. No estimate can be made of the future extent and profit of this great deposit. Time alone can disclose the wealth it holds for the enterprise and industry of our State.

SANDSTONE OF INDIANA.

Wherever the rocks of the lower coal-measures are at or near the surface massive and evenly bedded, sandstones are apt to be found, and among these appear strata of the most beautiful building stone.

From Warren, Fountain and Montgomery counties southward these sandstones outcrop along the dividing line between the coal-measures and the sub-carboniferous rocks. In consistency, the sandstones of the Chester group are quite often very similar to those of the lower coal-measures, but the latter are more apt to be homogeneous, elastic and durable.

Geologically, all our sandstones mark the sites of ancient shore-lines, and the vegetable fossils found in them show that they are the flotsam and jetsam of seas more or less shallow and stormy. Extinct species of shore plants and marsh grasses are found in fragmentary and obscurely preserved traces. The more plainly marked species represented by
broken and flattened stems of *calamites* are found embedded in the coarser grained and loosely cemented parts of the rock, while the vague markings of the obscure species are found usually in the more compact and even-grained strata.

The composition of our best sandstone is quartz in the form of irregular fine crystal particles cemented together with great evenness and firmness. It comes out of the quarry soft and easily workable, but soon hardens to the consistency of the best elastic and resonant building material. I have seen it cut from the outercrop with a common ax, and readily hewn into any desired shape; in a few days it had set and become so hard that a bush hammer would ring upon it as if struck upon bell metal, emitting sparks freely. The hardest tests have shown the qualities of this stone to be surpassed by no other sandstone in the world, and it is a matter of surprise that it has not been more used. No doubt the future will see the development of this valuable and beautiful source of wealth.

**Indiana Coals.**

No formal report upon our coal deposits is needed here unless it could include the results of a resurvey of the field, a thing much needed, but which has been impossible under existing circumstances. Practically inexhaustible, easily mined and of the very best quality, our coals are the most desirable of their kind in the world. The number of workable veins is remarkable, and the coal itself varies in character from a pure cannel coal to what has come to be known as "block coal" all over the country. While we have no anthracite, the extraordinary quality of the block coal sets it above every other bituminous variety. The mines of this coal in Clay County afford immense quantities and are worked with great skill by the operators. Still it must be said that as yet our coal fields are in the early infancy of their profitable development, and it requires no gift of prophecy to foresee what coming years have in store for the owners of our exhaustless mines.

At present the equilibrium of manufacture is disturbed by the advent of natural gas as a great new factor, and it will require some time and experiment to determine just the limit between it and coal. It is natural that for a season the rush should be to the gas fields pell mell without any careful weighing of the facts in advance. One thing favors coal in this race for supremacy: we know that it is practically inexhaustible, while the supply of gas must be left in doubt with the weight of probability on the side of a comparatively early failure. The form of our fuel may change permanently, but it is to our coal beds that we must look as our base of permanent supply, for a long time to come.

When it is borne in mind that we have a coal area of almost seven thousand square miles, under which there are in many places several suc-
CESSIVE WORKABLE VEINS, THE ENORMOUS VALUE OF THE DEPOSIT BECOMES APARENT.

THE READER IS REFERRED TO THE FIFTEENTH REPORT OF THIS DEPARTMENT FOR A GEOLOGICAL SKETCH OF THE COAL MEASURE ROCKS AND A CONCISE EXPOSITION OF THE THEORY TOUCHING THEIR DEVELOPMENT.

COAL OF EXCELLENT QUALITY, AND OFTEN IN INEXHAUSTIBLE QUANTITY, IS FOUND IN THE FOLLOWING COUNTIES OF INDIANA: POSEY, VANDERBURGH, WARRICK, SPENCER, PERRY, CRAWFORD, GIBSON, PIKE, DUBOIS, KNOX, DAVIESS, MARTIN, SULLIVAN, GREEN, CLAY, OWEN, VIGO, PARKE, VERMILLION, FOUNTAIN AND WARREN. IN MANY LOCALITIES THE MINING IS BY THE PROCESS KNOWN AS "DRIFTING," BUT THE LARGER PART IS BY A SYSTEM OF SHAFTING. THE MINES OF INDIANA ARE BY LAW KEPT WELL VENTILATED AND DRAINED.

INDIANA IRON ORES.

COMPARED WITH THOSE OF OTHER PARTS OF THE COUNTRY, THE DEPOSITS OF IRON IN INDIANA ARE INSIGNIFICANT AND INFERIOR, THOUGH WE HAVE SOME BEDS OF EXCEEDINGLY FINE ORE. MOST OF THE SWAMP REGION OF THE KANKAKEE COUNTRY HAS CONSIDERABLE DEPOSITS OF BOG IRON; THESE WERE FORMERLY WORKED SUCCESSFULLY AT SEVERAL POINTS, BUT AT PRESENT THEY ARE ABANDONED PRACTICALLY. NEARLY ALL THE COAL-MEASURE COUNTIES HAVE IRON ORES IN WORKABLE QUANTITIES AND OF GOOD QUALITY WHEN MIXED WITH FOREIGN ORES, AND THE PRESENCE OF LIME AND COAL MAKES IT PRACTICABLE TO MANUFACTURE A GOOD GRADE OF IRON WELL WITHIN A PAYING MARGIN OF PROFIT. IN CLAY AND VIGO COUNTIES ESPECIALLY FURNACES HAVE BEEN QUITE SUCCESSFUL, BUT THIS HAS BEEN DUE MUCH MORE TO THE EXCELLENT COAL NEAR AT HAND THAN TO ANY LOCAL DEPOSITS OF ORE.

INDIANA LIME AND CHALK.

FINE LIMESTONE FOR BURNING INTO LIME IS FOUND IN NARROWLY EVERY NEIGHBORHOOD WHERE THE STRATIFIED ROCKS ARE OUTCROPPING. FROM AS FAR NORTH AS MONON AND DELPHI SOUTHWARD TO THE OHIO RIVER, KILNS HAVE BEEN ERECTED AND THE MANUFACTURE OF LIME MADE VERY PROFITABLE. THE PRODUCT IN MOST Instances IS EXTRA FINE AND VERY POPULAR IN THE MARKET.

AS YET THE MANUFACTURE OF CEMENTS HAS NOT BEEN GIVEN THE ATTENTION WHICH THE PROSPECTS OF SUCCESS WOULD WARRANT. AMONG OUR WIDELY VARYING DEPOSITS OF LIMESTONE EVERY QUALITY IS TO BE FOUND, FROM A PRACTICALLY PURE CARBONATE OF LIME DOWN THROUGH ALL THE SHADES OF IMPURITY TO THE SILICEOUS AND ALUMINOUS SHALES THAT BEAR A MINIMUM OF CALCEROUS MATTER. SPECIAL INVESTIGATION WOULD DOUBTLESS DISCLOSE TO THE PROSPECTIVE MANUFACTURER, AT ONE POINT OR ANOTHER, JUST THE MATERIAL SUITED TO HIS PARTICULAR NEED.

PROFESSOR GORBY, IN HIS REPORT ON THE GEOLOGY OF WASHINGTON COUNTY, DESCRIBES IMMENSE DEPOSITS OF CEMENT ROCK OCCURRING AT SEVERAL PLACES IN THAT COUNTY. INDEED, IT IS SAFE TO ASSUME THAT HYDRAULIC CEMENTS CAN BE SUCCESSFULLY MANUFACTURED AT MANY POINTS IN INDIANA.
The survey has not yet reached the northern counties of the State wherein are found the considerable deposits of chalk, or so-called lime-marl, but from specimens of this substance examined recently it would appear that by the addition of the proper amount of clay a fine hydraulic lime, or cement, might be made from it.

Wherever beds of magnesian limestone are found the rock may be examined and tested with a view to determine its hydraulic qualities. A simple test may be made with acid. If the residuum after dissolving is a jelly-like silicious mass it is evidence that the stone has hydraulic qualities.

The best combination of substances for hydraulic purposes would be nearly this:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>56</td>
</tr>
<tr>
<td>Alumina</td>
<td>36</td>
</tr>
<tr>
<td>Oxide of iron</td>
<td>8</td>
</tr>
</tbody>
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The oxide of iron is of no value, but is rarely absent from the impure limestones sought after for the manufacture of hydraulic lime and cements.

Recently attention has been directed to our limestones in connection with the manufacture of Portland cement, but as yet little progress has been made, though every fact would indicate the certainty of success under a properly directed experiment. The agent of a German company has been prospecting with a view to locating a manufactory where the presence of proper materials and the best facilities for transportation are to be found. It is hoped that the effort will end in the success which would insure the establishment of a new and paying industry in Indiana.

The Portland cement of England is made by calcining together, in certain proportions, chalk and the clayey mud of the river Thames. It is scarcely to be doubted that our chalk beds could be utilized for the same purpose successfully after a little experiment necessary to discover the proper formula for the addition of clay. In connection with the oolitic limestones there are various grades of magnesian and clay strata which offer very promising subjects of study with this object in view. It is to be hoped that the impetus given to manufactures by the discovery and development of our fields of natural gas will add strength to the movement toward a general development of the mineral resources of the State.

When the survey reaches, as it soon must, the area in which lie the chalk deposits, an exhaustive examination of these will be made with confidence that a new and very rich element of wealth may be developed in time. The manufacture of farm and garden fertilizers will soon claim attention in this State, and these chalk deposits may prove to be immensely valuable in this connection.

Geologically considered the chalk beds of Indiana are exceedingly interesting on account of the difficult problem arising out of the nature
and mode of their deposit. To find a vast lenticular mass of almost pure carbonate of lime lying in a basin scooped in the boulder clay, and covered with a heavy deposit of swamp mud, presents a question not as easily disposed of as might at first be supposed, nor is it my purpose to attempt its solution at this time. Doubtless the main element of the problem lies in the fact that water surcharged with calcareous matter will, when perfectly still, let fall the overweight of its burden, which will at once sink to the bottom. The evaporation of water will gradually overcharge the residue, because the entire body of foreign matter is retained, while the body of the water is shrinking. Still there are other elements of difficulty connected with the inquiry which appear at present scarcely reconcilable to any general scheme of solution. The present chief of this department has suggested a theory which may prove to be the correct one, namely, that a long period of drought, a rainless era, followed the withdrawal of the glaciers and that a season of evaporation must have been accompanied by a vast amount of sedimentary precipitation. This fully accounts for the purity of the lime deposits where otherwise we should have it mixed with all manner of clayey washings from surrounding surfaces affected by rain and superficial drainage. The author of this theory further suggests that much of the precipitation of chalk may have gone on while the water was covered with ice, and that the deposits were thus protected from the invasion of surface washings and other alien matter.

OTHER MINERALS AND ORES.

Natural gas, for the reason that it is fully treated in another part of this volume, will not be more than mentioned here. The reader is referred to Professor Gorby's able and comprehensive paper.

Gold is found in the form of minute spangles and scales in many drift areas, but nowhere in this State is there a quantity sufficient to make a search for it profitable in any degree. Traces of silver have been discovered in some of our limestones, and here and there small quantities of lead have been reported. Copperas exists in considerable deposits in various parts of the southwestern region of the State. Iron pyrites is plentiful. In all the coal region fire-clays of most excellent quality abound, and in nearly every county of the State good brick and farm tile clay is plentifully present. Indeed, it may be said with confidence that few States in this Union are blessed with a richer or more varied wealth of mineral deposits than is vouchsafed by the as yet undeveloped resources of Indiana. When the population of our State shall have doubled and trebled itself the exigencies of an advancing civilization will enforce the most economical and scientific use of all this hidden treasure. The labors of this Department from year to year have stimulated a wholesome spirit
of inquiry and experiment, so that in our schools and colleges the practical study of geology and its kindred sciences has become a prime favorite with many of the brightest and most energetic students.

The future of mineralogy and metallurgy doubtless depends much upon the simplification and perfection of methods for reducing ores and cheapening the manufacture of refined metals. The common clays of the earth are rich with a metal which, if it could be produced and rendered as cheap as iron, would revolutionize, in a large degree, the whole world of manufacture. This metal is aluminium, which occurs in the form chiefly of silicate of alumina, although the anhydrous forms, like the crystals, ruby, sapphire and corundum, appear in certain parts of the world and are much sought after for gems.

It is admitted by men of science everywhere that aluminium is almost the ideal metal, barring the difficulties attending its production, for a practically countless variety of economic purposes. In the first place it is extremely light, having a specific gravity, even when condensed by hammering, of only 2.87, and then its malleability, its ductility and its strength render it singularly desirable. As yet no process has been discovered for cheaply separating it from the clay and aluminous shales in which it is so abundant. Here is a problem for the genius of our time. What young man will cover himself with glory and send his name forever down the future by overcoming the difficulty which bars this greatest of all metals away from the eager hands of the nineteenth century people?

One of the highest functions of our educational institutions should be to keep problems like this constantly before the eyes of the young, energetic and ambitious students who will be easily persuaded to devote themselves to systematic and patient experiment, having in view the attainment of a crowning victory which of itself would give to our civilization the greatest impulse it has received since the application of steam to commerce and manufacture. An investigator of Edison's stamp would find a field of wide possibilities in subduing a problem of such importance; nor is there any good reason for believing that the undertaking offers greater resistance to genius than did the electrical problems so readily mastered by the efforts of Edison.

The manufacture of alum and sulphuric acid might, it seems, be made quite profitable at many points in Indiana; and attention can not be too often called to our deposits of aluminous clays and shales.