THE CLAYS OF INDIANA

I.

KAOLIN AND OTHER CLAYS.

The word *Clay*, when used in economical mineralogy, signifies mineral matter in a finely divided state, capable of being rendered plastic by the addition of water, and of retaining its shape when manipulated or moulded.

The color of clay varies from pure white through many shades of gray, brown, blue, greenish and yellow to black. Metallic oxides (when present) determine the color. The oxide of iron is, perhaps, the most common impurity, causing the clay to burn red. Clays are, chemically speaking, hydrous silicates of alumina.

Kaolin, or *China Clay*, is the purest form of clay. When found in its best state its elements are:

Silica	46.3
Alumina	39.8
Water	13.9

Examined under the microscope some kaolin is found to contain scales or six-sided crystalline flakes of a pearly appearance which have been determined by Johnson and Blake as belonging to a mineral substance named *Kaolinite*. This mineral substance is a hydrated silicate of alumina, and forms, it has been claimed, the basis of pure kaolin. Spangles of mica are often present in this clay.

The name *Kaolin* appears to have been derived from the Chinese Kaoling, the name of a mountain where China clay was found in large quantities at a very early date. Not far from the beginning of the eighteenth century kaolin was introduced into Europe. Soon afterward beds of it were discovered in England and on the continent, and later in America.

The porcelain clays (*terre á porcelaine*) of China and Japan are nearly pure white, very unctuous to the touch and contain considerable traces of mica, while those of Saxony are tinged with a yellow which disappears before heat. Near Limoges, in France, at Saint Yrieix-la-Perche, kaolin is found in beds of granite or feldspathic rock. It is fairly white, containing scarcely any mica, and can be used without the addition of any flux. So in England fine beds of kaolin are found in Cornwall and Devonshire. The clay is soft, unctuous to the touch, very white and of excellent quality for pottery.

The French, German and English scientists are pretty well agreed that most of the kaolins are the result of the decomposition of the feldspar which is a constituent of granite, though the theory has been questioned, and even assailed by high authority. The chief difficulty to overcome, in view of the facts, is to account for the process of disintegration and deposit. Granite is composed chiefly of feldspar, mica and quartz, with irregular additions of hornblende and schorl. Now, if the feldspar is decomposed to form the clays, what becomes of the other constituents? Of course they enter into the mass of the clay, is the answer; but upon careful examination we can find no evidence of any rule of deposit. In other words, say the scientists, gravitation appears to have had nothing to do with the arrangement of the mass. The reduction appears to have been mechanical, so far as those clays are concerned which have been derived from granite, but some fine white clays have been found formed from the chemical destruction of calcareous rock by water bearing carbonic acid, a process which would leave the silica, alumina and magnesia contained in such rocks in the form of an insoluble, impalpable powder. As might be expected, clays derived thus chemically from limestones will be found of every grade between a coarse marl and the finest plastic material. It is rarely free from iron in some form, from which its color is, as a rule, derived.

All forms of plastic clay may be described generally as composed of silicate of alumina, magnesia, free silica and alumina, with water in combination. Carbonaceous matter is sometimes present.

Some kaolins contain a strong proportion of pebbles and gritty matter, while others are fine and soft as flour.

The presence of iron in any form injures the clay for the purposes of manufacturing fine white pottery or porcelain, but it is valuable as a pigment or coloring matter when the clay is used for encaustic tiles, terra cotta work, or coarse pottery and brick.

Calcareous matter is injurious to clay. The presence of carbonate of lime in an undesirable quantity may be known by the clay effervescing in acid.

Kaolin exists in Indiana, covering with its beds a large area and presenting various grades of fineness and color from a pure white impalpable powder to a red or brown-red, gray, whitish, greenish and bluish clay, unctuous to the touch, and perfectly plastic and ductile when softened and mixed with water. The colored kaolins are all iron-bearing. The gray clays owe their color to protoxide of iron chiefly, while the brown and reddish-yellow clays are probably all tinged by the hydrous sequi-oxide of iron. Some of the kaolins having a pale buff tinge may owe their color to matter other than iron oxide, in which case they may burn out perfectly white.

The white kaolin of Indiana has had the name Indianaite proposed for it, but I can see no need for the word from any point of view, especially seeing that it has neither *raison d'etre* nor appropriateness to recommend it, to say nothing of its disagreeable sound. It is kaolin, nothing more, nothing less, having the following parts, according to analysis of one specimen:

Silica		46.
Alumina		40.20
Lime	Trace	.20
Magnesia	"	
Water		12.62

This shows a very small difference from the average of kaolins all over the world; especially is it near to the clay of Cornwall, in England, and that of Trenton, New Jersey. Compare it with that of Saint Yrieix-la-Perche, in France:

Silica	48.37
Alumina	34.95
Oxide of Iron	1.26
Soda and Potash	2.40
Water	12.62

In fact this so-called *Indianaite* differs no more from other kaolins than they differ from each other.

Professor E. T. Cox gave the following as an analysis of kaolin from Lawrence County:

Silica	45.90
Alumina	40.34
Lime	Trace.
Water	12.26

Compare the following analysis of kaolin from Cornwall, England:

Silica	46.32
Alumina	39.74
Oxide of Iron	.27
Lime	.36
Magnesia	.44
Water	12.26

Or the following from the beds of Trenton, New Jersey:

Silica	45.30
Alumina	37.10
Oxide of Iron	1.30
Lime and Magnesia	.39
Potash	1.30
Zirconium	1.40
Water	13.40

But analyses will differ appreciably, even when they are all made of clays from the same deposits, on account of the presence or absence of impurities either accidental or constitutional.

It was long ago settled that certain of the white clays have been formed by chemical decomposition of limestone, as I have said. In England, mineralogists and geologists have referred the white clays of the Lower Tertiary to this origin, and Prof. Cox has rightly suggested that our kaolins are the result of the chemical action of carbonated water upon beds of limestone.

After all, it is not in the least strange that clay, formed of the remains of silicious rocks disintegrated by mechanical means, should be almost identical with clay resulting from the chemical destruction of silicious rocks. Feldspar, quartz, mica, and the other occasional silicates that make up granite, may, upon the disintegration of the rock by the decomposition of the feldspar, form themselves into a mass consisting of mica, quartz and clay. So the chemical destruction of the limestone by the acid may leave a residuum of silica, alumina and water, with traces of iron, lime, magnesia and perhaps other matter. When the silica and alumina chance to be in the proper proportion with the absence of iron, we have a fine kaolin, no matter whether it be from a granitic or a limestone source.

The kaolins of Indiana are found occupying the space which at other points is filled by a stratum of limestone in the Coal-Measure rocks. In Lawrence County the bed is next below the Conglomerate and occupies the place of a limestone which, not far away, is still seen in position. No doubt the lime rock had been so constituted in the first instance that its disintegration was easily accomplished by carbonated water, and, in the next place, the overlying sandstone was just the vehicle for conveying such water to the proper place for doing its work. Indeed, the limestone may never have been more than a porous marl in its consistency, with every condition present for the ready action of the transforming agent.

When I first began an examination of this subject I could not account for the large per centum of silica in the clay. The question arose thus: How could the chemical destruction of a stratum of Archimedes limestone furnish a clay nearly one-half silica, especially when the stratum of clay is so thick in proportion to the stone stratum destroyed? No answer of a satisfactory nature suggested itself. I felt sure that Professor Cox was right in his theory of the method by which the kaolin had been produced, but I was just as sure that he had not accounted for the presence of so much silica. In the first place it would require a large portion of carbonate of lime in the rock to insure disintegration under the action of acid-bearing water, and in the next place a limestone thus comparatively pure would have little silica in it. It must be remembered, however, that silica is taken up more readily by pure than by carbonated water, while the silicates of lime, magnesia and manganese are swiftly decomposed before the action of the latter. Warm rainwater doubtless has the power to slowly affect silica and take it up in solution even while percolating through sandstone in whose composition exists quartz, mica and feldspar in an infinitessimal state of pulverization. Various kinds of pseudomorphism result from the chemical destruction and re-arrangements of mineral matter by this action of water. Molecular affinity operates usually toward an imitation of some one of the minerals entering into the new combination. In the destruction of rocks by carbonated water the lime, magnesia, manganese, etc., are quickly separated. Iron held in the water in the form of carbonate is changed, upon evaporation, to peroxide. The silica and alumina will be combined and precipitated in the form of a powder, in which may be caught enough of the iron oxide to color it. With these truths in mind let us turn now to the geological conditions under which our kaolin is found. The constituency of this clay would lead us to expect that it would vary in appearance in different parts of the same bed, and upon examination this is found to be the case. The silica and alumina have combined in many proportions, from the finest white impalpable kaolin to a massive allophane on one hand, while on the other hand the product shades off from coarse, brown, somewhat gritty clay to a cherty, iron-bearing limestone, or calcareous shale. It is worth noting here that Professor Gòrby, while surveying the "flint beds" of Tippecanoe County, found a coarse, greenish-blue allophane associated with the other silicious deposits there.

The Conglomerate sandstone overlying the clay is a coarse, exceedingly open, pebbly "grit-stone," through which water now passes almost as freely as through a gravel bed. This massive sandstone has been formed from the *debris* of granite, gneiss and other metamorphic rocks ground up and deposited here. At the time it was deposited it no doubt contained a small per centum of feldspar and mica and some quartz, all in an infinitessimally fine state of mechanical separation. Now, the sandstone, being porous, freely admitted water, which, as it passed through, bore with it all this fine material by first dislodging the feldspar and thus loosing the mica and quartz dust. As the water acted upon the limestone below, decomposing it, it at the same time precipitated its load gathered from the Conglomerate above. Thus the silica came to overbalance the alumina. No doubt the action of the air had much to do, too, with the freeing of the impalpable dust of feldspar, mica and quartz from the body of the coarse Conglomerate. The percentage of mica in the clay is very small, barely perceptible, indeed, in the form of spangles observable at rare intervals with a high-power glass. Quartz occurs in occasional pebble-like grains and rarely in the most infinitessimal sand crystals.

The material of this white kaolin, when magnified under a microscope, has the appearance of many other flour-like chemical precipitates—a fluffy, fleecy, loosely concretionary texture—which one of my assistants graphically compared to that of the inner part of well-cooked "popcorn." In fact, the rounded concretion-like particles, into which the mass separates, are very much of the same appearance as those of lime marl, save that the latter are far coarser. I have not been able to detect the presence of the so-called "crystals of kaolinite" in this clay. The fact is the mineral is not there in the form described by Johnson and Blake, and I therefore suspect that the presence or absence of the "pearly scales" of *kaolinite* may mark the distinguishing line between clay formed by the decomposition of feldsathic rocks and that derived from the chemical destruction of limestones. Be this as it may, the kaolin of Indiana is, beyond question, the result of chemical action, aided by the addition of a certain amount of silica in the form of quartz and mica, in an impalpably fine state of mechanical division.

Although somewhat foreign to the subject of clays, I may well suggest here that many of the chert, flint and other silicious beds in this State (for instance, the great flint deposits of Tippecanoe County) are examples of the "leeching" of sandstones and other silicious rocks, and had the alumina been present we should have had kaolin in the place of the "flint beds." In every deposit that I have examined these flint or chert beds lie below massive sand rocks, and sometimes they usurp the space of a lime rock, as does the kaolin, and like it are associated with the greenish blue allophane.

The colored or tinted kaolins of Indiana appear to occupy parts of a greater area than does the white variety. They vary as much in quality as in color, but as yet I have not been able to complete my study of them. The coloring matter is iron obtained from the sandstone (just as I have shown that a part of the silica has been obtained) by means of water. These tinted clays would certainly make beautiful terra cotta work and most excellent pottery. Some of them would probably burn out nearly white, but most of them will burn reddish yellow. Many of these tinted deposits are quite as smooth and fine as the white. In places they are somewhat laminated, and have the appearance of steatite in color and consistency, but they contain no more than a trace of magnesia, while steatite shows about the following analysis:

Silica	62.14
Magnesia	32.92
Water	4.94

The white kaolin of Lawrence County is probably identical with the clay of Golconda, Ill., as its horizon is the same, and its similarity to that of New Jersey, is very close, though the latter is found in the Cretaceous rocks. The Ball clay of Missouri is much more silicious, and, further, its silica, as well as that of the New Jersey clays, is, in a larger ratio, free and "grainy."

The uses to which kaolin can be put are various. The making of chinaware and pottery of all grades is the chief, but brick and tiles of the most beautiful kinds, as well as fire-brick, and all manner of terracotta work, are made from it. It is also largely used in the manufacture of paper and alum, and in a number of other processes known to manufacturers.

The time must come when the vast beds of kaolin in Indiana will be of immense value. The exceeding purity of the white variety will especially recommend it.

The fire-clays underlying the coal-seams of Indiana are often of sufficient purity to answer the purposes of the potter and manufacturer of terracotta ware. These clays vary through a wide reach of composition. Some of them are extremly silicious. Incomparably fine fire-brick have been made from these clays.

Of the coarser clays, such as are used in manufacturing building bricks, little need be said. They are to be found in beds over almost the entire area of the State. A large part of the Drift clays, especially where not too sandy, is readily workable into brick and into tubular drain-tiles. In fact the manufacture of porous clay tile for subsoil land drainage has become an extensive and remunerative industry in Indiana, and has had a wonderfully invigorating effect upon agriculture and the health of our people.

But, to return to the finer clays. In Harrison County pockets of white kaolin were found in the "glass-sand" deposits. Doubtless this sand has served the same purpose as the Conglomerate in the formation of the kaolin. Indeed, as might be expected, large beds of flint are found in the same vicinity imbedded in silicious clay. There is also in Harrison County an immense deposit of tinted kaolin admirably adapted to the purposes of the potter and terracotta worker.

Owen County, too, has practically inexhaustible beds of the very best kaolin. The attention of manufacturers is especially directed to these deposits, and it is almost certain that other beds will be discovered. But the kaolin of Lawrence County, taken alone, is sufficient to build up and maintain for many years a manufacturing center as great as any of the pottery and porcelain establishments of England, France or Germany. It will pay the State of Indiana a good and lasting income to advertise her internal resources to the world. Her mineral wealth is to-day greater than that of many States whose gold and silver mines are the wonder of the world.