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To the Honorable, the Board of Geological Survey of Michigan:

Gentlemen—Herewith I transmit as Part I of Vol. VIII, a report by Dr. H. Ries of Cornell University containing the results of his examination of the clays and shales of the State in the summer of 1899, and his tests upon them last winter.

Although it does not pretend to be exhaustive in its description of the wealth of the state in these abundant materials, it seems to me to give a clear description of the more important and common kinds, and an interesting account of the uses to which they may be put. I trust it may prove of value.

> With great respect I am your obedient servant,
> ALFRED C. LANE,
> *State Geologist*.

CHAPTER I.
PROPERTIES OF CLAY AND SHALE.

§ 1. Origin of clay.

Clay is a familiar material and known chiefly by the curious property which it has of forming a pasty or plastic mass when mixed with water, allowing itself to be molded into any desired shape. It is mostly a fine, aluminous sediment that has been deposited on the bottom of lakes or seas. If nothing else were deposited on the top of this clay sediment before the lake evaporated or became drained, or before the sea bottom was lifted up and became dry land, the material would retain the soft plastic condition that many of our surface clays show.

Clays may, however, originate in another manner, viz.: by the decomposition of feldspathic rock *in situ*. The feldspar alters to the mineral kaolin, which is found in variable amounts in all clays. Such clays are known as residual clays, and so far as we know do not exist in any quantity in Michigan.* Very often, the clay, when deposited in the sea, becomes covered by many feet of other sediments of a different nature, and by the weight of these overlying beds it is pressed and consolidated into quite a firm mass. When this consolidation has gone sufficiently far to form a rock-like mass (using the term rock in a popular sense) of the material, we speak of it as shale. (That pressure alone will consolidate clay particles is seen when bricks are molded by the dry clay process.)

Sometimes the firmness and hardness of the shale is increased by mineral-bearing waters filtering through the mass and cementing more or less of it together.

Shale thus originates by the consolidation of clay under pressure, and, depending on the amount of pressure it has been subjected to and the amount of cementation of the particles that has taken place, we find variations from soft shales that crumble easily under the action of the weather to hard ones so dense and brittle that they appear and ring like slate. Indeed, shale is very commonly and erroneously called slate, especially when associated with coal; slate and shale, however, are two different materials.

Shale being of sedimentary origin was laid down or deposited in layers or beds, and it splits along these layers or planes of stratification. Furthermore, when it is ground up and mixed with water, it becomes a soft, pasty mass like clay, so that shale, simply denned, is clay which has become consolidated into a hard mass by pressure. Shales are often erroneously called slate, especially when they occur in association with coal. Slate, however, possesses no plasticity. It is a rock that has been formed from shale under the action of heat and pressure. These two agents have obliterated the original layers of stratification so that it no longer splits along them, but on the other hand a new direction of splitting has been produced, parallel to which the slate splits

evenly and readily. But what is even more important is that, if the slate be ground up and mixed with water, it does not form a pasty, plastic mass like clay.

We can say in general that shales occur in those regions where the rocks lie flat or nearly so, while slate is found where the rocks have been disturbed, tilted and folded. Thus the iron bearing formations of the Upper Peninsula yield slate, while the sedimentary rocks of the Lower Peninsula carry an abundance of shale. Aside from their difference in hardness, clay and shale are practically alike in their properties, so that in this report the word shale could, in every instance, be substituted for clay without destroying the truth.

*Kaolin is, however, found at Hersey, Wisconsin, so that it is not altogether hopeless to look for it in the Upper Peninsula.

§ 2. Physical properties.

The properties of clay or shale can be divided into two classes, viz.: physical and chemical. The former are more important and have a greater practical bearing than the latter, except where the material is to be used for making Portland cement.

The most important physical properties are: slaking; plasticity; behavior under heat; shrinkage in drying and burning; color; and tensile strength.

§ 3. Slaking.

If a bed of shale is opened up, it at first appears hard and fresh, but after a while it begins to flake off in large and small pieces which either lie on the surface or fall to the base of the cliff, and these fragments continue to subdivide until the mass is broken down or slaked to clay.

If the shale crops out on a flat surface, we shall find the clay on top, and as we pass downwards a mixture of clay and partially slaked shale fragments is met with, and this mixture in turn grades into the fresh, unslaked or unweathered shale. Clays even when fresh will commonly slake rapidly in water.

Nature will often produce a far more plastic mass by weathering than could be produced by grinding the fresh material. Indeed, these weathered shale beds are often extensively employed in the manufacture of clay products. At East Jordan, for example, the material used for making brick is simply the weathered outcrop of a shale bed, and a similar material is utilized at the Coldwater cement works.

The paving brick works at Saginaw, however, mine the fresh shale and render it plastic by grinding and mixing with water.

Now, it stands to reason that the denser and more firmly cemented the shale mass is the less easily will it slake under the action of the weather, and such a shale would also be harder to grind, that is it will take longer grinding to break it up thoroughly. We therefore see that the condition of a weathered outcrop is a certain index to the way in which the shale will act in the grinding machines, it being more desirable, of course, to have a material that comminutes readily.

§ 4. Plasticity.

This we can define as the property which shale or clay possesses of forming a plastic mass when mixed with water, thus permitting it to be molded into any desired shape, which it retains when dry. It is hard to realize what an important character this really is, for without it we could do but little with the material.

Clays vary from those in which the plasticity is low to those in which it is very strong. The former are said to be lean, the latter fat or strong.

The very plastic clays and shales, other things being equal, are best adapted for making stoneware and sewer pipe and terra cotta; those of moderate plasticity find their application in the manufacture of paving brick, while the lean ones are used mostly for dry pressed brick and common brick.

If a shale is lean its plasticity can be increased by the admixture of a more plastic one; or, if, on the other hand, it is too fat, it can be tempered by the addition of sand. Sand is a powerful destroyer of plasticity, but it should also be borne in mind that the more sand that is added the greater will be the porosity of the product. Manufacturers of common brick unfortunately have a tendency very often to add too much sand to their clay, because it makes it so much easier to work. The subject of plasticity will again be referred to under shrinkage.

§ 5. Behavior under heat.

When shale is heated up to a temperature of redness or above, depending on the refractory quality of the material, a hardening of the mass takes place, owing to the softening of the particles under the action of the heat, the result of this being that they stick together and make the product when cold as "hard as a rock." It is this property of hardening under fire that makes clay products so resistent and durable.

All clays and shales do not, however, act alike when heated. Some soften very rapidly when burned; others very slowly. Some soften at a very low temperature and are consequently said to be easily fusible; others do not soften until burned to a very high temperature and are called refractory.

A clay may fairly be classed as refractory which softens only at a temperature of 2700° F. (cone 18), though the exact limit depends upon the use to which the fire brick made of it is to be put.

Fire clays are refractory and brick clays are usually easily fusible.

When clay is put into a kiln or furnace and burned, the first signs of fusion are a softening of the particles. If the

clay be now cooled, it will be a solid mass, and hard enough to cause difficulty in scratching it with a knife. It has been heated to a condition of incipient fusion. If the same piece is heated still higher, the particles soften so much that they are able to adjust themselves better and to pack to a dense, impervious mass, and when cool the individual grains will no longer be recognizable. This is the condition of vitrification, and all stoneware, paving brick and sewer pipe makers try to vitrify their wares.

If the piece of clay is once more put into the fire and heated to a higher temperature than before, the clay will finally become so soft as to cause the mass to run or become viscous.

This is known as the condition of viscosity. Now, the practical bearing of all this is that, in burning a kiln of ware to vitrification, it is impossible to bring the temperature just up to that point and then stop it; on the contrary, the heat is apt to go a little beyond before it can be stopped. If the shale passes rapidly from the condition of vitrification to viscosity, then there is danger of melting the contents of the kiln in attempting to vitrify them. But if the two points mentioned are some distance apart, then there is not so much danger in slightly overstepping the point of vitrification.

To safely vitrify a clay, the points of vitrification and viscosity should be at least 125° Fahrenheit apart and preferably 200°. In clays containing a high percentage of lime, they are not over 50° apart, and hence such clays are not adapted to making vitrified wares. (See "Lime" under chemical properties.)

§ 6. Shrinkage.

All the clays or shales when mixed with water, molded arid then set aside to dry shrink a variable amount as the water evaporates. This is known as the air shrinkage, and the more plastic the material the greater it is, while the leaner or more sandy the shale the less will be the air shrinkage.

A low shrinkage is more desirable for the reason that there is less danger of the ware warping or cracking in drying. When the ware is burned an additional diminution in volume takes place, which is known as the fire shrinkage, and for the same reasons this should be as low as possible. Most shales have a total shrinkage in drying and burning of from 12 to 15 per cent. Knowing the effect of sand on the shrinkage, it is possible to reduce it materially.

§ 7. Color.

Here we have two kinds to deal with, viz.: the color of the unburned or green clay, and that of the burned material.

Color of the Unburned Shale.—Many persons call a shale associated with coal a fire clay, simply because it is gray or reddish in color, and, while it is true that many fire clays are of this shade, still a large number of fusible ones show the same color, so that this cannot be used as a guide in determining the qualities of shale. Few deposits are wanting in organic matter, such as plant tissue, which is sometimes scattered through the shale in a very finely divided condition, coloring it gray, brown or black. When the shale is burned the organic matter simply burns off. Iron oxide is the second powerful coloring agent, and, depending on the chemical condition in which it exists in the shale, the color of the latter may be red, yellow, brown or even gray. The iron coloration may often be masked though, by the presence of much organic matter. The various states of combination, in which iron is found in the shale will be mentioned under chemical properties.

Color of Burned Clay.—This is most commonly red, owing to the presence of iron oxide in the clay, and provided the combustion of the fire within the kiln is complete. If, however, there is not enough air admitted to permit complete combustion then the iron oxide is reduced to a lower condition of oxidation and the color will be bluish black instead of red. The same color will be produced where the clay is burned to viscosity, examples of this being bricks which have been melted in the arches of a kiln.

Shales with only 2 to 3 per cent iron oxide burn buff, while those with 4 or more per cent burn red.

A buff or cream color is also produced if the clay contains much carbonate of lime, say three times as much lime as iron, and this is what causes many of the Michigan brick clays to burn a cream color.

Magnesia exerts the same coloring effect on the burned ware as lime, and alkalies tend to turn the iron red into a brown. Silica has no effect on the color in burning. See also § 9.

§ 8. Tensile strength.

By this is meant the resistance shewn by air dried briquettes when pulled apart in a testing machine. Expressed in pounds per sq. in. it varies from 50 to 75 in many brick clays to 200 or more in very plastic pottery clays. It indicates the degree to which the clay particles will hold together and resist tearing in drying or molding.

§ 9. Chemical properties.

This includes those which are due to the chemical character or composition of the material. An analysis of pure clay would show only three ingredients, viz.: silica, alumina, and chemically combined water. Such a clay is, however, an extreme rarity, so that, in addition to the above, we usually find variable amounts of ferric oxide, lime, magnesia, and alkalies, and it can be said in general that the purer the clay the lower the percentage of the last mentioned substances. Since we speak of them as impurities, it suggests that some of them may be undesirable constituents of the clay or shale, and such is at times the case, for all of them affect some of its properties. Some influence the color, others the

shrinkage, while all exert more or less effect on the fusibility of the material, the influences in each case increasing usually with the amount of the impurity which the shale contains. We can perhaps tabulate the above statements by giving in the following lines first the name of the property and after it the substances which affect it:

Fusibility: Silica, ferric oxide, lime, magnesia, alkalies.

Color: Ferric oxide, lime, magnesia, alumina.

Shrinkage: Silica, alumina, water.

On comparing these properties with those mentioned or enumerated in the first paper, it will be seen that there remain some which the chemical composition does not seem to affect, and brings up the question: What can we learn about a clay from its chemical analysis?

As we shall see below, we can learn much, and yet at the same time it is not safe to attach too much importance to this point, for two clays may agree very closely in their chemical composition, and yet be totally unlike physically.*

It is commonly the custom to divide the impurities of clay into fluxing and non-fluxing ones, but this is true only in a relative sense, for nearly all of them act as fluxes if present in sufficient quantity, and if the clay be heated to a sufficiently high temperature, but at the same time these latter tend to increase the refractoriness of the clay up to a certain point.

Those impurities, which exert a fluxing action at low or medium temperatures, include the alkalies, ferric oxide, lime and magnesia, and their effectiveness so far as we know is in the order given above.

We could therefore have two clays with the same physical properties and the same total percentage of fusible impurities and yet the one might be more fusible than the other on account of having a larger percentage of the more active fluxes in its composition. For some purposes a low percentage of fluxes is desirable, while for other purposes a higher amount is required.

*See an article by the writer on "the Ultimate and the Rational Analysis of Clays and their relative advantages." Trans. Am. Inst. of Mining Engineers, 1898, p. 1.

§ 10. Alkalies.

These are commonly potash and soda, and are to be found in almost every clay, varying in total quantity from a trace up to nine or ten per cent. They are often present as a constituent of undecomposed feldspar grains, which the shale may contain, or in some cases the potash may come from mica, whose tiny glistening scales are easily discernible when present. Alkalies are usually present in the form of feldspar (which is a complex silicate), and, on account of their fluxing properties, are frequently of an advantage, as they serve in burning to bind the particles together in a dense, hard body, and to permit the ware being burned at a lower temperature. So far as is known the alkalies exert little influence on the color of the burned ware.

If present as sulphates or chlorides they are soluble in water and may be brought to the surface in drying, where they are left by the water evaporating from the brick and form an unsightly white coating. This can be prevented.

Efflorescence on Bricks.

Many bricks either in drying or after burning become covered by a whitish coating, which is due to the presence of soluble mineral salts, especially sulphates, which are brought to the surface by evaporating moisture and deposited there.

A very small amount of these salts, say .1% is sufficient to cause an incrustation, and yet they need not be feared if the clay is properly treated, which consists in the addition of some barium compound to the clay, and this reacting with the injurious ingredients renders them insoluble. Either barium chloride or barium carbonate may be added to the clay for this purpose, thus 'for example:

$$Ca\,SO_4\ (\text{Soluble salt}) + Ba\,CO_3 = Ca\,CO_3 + Ba\,SO_4.$$
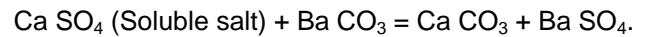
The barium carbonate being insoluble in water must be added to the clay in a very finely divided condition, and be mixed with it as thoroughly as possible. We may give an example.

If, for instance, the clay contained .1% sulphate of lime, this would mean that one pound contained .4 of a gram, and theoretically every gram of sulphate of lime needs 1.45 grams of barium carbonate to render it insoluble; therefore theoretically a pound of clay would require .6 of a gram of barium carbonate, or for safety 6 or 7 grams should be used for every pound of clay. This would be about 100 lbs. for every thousand bricks, based on the supposition that every green brick weighs 6 or 7 pounds. With barium carbonate at 2½¢ per pound this would be $2.50 per 1,000 brick. If barium chloride were used, it is much cheaper and costs only about 32¢ per 1000 brick, for the reaction is quicker and less material is required.

§ 11. Iron oxide.

Aside from being a flux, iron oxide is also the great natural coloring agent of clays in both their raw and burned conditions. There are many different mineral compounds which may serve as the source of iron oxide in shale, and of these the most common are the silicate minerals, mica and hornblende; the oxides, limonite, hematite and magnetite; the sulphide, pyrite and marcasite and the carbonate of iron, siderite. No matter what the original composition of the mineral, the decomposition of it usually sets the iron free in the form of the hydrated iron oxide or limonite, which tends to color the clay in various shades of red and yellow. In burning this changes to hematite. Aside from the mica, the only other mineral which is apt to be present in grains sufficiently large to be recognized by the naked eye, is pyrite, and this occurs in the form of glittering yellow metallic particles, which are often of cubical

shape, many of these grains being sometimes cemented together in the form of large masses, which are commonly known as "sulphur balls." The latter would tend to do much damage if allowed to remain in the shale, but owing to their size are easily extracted. If the finely disseminated pyrite remained in the clay it would be found after burning that the clay was dotted with fused spots of silicate of iron. Many of the first speckled, "Pompeian," brick so extensively used at the present time were made in this manner. The pyrite is a strong flux.

These should not be mistaken with carbonate of iron concretions commonly found in shale banks, and known as clay iron stone, or kidney ore, and sometimes erroneously called sulphur. They do not show any metallic particles unless grains of pyrite happen to be enclosed in them. The shales at Flushing, Grand Ledge, and Quincy, etc., contain many concretions of carbonate of iron.

When a shale Is exposed to an oxidizing fire in burning, the iron invariably tends to color the material red, and the depth of this color increases with the amount of iron present. If, however, the shale is exposed to a reducing action in burning, which is the case when an insufficient quantity of air enters the kiln, then the color instead of being red will be a bluish black. The same color is also produced if even in an oxidizing fire the shale is carried to a condition of viscosity, in which state a dissociation of the iron compound takes place, the ferric oxide being reduced to the ferrous condition.

Both ferric and ferrous oxide exert distinct coloring effects on the raw clays, so that the latter may be yellow, blue, brown, red or grey in color, depending upon the relative amount of ferrous and ferric salts present.

The amount of ferric oxide permissible or desirable in a shale depends upon the use to which it is to be put. Thus kaolins, which are to be utilized for making china, should have under one per cent if possible, while brick shales or pottery clays, on the other hand, should have four or five per cent of the same material in order to produce the good red coloration. A large excess of iron oxide also tends to cause blistering in burning.

The iron coloration may often be bleached out owing to the presence of lime, as will be mentioned further on.

§ 12. Lime.

There are scarcely any shales which do not contain some lime. The chemical combination in which it is present has much to do with its effect on the behavior of the shales. Thus it may occur as a silicate, when present in some species of feldspar, or again it may be found in the shale as a simple carbonate, represented by the mineral calcite, or as a double carbonate of lime and magnesia when the mineral dolomite is present. Thirdly, it may be found in the shale as a sulphate, namely the mineral gypsum. The latter is often known by its small transparent crystals, whose surfaces have a pearly

lustre. The presence of carbonate of lime can be detected by the effervescence produced when a drop of muriatic acid is put on the shale, and dolomite shows itself by acting similarly when hot acid is dropped on the rock.

When the lime is present as a silicate, it is useful as a flux, but in this condition it exerts no coloring action on the shale in burning. Carbonate of lime is extremely common in many shales, which have been derived from limestone areas, as in the State of Michigan, and it is never lacking in those beds of brick clay which are found around the borders of the Lower Peninsula, as at Detroit, Benton Harbor and Forestville, or even in many of the Upper Peninsula beds. Carbonate of lime if present in the form of lumps or pebbles is very injurious, and should be removed by screening or washing, for the reason that in burning it is reduced to quick lime, which if the brick is not vitrified absorbs moisture from the atmosphere, slakes, swells and bursts the product. Finely divided lime, however, if not present in too large quantities may be harmless, and shales containing 15 or 20 per cent of lime carbonate in this condition can be used for the manufacture of common brick or earthen ware, or in fact any products which do not have to be burned to a condition of vitrification.

Lime like iron and alkalies is also a powerful flux and tends to lower the fusibility of the shale to a marked extent; furthermore it tends to bring the points of incipient fusion and viscosity of the clay together so close that shales which contain a large amount of carbonate of lime can not be burned to a condition of vitrification without danger of fusing.

The effect of lime as a coloring agent is that, if iron oxide is present, the lime unites with it and the silica, and alumina of the shale giving a complex silicate, and coloring the brick buff or cream instead of red. This is especially effective when the ratio of lime to iron is not less than three to one.

In addition to this, lime also exerts a powerful influence on the shrinkage of shale, those which are highly calcareous showing a lower shrinkage in burning than those with a low lime percentage.

§ 13. Magnesia.

This element rarely occurs in either shales or clays in the same amount as lime, and indeed it rarely exceeds two per cent. But curiously enough the shales and the clays at many localities in Michigan often seem to contain as much magnesia as lime.*

Magnesia may be derived from the same class of compounds as lime, and, so far as known, the action of it on the clay in burning is exactly the same.

*Prof. C. A. Davis has found some shales from the Grand Traverse region to be very high in magnesia. The irregularity in the amount of magnesia in the calcareous surface clays is well shown in the two analyses from Ionia.

§ 14. Silica.

Chemical analysis distinguishes two classes of silica, first, that combined with alumina in kaolin, and, second, sand. The latter includes both quartz and silica present in feldspar or mica.

Free silica or quartz is present in all shales, and varies in amount from a fraction of a per cent to about 20 or even 50 per cent. Its most important effects are that it tends to lessen the plasticity, diminish the tensile strength, and also lower the shrinkage of the material, both in drying and in burning. Indeed, if silica is present in a very large amount and grains of large size, it may even cause the shale to expand in burning.

Silica, namely quartz, tends to increase the refractoriness of a clay up to a certain point, namely about 2800° F. Beyond that point, however, an increase in the amount of silica tends to increase the fusibility of the clay up to a certain point, after which the refractoriness again rises. This is a question which has a practical bearing, however, only in connection with the highest grades of fire bricks.

§ 15. Titanium.

While this is widespread in many clays in the form of the mineral rutile or ilmenite, at the same time it is present in such small quantities that its effect need not usually be considered. Its action is somewhat similar to that of silica.

§ 16. Organic matter.

This substance is found in many different shales and usually makes its presence known by the dark gray or black color which it imparts to the material. It generally consists of finely divided pieces of plant tissue, or large pieces of stems and leaves, which have settled in the shale during its deposition.

The color exhibited by clays carrying organic matter is no indication of the color they will have when they are burned, for a clay which is jet black might contain no iron, and consequently would burn with a white color, as the plant tissue passes off at a bright red heat. On the other hand, a clay might contain an appreciable per cent of iron, whose presence would be masked by the presence of organic matter, and consequently the clay would burn red.

When found in a very finely divided condition, organic matter tends to increase the plasticity of the clay, unless there is a large amount of sand present, and furthermore in the weathering of shales organic matter by its oxidation and consequent evolution of carbonic acid gas helps to break up the material and render it more plastic.

§ 17. Water.

All shales and clays contain two kinds of water, viz.: hydroscopic water, or moisture and chemically combined water.

Moisture.—Shales contain from 30 to 40 per cent of moisture, when freshly taken from the bank, and in air drying most of this is expelled, the clay shrinking at the same time. The amount of water that an air dried clay needs in order to develop an easily workable mass varies from 12 to 20 per cent in lean ones, and from 25 to 35 in fat ones. The more plastic the shale the greater the quantity of water required.

Combined water.—It may be said roughly that the amount of combined water in shales is usually about one-third of the amount of alumina, although if the clay contains much limonite it would be much greater than this. Combined water is driven off at a low red heat, and the only effect of it is that when this takes place the shale suffers additional loss in volume or shrinks, otherwise combined water has little or no effect. It is a curious fact, however, that while the amount of combined water does not seem to stand in any close relation to the plasticity of a clay, nevertheless when once driven off the clay can never again be rendered plastic by the addition of water. The shrinkage that does take place when combined water is driven off will vary from two to twelve per cent.

§ 18. Minerals in clay.

There is really no limit to the number of minerals that may be found in clay, when we consider that it has originated by the breaking down of many other rocks. Unfortunately, however, very little systematic work has been done in this line so that the number actually identified is few.

All that it is desired to do here is to simply call attention to a few of the commoner species that are often noticeable in clay, especially with the naked eye or a hand lens.

Quartz is perhaps the most abundant. It is present in nearly all clays, in the form of tiny angular or rounded grains. In washing the clay they usually settle out quickly, and are included under the term of sand, which however may include other gritty mineral fragments coarse enough to be felt between the teeth. The chief purpose which quartz serves is to dilute the shrinkage. Its presence can be determined by the fact that it will scratch glass. In some clays quartz forms large lumps and is then spoken of as flint or chert.

Feldspar is a common constituent of many clays; so are garnet, hornblende and pyroxene. They are all complex silicates, which fuse at a much lower temperature than quartz. Up to their fusing point they act like quartz in retarding the shrinkage of the clay, but above that they probably increase it.

They rarely occur in clay in sufficiently large grains to be recognized except by the aid of high power lenses.

Mica is a very common ingredient of clays, and while it is a complex silicate like the preceding, still it is so different in its effect as to necessitate giving it separate mention.

Its form is that of shining scales, which are usually distinguishable on account of their brilliant surfaces, even though very small.

There are two common types of mica, the one known as muscovite or white mica, and the other known as biotite or dark mica. The former contains but little iron oxide, and weathers very slowly, while the latter has much and weathers rapidly. Hence it is the former usually that is found in clay. The effect of mica is to increase the refractoriness of clay and decrease its plasticity, and it is often noticeable that the mica scales retain their lustre, and refrain from fluxing with other elements of the clay, even when heated to bright redness.

Gypsum, the sulphate of lime, is abundant in many shales and clays, and while it, like mica, is often present in the form of tiny, shiny, scales or plates, still their effect on the clay is different.

They can be distinguished from mica in several ways. First, their lustre is pearly; second, they are soft enough to be scratched with the finger nail, while it takes a knife to scratch mica; third, at a temperature of 300° F. (much below redness) they lose their lustre and change to a white, powdery mass.

In burning they serve as a flux, and furthermore if present in the clay in large quantity, the gypsum dissociates at redness, allowing the escape of sulphuric acid gas, which, if abundant, may cause blistering of the ware.

Calcite or carbonate of lime, is often found in clays either as tiny grains, large lumps and pebbles, or as an ingredient of the concretions often seen and sometimes called "clay dogs."

It serves as a flux and otherwise as explained under the chemistry of clays. If in the form of pebbles or concretions it should be either ground up in the clay or removed by screening, as underburned lumps are sure to slake and burst the brick.

Pyrite is still another constituent that often impresses itself on our notice, by its occurrence either in the form of yellow, metallic grains or larger lumps of concretionary nature. It is often spoken of by the clay workers as "sulphur" or "sulphur balls."

It is an undesirable constituent, and should be removed when possible; it is apt to be found in many fire clays and shales.

Limonite should be mentioned as absent from very few clays, but it is present commonly as a film coating the other mineral grains. It is an important coloring agent in burning, and in the raw condition colors the clay yellow or brown.

Many other species might be mentioned, but they are all microscopic and only determinable by careful study.

Siderite or iron carbonate is a common cause of concretions in clay, and especially shale. It should be treated in a similar manner to lime carbonate concretions although in burning it simply acts as a coloring agent and flux.

CHAPTER II.
USES OF CLAY AND SHALE.

§ 1. Clay products.

This represents by far the most important use to which shale is put at the present time, and for its successful application depends on the two properties mentioned in the previous chapter, viz.: plasticity and hardening when burned. The various chemical and physical properties of shale which have been described in the preceding papers bear chiefly on the use of shale for this purpose.

For the manufacture of all of these clay products the shale must be plastic, but aside from this the characters to be considered for any particular grade of products are not always the same. The necessary qualities may be summed up briefly therefore as follows:

§ 2. Common brick.

A sufficient amount of iron oxide to give the brick a good red color is desirable but not absolutely necessary, otherwise we should be excluding the use of calcareous shales, which are sometimes employed, from a matter of necessity rather than choice. There should be enough fluxes in the shale to make it burn to a hard product at a comparatively low temperature, giving a brick whose density should not allow over 15% absorption.

§ 3. Front brick.

The same characters are called for as in the case of common brick, but the color after burning is of prime importance, it being necessary that the shade, whatever it is, should be uniform. A dense brick is desirable, and the shrinkage should be low enough to prevent warping or cracking in burning. These two points are also influenced by the proper manipulation of the clay. Furthermore, soluble salts must always be guarded against, for they produce a bad discoloration on the surface of the ware. If their presence is known they can be rendered harmless by the addition of barium chloride or barium carbonate to the clay, the chemical reaction which takes place as a result of this addition rendering them insoluble.

§ 4. Manufacture of brick.

While it is not proposed to go into a detailed discussion of the methods of manufacture, still there are a few

general points which call for attention. In the manipulation of clays and their forming into brick, the different steps of the process commonly followed are:

Preparation.
Tempering.
Molding.
Drying.
Burning.

Under preparation is meant the bringing of the clay into a condition suitable for mixing with water. Soft plastic clays require little preparation, but shales have to be ground before they can be made into a plastic mass.

The increase or development of plastic qualities is in many places effected by simple grinding, at others by weathering, the raw material being allowed to remain in the open air exposed to the elements for several months, or even a year. This method comes into use when clays are employed for pressed brick, or to a still greater extent when they are employed for refractory wares.

The tempering involves the mixing up of the clay or shale with water, in order to bring it into a mass of the proper consistency for molding. Sometimes several clays are mixed together, or sand has to be mixed in if the clay is highly plastic and shrinks too much. At any rate, too much stress cannot be laid on the importance of thorough tempering, a point whose value increases with the grade of the ware.

The molding may be done in several different ways, depending on the clay and the quality or nature of product to be produced.

The methods are characterized as:

1. Soft mud, the clay being molded soft.
2. Stiff mud, the clay being molded stiff.
3. Dry press, in which the clay is forced into the molds as dry powder.

Soft mud bricks are thoroughly homogeneous and when properly burned seldom disintegrate under the action of frost. They represent the method commonly employed for common brick. Paving bricks are in rare instances made by this method, the objection to its use for this class of products being comparatively low capacity of output.

The stiff mud process is one of high capacity, and is usually employed for making pavers. It is not applicable to very plastic or very lean clays.

The one objection to its use is that it develops a spiral structure in the bricks, but if properly burned, and sometimes repressed, the effect of this feature is less felt.

The dry press process produces a smooth face and sharp edged brick at one operation, arid consequently is especially adapted for the manufacture of face brick.
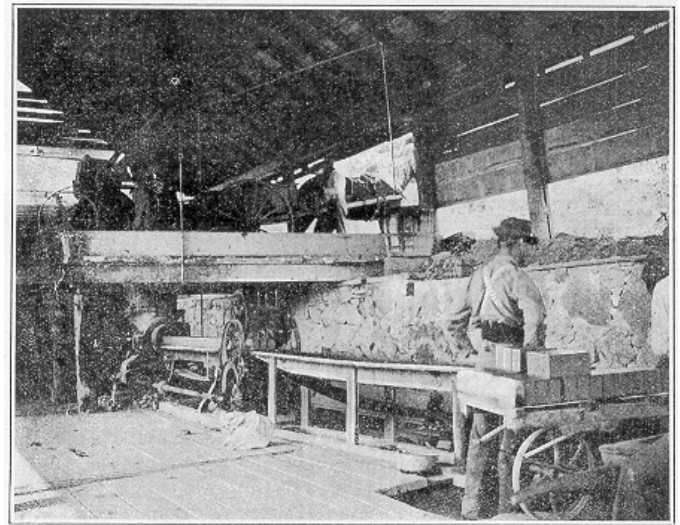
Figure 1. Molding bricks on auger machine with triple die.

The drying is carried on either out of doors or under cover, and in the latter case artificial heat is often made use of. Still it is not always safe to hurry this step of the process of manufacture for many clays will not stand it.

The same care has to be taken in the burning, for a large portion of the success of clay working, depends on its proper manipulation. Some clays require slow heating, others can be burned quickly.

The higher the grade of product, the greater the care which has to be exercised. Better wares are also burned in more complicated forms of kilns, for in these the heat can be regulated with greater precision. Even with the best types of kilns, and the utmost care, the burned ware has at times to be sorted.

§ 5. Paving brick.

The production of these calls for a clay or shale that will not only keep its shape in burning but also yield a vitrified or impervious product. To produce the latter in large quantities at a time, it is necessary that the points of incipient fusion and viscosity of the shale should be separated by at least 250° Fahr., and preferably 400° The product should have little or no absorption, and should also withstand abrasion, this being even of more importance than the crushing strength of the brick, although the latter should not be lost sight of, and be at least 7,000 or 8,000 pounds per square inch.

§ 6. Terra cotta.

The same requirements have to be considered as in the case of front brick, but they must be complied with even more strictly. The necessary plasticity to permit the molding of intricate designs is also of the highest importance.

§ 7. Pottery.

Here plasticity has to be considered, and should be made high in order to permit the turning or molding of the ware. Color is sometimes of importance, and, for stoneware, the shale must burn to a vitrified body. So far as the writer is aware, shale has never been used for the manufacture of white ware, for the reason that shale being of sedimentary origin it usually has too much iron oxide in its composition to permit its burning to a white body.

§ 8. Firebrick.

These are very frequently manufactured from shale. The great element to be considered in this case is ability of the ware to withstand high temperatures. This calls for a low percentage of fluxes in the raw material. Fineness of grain always plays an important roll. Coarse-grained shales withstand high temperature best, while fine-grained ones are better adapted to resist the corrosive action of molten materials.

It is frequently found that a mixture of shales often yields much better results than when one alone is used.

§ 9. Portland cement.

In the manufacture cf Portland cement a mixture of shale and marl is usually taken, the two being mixed in such proportions as to give a mixture of the proper chemical composition, the physical properties of the material being of minor importance. The three essential elements of such cement are silica, alumina and lime, the first two of which are supplied by the shale and the latter by the marl or limestone. The best results are obtained from a mixture in which the lime percentage is equal to 2.8 times the silica plus 1.1 times the alumina.*

*A shale or clay to be suitable for use in cement manufacture should be free from grit, that it may not be expensive to grind, and mix, and should be free from carbonates, i. e., should not effervesce with acids. This is not theoretically requisite, but practically it is found that calcareous shales are likely to prove irregular in composition, and introduce uncertain quantities of magnesia. The glacial clays are rarely suitable, being too calcareous. The shales of the coal measures when not gritty appear more suitable. But of particular value are the shales of the Coldwater (Cuyahoga) series. See Ch. III, § 7, [p 18].

§ 10. Mineral paint.

Shale to be thus employed is usually ground up and mixed with oil. Two characters enter into the consideration of its applicability for this purpose. First, the amount of oil required to mix with a given quantity of shale, and, second, the color of the raw material, which is influenced by the amount of iron oxide and organic matter in the raw material. The paint is usually some kind of ochreous paint.

§ 11. Road material.

In many localities excellent roads are produced by the use of shale, the varieties yielding the best results being those of a somewhat hard and silicious nature. Shales which are soft and low in silica tend to crumble rather rapidly to dust and produce a greater amount of mud in wet weather.

When burned the results are much better. The black shales and sulphurous coal waste from coal mines and the broken waste from brickyards are material which may well be more largely used. In Missouri a black silty clay mud called gumbo is largely burned for road metal and railroad ballast.

§ 12. Slip clays.

These are clays of a highly fusible quality, which are used to give a brilliant color and finish to stoneware. The clay from Albany, N. Y., is the best known, and normally gives a dark color. A slip clay must be fusible thoroughly at a temperature at which the body of the stoneware will not soften. The Rowley slip, the Northern Michigan slip described below, burns to a yellowish green glass, (Analyses Nos. 32 and 33), and so does the Harrietta clay (Analysis No. 42). Orton gives us an average composition for slip clays: 31% clay base, 39% sand, 21% fluxes, 9% water and carbonic acid, and it will be seen that very many of the Michigan surface clays ought to make good slip clays.

CHAPTER III.
TESTS.

§ 1. Introduction.

Michigan contains two types of clay materials, viz.: clays proper and shales. The former are mostly surface deposits, while the latter are found both outcropping at the surface and are also encountered in sinking shafts for the purpose of mining coal or other mineral products.

The present report does not aim to be an exhaustive one on these materials so far as Michigan is concerned, but is intended to serve the purpose of pointing out in a general way what the properties of these materials as they occur within the state are, so that some judgment can be formed as to what they are probably good for.

A state can have valuable clay resources, without containing any deposits of the highest grades of clay such as kaolin. Michigan so far as is known does not contain any kaolin, and although there are rumors of its occurrence in the upper Peninsula, still careful inquiries in that region failed to develop the presence of any.

None of the shales so far as examined are refractory in the true sense although many of them are spoken of as fire clays, especially when they underlie the coal. Many of them however have developed qualities which should make them suited for other types of ware of importance.

In collecting the samples for this work the plan followed was to visit a number of localities where extended and

typical outcrops could be found of the different geological clay bearing formations.

While a great number of samples were collected, about thirty-two of them in all were subjected to a physical test, and in some cases a chemical analysis was also carried out. The analyses were made by Mr. A. N. Clark.

§ 2. Methods of testing.

The physical tests carried out on the different samples, were determination of the slaking properties, plasticity, tensile strength, amount of water required to mix up the clay or shale, points of incipient fusion, vitrification and viscosity, color when burned, shrinkage in drying and burning, and the percentage of soluble salts contained in the clay or shale.

The object of such tests is a double one. It gives us in the first place a clue or several clues to the uses of the clay, it serves to give information to a manufacturer who is searching for a particular clay or shale, and thirdly it may be used as a basis of comparison with other materials which are being used.

Pyrometric cones.

In many works the completion of the firing is judged by trial pieces placed in the kiln, these being withdrawn singly from time to time, and their condition examined.

A surer method and one gaining favor in this country, is by the use of Seger's Pyramids.

These consist of different mixtures of kaolin and fluxes, which are compounded so that there shall be a constant difference between their fusing points. Seger's series were numbered from 1 to 20, and the difference between their fusing points is 36° F. A later series, introduced by Cramer, runs from 01 to 022 with a difference of 54° F. between their fusing points. The higher numbers of the cones have also been extended up to 36.

These pyramids have been recently recalibrated, and therefore the fusing points and composition of the different numbers are given herewith, being taken from the recently issued circular of the Thonindustrie Laboratorium, in Berlin, where these cones were first made.

FUSION TEMPERATURES BASED UPON RECENT RECALIBRATIONS FOR SEGER'S PYRAMIDS:

Number of cone.	Composition.	Fusion point. Cent.	Fahr.
022	0.5 Na$_2$O / 0.5 Pb O — {2 SiO$_2$ / 1 B$_2$O$_3$	590	1094
021	0.5 Na$_2$O / 0.5 Pb O — 0.1 Al$_2$O$_3$ {2.2 SiO$_2$ / 1 B$_2$O$_2$	620	1148
020	0.5 Na$_2$O / 0.5 Pb O — 0.2 Al$_2$O$_3$ {2.4 SiO$_2$ / 1 B$_2$O$_3$	650	1202
019	0.5 Na$_2$O / 0.5 Pb O — 0.3 Al$_2$O$_3$ {2.6 SiO$_2$ / 1 B$_2$O$_3$	680	1256
018. Dull red heat	0.5 Na$_2$O / 0.5 Pb O — 0.4 Al$_2$O$_3$ {2.8 SiO$_2$ / 1 B$_2$O$_3$	710	1310
017	0.5 Na$_2$O / 0.5 Pb O — 0.5 Al$_2$O$_3$ {3.0 SiO$_2$ / 1 B$_2$O$_3$	740	1364
016	0.5 Na$_2$O / 0.5 Pb O — 0.55Al$_2$O$_3$ {3.1 SiO$_2$ / 1 B$_2$O$_3$	770	1418
015	0.5 Na$_2$O / 0.5 Pb O — 0.6 Al$_2$O3 {3.2 SiO$_2$ / 1 B$_2$O$_3$	800	1472
014	0.5 Na$_2$O / 0.5 Pb O — 0.65Al$_2$O$_3$ {3.3 SiO$_2$ / 1 B$_2$O$_3$	830	1526
013	0.5 Na$_2$O / 0.5 Pb O — 0.7 Al$_2$O3 {3.4 SiO$_2$ / 1 B$_2$O$_3$	860	1580

Number of cone.	Composition.	Fusion point. Cent.	Fahr.
012. Cherry red heat	0.5 Na$_2$O / 0.5 Pb O — 0.75Al$_2$O$_3$ {3.5 SiO$_2$ / 1 B$_2$O$_3$	890	1634
011	0.5 Na$_2$O / 0.5 Pb O — 0.8 Al$_2$O$_3$ {3.6 SiO$_2$ / 1 B$_2$O$_3$	920	1688
010	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.5 SiO$_2$ / 0.5 B$_2$O$_3$	950	1742
09	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.55 SiO$_2$ / 0.45 B$_2$O$_3$	970	1778
08	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3 60 SiO$_2$ / 3.40 B$_2$O$_3$	990	1814
07 } Clear cherry red heat	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.65 SiO$_2$ / 0.35 B$_2$O$_3$	1010	1850
06	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.70 SiO$_2$ / 0.30 B$_2$O$_3$	1030	1886
05	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.75 SiO$_2$ / 0.25 B$_2$O$_3$	1050	1922
04	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.80 SiO$_2$ / 0.20 B$_2$O$_3$	1070	1958
03	0.3 K$_4$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.85 SiO$_2$ / 0.15 B$_2$O$_3$	1090	1994
02	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.9 SiO$_2$ / 0.1 B$_2$O$_3$	1110	2030
01	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {3.95 SiO$_2$ / 0.05 B$_2$O$_3$	1130	2066
1	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.3 Al$_2$O$_3$ {4 SiO$_2$	1150	2102
2 } Deep orange heat	0.3 K$_2$O / 0.7 CaO — 0.2 Fe$_2$O$_3$ / 0.4 Al$_2$O$_3$ {4 SiO$_2$	1170	2138
3	0.3 K$_2$O / 0.7 CaO — 0.5 Fe$_2$O$_3$ / 0.5 Al$_2$O$_3$ {4 SiO$_2$	1190	2174
4	0.3 K$_2$O / 0.7 CaO — 0.5 Al$_2$O$_3$ {4 SiO$_2$	1210	2210
5	0.3 K$_2$O / 0.7 CaO — 0 6 Al$_2$O$_3$ {5 SiO$_2$	1230	2246
6	0.3 K$_2$O / 0.7 CaO — 0.7 Al$_2$O$_3$ {6 SiO$_2$	1250	2282
7	0.3 K$_2$O / 0.7 CaO — 0.7 Al$_2$O$_3$ 7 SiO$_2$	1270	2318
8	0.3 K$_2$O / 0.7 CaO — 0.8 Al$_2$O$_3$ 8 SiO$_2$	1290	2354
9. White heat	0.3 K$_2$O / 0.7 CaO — 0.9 Al$_2$O$_3$ 9 SiO$_2$	1310	2390
10	0.3 K$_2$O / 0.7 CaO — 1.0 Al$_2$O$_3$ 10 SiO$_2$	1330	2426
11	0.3 K$_2$O / 0.7 CaO — 1.2 Al$_2$O$_3$ 12 SiO$_2$	1350	2462
12	0.3 K$_2$O / 0.7 CaO — 1 4 Al$_2$O$_3$ 14 SiO$_2$	1370	2498
13	0.3 K$_2$O / 0.7 CaO — 1.6 Al$_2$O$_3$ 16 SiO$_2$	1390	2534
14. Bright white heat	0.3 K$_2$O / 0.7 CaO — 1.8 Al$_2$O$_3$ 18 SiO$_2$	1410	2570
15	0.3 K$_2$O / 0.7 CaO — 2.1 Al$_2$O$_3$ 21 SiO$_2$	1430	2606
16	0.3 K$_2$O / 0.7 CaO — 2.4 Al$_2$O$_3$ 24 SiO$_2$	1450	2642
17	0.3 K$_2$O / 0.7 CaO — 2.7 Al$_2$O$_3$ 27 SiO$_2$	1470	2678
18	0.3 K$_2$O / 0.7 CaO — 3.1 Al$_2$O$_3$ 31 SiO$_2$	1490	2714
19 } Dazzling white heat	0.3 K$_2$O / 0.7 CaO — 3.5 Al$_2$O$_3$ 35 SiO$_2$	1510	2750
20	0.3 K$_2$O / 0.7 CaO — 3.9 Al$_2$O$_3$ 39 SiO$_2$	1530	2786
21	0.3 K$_2$O / 0.7 CaO — 4 4 Al$_2$O$_3$ 44 SiO$_2$	1550	2822
22	0.3 K$_2$O / 0.7 CaO — 4.9 Al$_2$O$_3$ 49 SiO$_2$	1570	2858
23	0.3 K$_2$O / 0.7 CaO — 5.4 Al$_2$O$_3$ 54 SiO$_2$	1590	2894
24	0.3 K$_2$O / 0.7 CaO — 6.0 Al$_2$O$_3$ 60 SiO$_2$	1610	2930
25	0.3 K$_2$O / 0.7 CaO — 6.6 Al$_2$O$_3$ 66 SiO$_2$	1630	2966
26	0 K$_2$O / 0.7 CaO — 7.2 Al$_2$O$_3$ 72 SiO$_2$	1650	3002
27	0.3 K$_2$O / 0.7 CaO — 2.0 Al$_2$O$_3$ 200 SiO$_2$	1670	3038
28	Al$_2$O$_3$ 10 SiO$_2$	1690	3074
29	Al$_2$O$_3$ 8 SiO$_2$	1710	3110
30	Al$_2$O$_3$ 6 SiO$_2$	1730	3146
31	Al$_2$O$_3$ 5 SiO$_2$	1750	3182
32	Al$_2$O$_3$ 4 SiO$_2$	1770	3218
33	Al$_2$O$_3$ 3 SiO$_2$	1790	3254
34	Al$_2$O$_3$ 2.5 SiO$_2$	1810	3290
35	Al$_2$O$_3$ 2 SiO$_2$	1830	3326
36	Al$_2$O$_3$ 2 SiO$_2$	1850	3362

The theory of these pyramids is that the cone bends over as the temperature approaches its fusing point. If the heat is raised too rapidly, the cones which contain much iron swell and blister and do not bend over, so the best results are obtained by the slow softening of the cone under a gradually rising temperature. For practical purposes these cones are considered sufficiently accurate.

In actual use they are placed in the kiln at a point where they can be watched through a peep hole, but at the same time will not receive the direct touch of the flame from the fuel. It is always well to put two or more cones in the kiln, so that warning can be had not only of the approach of the desired temperature, but also of the rapidity with which the temperature is rising.

In order to determine the temperature of the kiln several cones of separated numbers are put in, as for example: .07, 1 and 5. Suppose .07 and 1 are bent over in burning, but 5 is not affected; the temperature of the kiln is therefore between 1 and 5. The next time Nos. 2, 3 and 4 are put in; 2 and 3 may be fused but 4 remains unaffected, indicating that the temperature reached the fusing point of 3. These cones can be obtained for

about one cent each from Prof. E. Orton, Jr., Ohio State University, Columbus, Ohio.

§ 3. Prospecting for clays.

In searching for clays or shales a few points borne in mind may often be of value.

The first point is to find exposures of the material sought, that will give us some clue to their extent and thickness. Ravines, railroad cuttings, bluffs along the lake shore and other natural or artificial excavations are admirable aids.

Location and homogeneity play an important role. Unless a clay is valuable, or used in enormous quantities, it will not often pay to open up a bank or pit remote from lines of transportation. If the deposit consists of layers of varying character, it does not pay to work out a few good ones, and strip off the others unless the value of the raw material is appreciable.

It is true that when a single bed 4, 6 or more feet thick is covered by many feet of rock, that underground mining is sometimes employed by running in a drift along the bed, if it outcrops on a hillside, or sinking a shaft to it. Shale beds can often be worked in connection with coal seams. If a bed of clay appears favorable on its outcrop, the extension of it under the surface can be probed by boring, or the sinking of a small shaft, still few people seem to realize the value of thoroughly determining the extent of a deposit by boring or shafting.

Another point to be remembered is that all shales do not grind up to masses of highly plastic qualities, and we may gain some ideas on this point from the manner in which they weather in the outcrop. Very plastic shales mellow down to a tough clay, while others do not exhibit these qualities, refusing to break up beyond angular particles of varying size.

Soluble salts may also occasionally make themselves noticeable by the formation of a white, powdery coating on the outcrop. This coating may be alum, carbonate of lime or gypsum.

§ 4. Geology of shale deposits.

The principal shale deposits occurring within the State are the following:

1. Coal measure shales, usually interbedded with the coal seams.

2. Michigan series of shales, associated with the gypsum beds.

3. Coldwater shales, outcropping in abundance near Coldwater and White Rock.

4. The St. Clair, Devonian or Genesee black shale. Besides these there are other beds of shale of minor importance apparently. There are considerable beds of shale in the Hamilton or Traverse and about the horizon of the Marcellus. The Hudson River group is not very

shaly in its northern part, though it is so found in borings to the south.

§ 5. Coal measure shales.

The coal measure shales are, as already mentioned, usually inter- bedded with coal seams, and most commonly known to the coal miners of the State as "fire clays." This term is erroneous, for none of the shales have developed very refractory qualities. The term has probably arisen from the fact that in many coal mining regions the coal beds are underlain by a layer of fire clay or refractory shale, which means the same thing. It is very difficult to give even a most general description of these Carboniferous shales, for the reason that they vary so at the different mines, but the same kind is sometimes met with at several mines in succession. The types which are most distinct are perhaps the following: 1, A light gray, sandy, shaly clay, often quite hard, and called fire clay. It not unfrequently contains plant remains. This material underlies the coal at the shaft of the Standard Mining Company near Saginaw. 2, A black fine-grained, brittle shale, with dull lustre and sometimes spoken of as cannel coal, owing to its appearance. This shale contains much bituminous matter, and would not serve well for the manufacture of clay products. 3, A dark, grayish black, fine-grained, hard, yet brittle shale, which produces appreciable plasticity when ground up and mixed with water. This is found at several mines near Saginaw and also Bay City, and is quarried at Flushing for the manufacture of paving brick. For analyses of the three types see the following pages.

Between these three types are intermediate gradations.

The following analysis shows the composition of the "fire clay" underlying the coal at the shaft of the Standard Mining Company at Saginaw:

ANALYSIS 1.

	Per cent.
Silica	55.30
Alumina	14.20
Ferric oxide	3.62
Lime carbonate	.30
Magnesium carbonate	2.61
Alkalies	2.15
Water and organic matter	21.82
Total	100.00
Fluxes	8.68

This shows a high percentage of organic matter, as the water does not exceed 5% probably, judging from the amount of alumina, and consequently there would probably be a considerable shrinkage in burning were it not for the high sand content. The fluxes are also too high for a fire clay, but the material may be semi-refractory.

These beds of shale at many of the coal mines are four to five feet in thickness, and there is usually an abundant supply of the material. At present it is either left in the mine or else brought to the surface and thrown on the

dump, where after a while it begins to slake, first to a scaly mass and then to a powder.

At Grand Ledge the coal measure shales are utilized for the manufacture of tile and sewer pipe, as described below, and at Saginaw there is a successful paving brick plant in operation.

The regions which were visited by the writer were Owosso, Corunna, St. Charles, Verne, Saginaw, Bay City and Sebewaing. Samples were collected from those localities which appeared promising.

Owosso.

There are two coal shafts near Owosso, viz.: those of the Owosso Coal Co. (Sec. 23, T. 7 N., R. 3 E), and the Corunna Coal Co. At both of these considerable shale is extracted with the coal and brought to the surface.

At the mine of the Owosso Coal Co., the coal is underlain by a light gray and at times sandy micaceous shale called fire clay locally. On exposure to the weather for several months the material slakes to a clay. The shale at times contains concretions of pyrite or even calcareous nodules with zinc, but these could be separated in mining the material. Overlying the coal is a black brittle shale containing considerable bituminous matter, and also pyrite. Both the underlying and the overlying material are of variable thickness, viz., from 2 to 8 ft.

The black upper shale is covered by sandstone.

At the shaft of the Corunna Coal Company the underlying shale is similar to that at the Owosso shaft, but the overlying material is similar to the upper clay used at the Saginaw Clay Mfg. Co. works. At both mines the coal is about 75 feet below the surface.

A sample of the underlying material at the Owosso shaft was tested with the following results:

Owosso Under Clay. (Lab. No. 226.)

This is a gritty, gray, sandy shale, which underlies the coal beet at Owosso, and is known as the fire clay. The material varies in thickness from 3 to 5 feet, and is not as much consolidated as the shales which are found associated with the coal at many of the other mines of Michigan, for when lumps of it are thrown into water they slake down slowly into angular fragments, while the shales from other localities do not slake at all. When mixed with water it gave a paste of very low plasticity; it required but 19% of water to work it up. The raw clay showed very little pyrite, but an abundance of mica scales. It did not effervesce much showing thereby the absence of any appreciable amount of carbonate of lime. The soluable salts in it amounted to only .3%.

In burning, when heated to cone 05 the color of the clay was buff; it could still be easily scratched by the knife and the mica scales still showed their lustre, the total shrinkage being 6%; incipient fusion did not occur until the clay had been heated to cone 02 at which point the total shrinkage was 7%, while the clay began to vitrify at between cone 4 and cone 5, with a total shrinkage of 9%, the color of the burned briquette being buff. Viscosity began at cone 9, thus showing that the material is not refractory as has been at times supposed. The iron oxide is not evenly distributed through the clay and produces fused specks.

The tensile strength of the air-dried briquettes is naturally very low owing to the coarse grain of the material, the lack of plastic particles and ranged from. 35 to 40 pounds per square inch the average being 37 pounds.

Although this shale is easily accessible and can be mined in considerable quantities, it has not up to the present time been utilized to any great extent, although it has been stated that at one time portions of it were shipped to the earthenware factory at Ionia.

It is hardly plastic enough for paving brick manufacture, but the best results could probably be obtained by mixing it with a more plastic clay.

St. Charles.

The mine of the J. H. Somers Coal Co., is located close to the Michigan Central R. R. station. The coal bed is 185 feet below the surface and is interbedded in shale. The overlying shale is rather brittle and gritty, but on exposure to the air slakes slowly to a granular mass. It also contains much soluble mineral matter.

Underlying the coal is what is known as "fire clay/' which is a gray, gritty, clay shale. That it is not fire clay is however shown by the following tests:

The clay grinds up rather easily but slakes very slowly when thrown into water. It shows no appreciable amount of mica, and no pyrite.

When mixed with 18% of water it gave a mass of rather low plasticity, but one which on account of its porosity and leanness stood rather rapid drying.

The bricklets made from the shale had an air shrinkage of 4%, while their total shrinkage at cone 1, when incipient fusion occurred, was 7%, and the color was buff speckled. Vitrification occurred at 5, with a total shrinkage of 12%, the color being grayish buff. The clay became viscous at cone 8.

We see from this that the fusion of the clay takes place very slowly, and that the beginning and end points are pretty well separated. From the fact that the clay fuses at cone 8 it cannot be considered as a fire clay. The percentage of soluble salts in it is .35%. With the shale alone we have a good material for the manufacture of pressed brick, but for making paving brick out of the material it would be desirable to mix a more plastic clay with it.

At the coal shaft one-half mile from the station in a westerly direction the character of the overlying and underlying shale is similar.

The shale or fire clay underlying the coal ten miles east of St. Charles is said to be very plastic. This occurrence is on the land of F. L. Parker, in the N. E. ¼ of Albee township, Sec. 23.

Verne.

The coal at the mines of the Verne Coal Co., 3 miles west of Verne Station, is underlain and overlain by a pyritiferous, black, shale; very brittle and containing much organic matter, including *Productus Prattenianus* and other shells. No sample of it was tested.

Flushing.

The Saginaw Clay Manufacturing Co. has a large quarry about one mile north of Flushing, which is connected with the railroad by a switch. The section consists of a dark grayish black shale, of rather fine grain, and brittle character, see analysis 3, and a lighter gray shale of softer quality and more open texture, analysis 4. The former is spoken of as shale and the latter as fire clay. The two are separated by a thin seam of coal, which is also sent up to the brick works to be used as fuel for burning the brick. There is five feet of stripping.
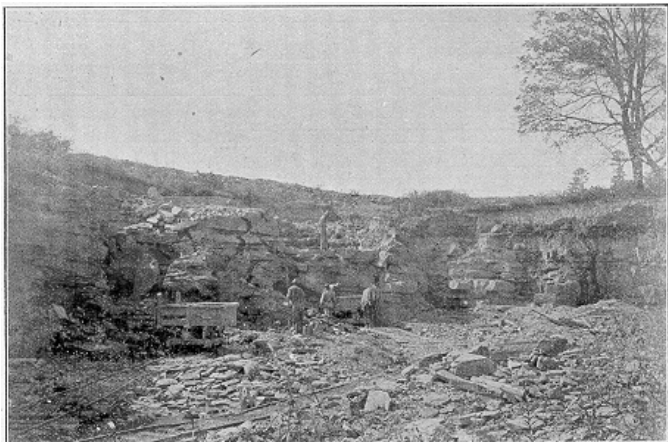

Figure 2. Shale quarry, Flushing.

The two clay materials found in the quarry correspond in general to the shales found over and under the coals at the different mines in the Saginaw region. Neither of them are soft enough to permit their extraction without the use of powder. In quarrying the shales are loaded onto cars as shown in the view, (Fig. 2.) and these are drawn to the base of an inclined plane by horse power, up which they are then hauled with a wire cable to the railroad track where they are emptied into the cars.

The two shales are mixed in about equal proportions in the manufacture of the paving brick. The upper shale is the more fusible and serves as a bond in the finished product, while the lower clay is the more plastic of the two and serves to hold the mass together in molding, and facilitate the flow of the clay mixture through the die

of the stiff mud machine. Owing to its more refractory nature it also serves to keep the form of the brick during the burning when the material is heated up to the temperature of vitrification. These differences are brought out in the tests of the individual clays, but could be emphasized if a mixture of the two were tested.

Analysis No.	2.* Gray shale.	3. Black shale.	4.* Fire clay.
SiO₂	63.00	54.50	70.55
Al₂O₃	21.80	30.75	21.20
Fe₂O₃	8.80	3.50	3.20
CaO	1.70	1.05	1.90
MgO	2.00	1.69	1.50
Soda	.79	.8	.74
Potassa	1.88	2.2	.90
Water		5.51	
Total	99.95	100.00	100.00

*Analyses from mineral resources, 1896.—Eighteenth Annual Report, Director U. S. Geological Survey, Part V, p. 68, from Saginaw Clay Manufacturing Company, H. and W. Heim, Analysts.

These analyses have also been printed in the Michigan Miner. As the absence of water shows, No. 2 and No. 4 cannot represent a natural unburned clay.

A sample of the lower or so called "fire clay" (183) required 20% of water to work it up and gave a moderately plastic mass, whose air shrinkage was 5%. When molded it showed a slight tendency to crack, unless much pressure was used. The tensile strength of the air dried briquettes was from 60 to 65 pounds per square inch, and while this may seem low, still it is no lower than that exhibited by many other shales used in the U. S. for the manufacture of paving brick. In burning incipient fusion began about cone 1 wiith a total shrinkage of 10%, the color of the clay being grayish buff. At cone 5 the shrinkage was 11%, and vitrification was not reached until cone 7. The color of the bricklet remained the same, but the shade deepened somewhat. The clay became viscous at cone 11. The raw clay contains considerable finely divided mica, and also some concretions of carbonate of iron, which the workmen in the quarry call sulphur.
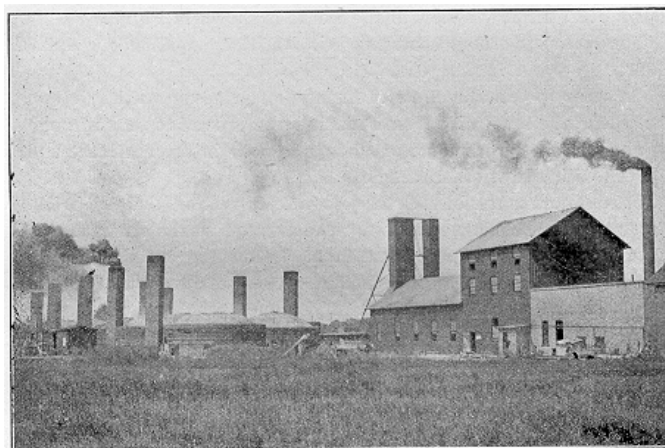

Figure 3. Brick works, Saginaw Clay Manufacturing Co., Saginaw.

The other ingredient of the paving brick mixture, viz., the shale (222), is hard and sandy, but darker colored. The sand is often concentrated into thin seams and there is

much fine grit, but little or no carbonate of lime, for the clay does not effervesce with acid. When ground to pass a thirty mesh sieve, and mixed with 20% of water, it yielded but a lean mass with an air shrinkage of 3 per cent. In burning, the clay showed a total shrinkage of 5% at cone 05 and incipient fusion was not reached until cone 1. At this point the color was red and the total shrinkage 7%.

The brick vitrified at cone 6, and gave a total shrinkage of 9%; the color being deep red. Viscosity was reached at cone 8.

The tensile strength of air dried briquettes ranged from 35 to 40 pounds per square inch, and the soluble salts were .3%.

The process by which the bricks are manufactured consists in grinding up the shale in dry pans, and then mixing the material in a pugmill after which the bricks are molded on a stiff mud machine. The drying (about 36 hours) is done in tunnel dryers and the burning (for 10 to 12 days, and about the same time for cooling) in circular down draft kilns. A view of the works is shown in Fig. 3.

For data as to orders, contracts, etc., see Michigan Miner for April, 1900.

In order to test the effect of fineness of grinding on the shale a sample of the lower clay from Flushing was ground to pass through a sixty mesh sieve instead of 30 as was done in the first case and indeed with all the other samples tested.

This ground material took 22% of water in mixing, and the bricklets had an air shrinkage of 5½%. The average tensile strength was from 55 to 60 pounds per square inch. In burning, incipient fusion occurred at 1, with a total shrinkage of 10%, vitrification at 5 to 6, and viscosity at 10. The effect of the finer grinding was to produce a more homogeneous tint or color in the burned brick, and to make it densify at a lower temperature, but the temperature of fusion remained about the same and the tensile strength and plasticity were not increased.

The following tests of their paving brick by the company may be of interest, though the variation in specific gravity of the brick substance shows that they are not very accurate and that probably No. 1 was not thoroughly soaked.

	1.		2.	
Weight in dry air at beginning	12 lbs.	12 oz.	31 lbs.	10 oz.
Weight in water dry at beginning	7 "	0	(17	12)†
Weight in water wet	7	4	18	7
Weight in air wet	13	0	32	5
Weight in air dry at end	12	12	31	10
Specific gravity of brick substance	2.32			2.62
Weight of brick in ozs. per cu. foot*	2,217			2,310
Ratio of absorption	1.96%			2.18%
Porosity, % of volume pores	4.6%			11.9%

*More precisely kilograms per cubic meter.
†Computed.

*More precisely kilograms per cubic meter.

†Computed.

Saginaw.

Standard Mining Co., Sec. 6, T. 11, N., R. 5 E.

The shale (217) under the coal at the shaft of the Standard Mining Co. is a dense brownish shale with plant stems, and small mica scales, but with very little grit. It burns to a good red brick at cone 1. The shale when ground to 30 mesh yields a moderately plastic mass with 20% of water and had an air shrinkage of 4%. The average tensile strength of the air dried briquettes was 55 to 65 pounds per square inch. The soluble salts amounted to .2%. Incipient fusion occurred at 1 with a total shrinkage of 10%, and the clay vitrified at cone 4, and became viscous at 9. The clay burns red.

Its composition is given in the following analysis by A. N. Clark:

ANALYSIS 1, (Repeated).	
Silica	55.30
Alumina	14.20
Ferric oxide	3.62
Lime carbonate	.30
Magnesium "	2.61
Alkalies	2.15
Water and organic matter	21.82
	100.00

This was probably not a thoroughly dried specimen.

In sinking a new shaft at the Standard Mining Co.'s property the following section was penetrated:

Sandy clay	90 ft.
Fine grained blue clay	10 ft.
Impure "fire clay"	3 ft.
Shale	8 ft.
Conglomerate	4 ft.
Black shale	20 ft.
Coal	
Fire clay (so called)	6 ft.

The 8 foot bed of shale was tested as it appeared promising, and could be extracted without much trouble in connection with the coal. While this sample (220) took 23% of water to work it up, still it did not give a very plastic mass, but one whose shrinkage was low, viz. 3%. The tensile strength ranged from 30 to 42 pounds per square inch, with an average of 35 pounds.

The soluble salts were .3%.

In burning, incipient fusion occurred at cone 3, vitrification at 7, and viscosity at 9.

The shrinkage and color were as follows:

Cone.	Shrinkage.	Color.
05	3%	Buff.
1	5%	Red.
3	7%	Red.
5	9%	Deep red.

At the shaft of the Pere Marquette Coal Co. the bed of shale overlying the coal is of a brownish black color and contains considerable organic matter. It is dense, somewhat brittle, but does not slake easily or only on long exposure to the weather. Neither mica, pyrite nor carbonate of lime were noticed in it.

The shale found over the coal at the Pere Marquette shaft No. 2 and at the Saginaw Coal Co.'s shaft is similar. Underlying the coal at these shafts is a gray sandy shale which is at times very silicious and would more properly be classed as a sandstone lithologically. In places it yields, however, considerable quantities of

plastic material, which does not contain an excess of the sand.

The following represents the physical condition and behaviour of one sample from under the coal at the Pere Marquette shaft 1.

The shale required only 16% of water to work it up, giving a mass of poor plasticity as might be expected. This low plasticity was due probably to the fact that the particles are pretty well cemented together and consequently on grinding yield a granular instead of powdery mass.

The air shrinkage was 5%, and the tensile strength of the air dried briquettes ranged from 38 to 45 pounds per square inch. The soluble salts amounted to .4%.

In burning, incipient fusion began at cone 01, with a total shrinkage of 6%. Vitrification was reached at 4, with 11% shrinkage, and viscosity at 7. The shale burns deep brownish red.

Bay City.

At the mine of the Central Coal Mining company, the coal seam which is 150 feet below the surface, is overlain by a brittle bituminous shale, and underlain by a red to gray shale, varying in thickness from 2½ to 4 feet. This underclay is quite homogeneous, and resembles somewhat that found at the Standard shaft near Saginaw, but is much softer, being easily cut with the blade of a knife. It is stated that this clay (228) was at one time tried for the manufacture of bricks at Saginaw and gave good results.

Unlike most of the other shales found with the coals in this region, it slakes in water, although slowly. It has a somewhat sandy appearance and contains numerous small mica scales.

It took 19 per cent of water to work it up to a lean but not granular mass, whose air shrinkage was 5%.

The tensile strength of the air dried briquettes was from 50 to 60 pounds per square inch, and the soluble salt contents .3%.

In burning at cone 05 the total shrinkage was 6%, but incipient fusion was not attained until cone 1, with a total shrinkage of 7%, the color of the bricklet being cream. At cone 4 the shrinkage was 9% and the color of the brick the same. Vitrification took place at 5, and above this the clay burned to a grayish color, beginning to show signs of viscosity on the part of some of the larger ferruginous patches at cone 8. The brick as a whole did not fail until cone 11.

At the mine of the Michigan Coal & Mining Co., the shale forms a layer two to three feet thick under the coal. It is soft when mined but hardens on exposure to the air. It grades downward into a bluish-black shale. Overlying the coal is an argillaceous sandstone.

The undershale resembles somewhat that found at the Central Coal Co.'s shaft. While the two types found

under the coal both appear hard when dry, still they differ in plasticity as already noted, when freshly mined, and this difference also shows itself in their further physical behavior.

The upper part of the under clay (187), behaves as follows:

Water required to temper, 25%; air shrinkage of bricklets, 6%; tensile strength of air dried briquettes, 150 to 175 pounds per square inch; incipient fusion reached at 05, with a total shrinkage of 9%, vitrification at 1 and viscosity at 5. Soluble salts .2%.

The bottom layer on the other hand does not slake as readily as the preceding one. It shows no mica nor pyrite. In mixing it up only 17% of water were required, and the resulting mass was granular and lean; it could be dried rapidly without cracking. The air shrinkage was 4%, and the tensile strength of the air dried briquettes ranged from 55 to 60 pounds per square inch. The soluble salts were .7%. The clay burns red at cone 06 and vitrified at 2.

The coal at the Wenona Coal Co.'s mine is 158 feet below the surface and both underlain and overlain by shale. The underclay has the usual term of fire clay applied to it, and is a very silicious clay shale. The over clay is similar to that used by the Saginaw Clay Mfg. Co., but has occasional streaks of bituminous brittle shale. The thickness of this upper shale is 8 to 10 feet thick in many places, but at times thins out to 2 feet.

A sample of this material (180) was tested with the following results. It gave no effervescence with hydrochloric acid, and showed little or no pyrite, but scales of mica were not uncommon in it. When thrown into water it slaked little or none.

In working it up, 18% of water were required, giving a mass of low plasticity, whose air drying could be carried on rapidly, and was accompanied by 3½% of shrinkage.

The tensile strength of the air dried briquettes was also low amounting to an average of 55 pounds. The soluble salts were .6%.

In burning, incipient fusion took place at 2, with a shrinkage of but 4%, vitrification at 6, and viscosity at 8. The shale burned red.

At the shaft of the Monitor Coal Co. the overlying shale is similar to that at the Wenona Coal Co.'s shaft (which see) but contains more bituminous matter. It has somewhat less resemblance to the shale used at the Saginaw Clay Mfg. Co's Works. The so called fire clay underlying the coal is similar to that quarried in the quarry at Flushing, and used in the paving brick mixture at Saginaw. A car-load of the two shales was sent to Saginaw some time ago, for testing, and found to yield very favorable results. The fire-clay at this mine is said to average 8 to 10 feet in thickness and the shale 10 to 21 feet.

The Bay Coal Co. also has shale under its coal, as well as over it, which in its general character resembles the preceding very much. It is said to be four feet thick.

The following analyses by A. N. Clark give an idea of the nature of the shales above described:

Analysis No.	5.	6.
SiO_2	52.45	57.10
$Al_2 O_3$	23.27	20.02
Iron as $Fe_2 O_3$	7.93	8.18
Lime as $Ca CO_3$	1.82	0.71
Magnesia as $Mg CO_3$	1.06	1.47
Alkalies as K_2O	4.37	2.76
Difference, largely H_2O and organic	9.10	9.76
Sum	100.00	100.00
Ferrous iron as FeO	1.57	1.47

No. 5, field No. 12. (180.)
No 6, field No. 6. (187.)

Jackson.

Not much has been done on the shale around Jackson. Judging from the analysis the clay of G. H. Wolcott's yard in Springport township is practically a coal measure shale. (Analysis 31.)

Sebewaing.

The Michigan Standard Coal Co. has a shaft at the southern end of the town at which the coal is interbedded with shale.

That over the coal is a brittle black bituminous shale with numerous nodules of pyrite, while that under the coal is gray and sandy. On exposure to the air it slakes readily to lumps the size of a hazel nut, but to get it finer requires grinding. Some of it was tried at the neighboring brickyard, and it was not found possible to melt it in the scove kilns.

It was consequently thought desirable to test it physically.

The sample collected (182) gave no effervescence with acid, and slaked very slowly in water. When mixed with 17% of water it gave a mass of good plasticity whose air shrinkage was 5%, and the air dried briquettes made from it had an average tensile strength of 100 pounds per square inch with a minimum of 90 lbs.

In burning, incipient fusion began at cone 1, with a total shrinkage of 8%; the color being buff. It vitrified at 5, and became viscous at 9. The shrinkage at vitrification amounted to 13%. The soluble salts were .25%.

Grand Ledge.

Near Grand Ledge are the most extensive exposures of the coal measures naturally in the state. The shales are exploited by the Grand Ledge Sewer Pipe Co., Frank A. Taber, Secretary. Their principal product is vitrified sewer pipe of dark color and good quality. A full description of this region was given by Dr. Rominger.*

The works are close to the N. E. corner of Sec. 10, T. 4 N., R. 2 W. and their raw material is mainly derived from pits about a quarter of a mile north, close to the

Spiritualist camp meeting grounds, at the summit of a bluff overlooking the valley of Grand River and a small tributary creek. The section is:

| 3 feet stripping of till.

7 | 4 feet grey shale.

8 | 1 foot black shale passing into coal.

10 | 2 feet white shale, so called fire clay. The lower line of this white shale undulates so as to indicate that it is merely an alteration of the shale below.

14 | 4 feet blue shale. This and the shale above the coal both contain nodules of kidney iron ore, sometimes showing some zinc-blende. This also shows traces of ferns, *Sphenophyllum cuneifolium*.

15 | 1 foot darker shale, the floor of the shale quarry.

Below in the bluff the section is continued by twenty feet of light and dark thin bedded sandstones or sandy shales, readily checking or cracking and slaking on weathering, down to a foot and a half of coal, which is the seam that is worked in a series of adits to the north, clear to and beyond the town line, at about the same level of ten or fifteen feet above the stream. The analyses of the darker and lighter shales from this pit are Nos. 7 and 8.

South of the works there is also a pit which lies much lower, in the valley of a stream and filled with water when not in use, which seems to be below the bed of coal. It is also said to be of different quality from the other, and richer in ferns. The section is:

15 feet cross-bedded sandstones.

17 | 2 feet coal with *Lingula mytiloides* just above and ferns just below.

20 | 3 feet white shale.

The coal measure shales are also exposed near Williamston and in Chester township of Eaton county, but have not been exploited.

Analysis of shale from Spiritualist camp meeting grounds, Grand Ledge, Mich., A. N. Clark, analyst.	7. Black Carboniferous Shale.	8. Grey Carboniferous Shale.
SiO_2	44.30	57.20
Al_2O_3	23.72	18.95
Fe_2O_3	7.68	8.31
CaO	1.11	0.83
MgO and Mn_3O_4	1.50	1.83
K_2O and Na_2O	2.00	2.70
H_2O and organic matter	17.64	9.00
CO_2	2.36	1.32
SO_3		0.12
Sum	100.31	100.26

P_2O_5 is probably included with alumina.

*Geol. Sur. Mich., Vol. III, Part I, p. 131.

§ 6. Michigan series of shales.

The shales of the Michigan series form a belt 10 to 20 miles in width, surrounding the area of Carboniferous rocks in the Lower Peninsula. They are, however, best exposed at Grand Rapids, where they form a bed of 6 to 10 feet thick overlying the gypsum. They are also

exposed in Huron county and Arenac county, and in Tuscola county along the Cass River where it has been proposed to exploit them for the manufacture of Portland cement.

Grand Rapids.

The character of the shales associated with the gypsum can be well judged from its occurrence at two localities in this vicinity, viz.: at the shaft of the Powers Plaster Co. and in the quarry of the Alabastine Co., Fig. 4.
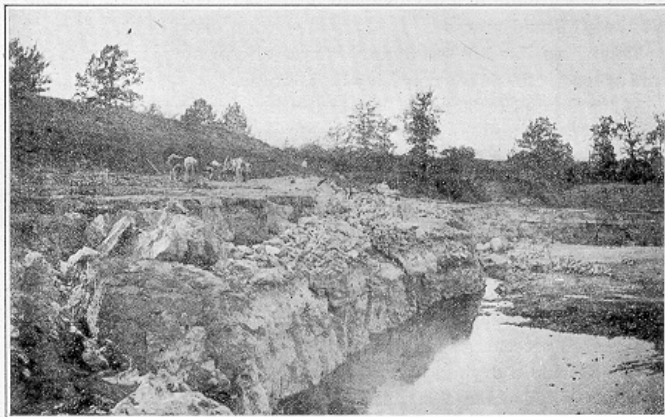

Figure 4. Shale and gypsum quarry. Alabastine Co., Grand Rapids.

In order to determine the degree of variation at this locality, samples were examined from both of these points.

The first was taken from the shaft of the Powers Plaster Co. (216), and this was a dense, brownish gray shale, containing but little mica, and no pyrite, and slaking with extreme slowness, although it mellowed down slowly when exposed to the air. In tempering the material and working it up, 26% of water was needed, the bricklets made from this having an air shrinkage of 6%, and the air dried briquettes ranging in strength from 180 to 155 pounds per square inch.

Incipient fusion occurred at 05 with 12% total shrinkage, vitrification at cone 2 and viscosity at cone 6.

The shale burned to a good red color. The soluble salts amounted to .9%.

The second sample (227) was taken from the quarries of the Alabastine Company, at Grand Rapids, (Fig. 4), where it forms a bed 7 feet thick overlying the gypsum. The shale is itself covered by three feet of drift material.

At present the shale is used in the manufacture of common brick. Before molding it is spread out under a shed to dry and slake, after which it is ground in a dry pan and tempered. The molding is done by the stiff mud process.

This shale like the preceding sample shows no pyrite or mica, and when fresh slakes very slowly in water.

When ground to 30 mesh, it mixed up to a very plastic mass requiring 32% of water. The air shrinkage of

bricklets made from this mixture was 6%. The average tensile strength of air dried briquettes was 105 pounds, with a maximum of 110 pounds. The soluble salts amounted to .9%. In burning, the bricklets were a good red, which of course deepened with harder firing.

Incipient fusion occurred at 05, vitrification at 01, and viscosity at 3. At the first of these points the total shrinkage was 12%, and at the second one 16%.

The high percentage of soluble salts caused a white scum to form on the bricks in drying, but this could be prevented by the use of barium chloride or carbonate.

Compare the analysis of this clay from Grand Rapids by S. P. Sharpless, cited in Mineral Resources for 1895,* to wit:

ANALYSIS 9.

SiO_2	58.70
$Al_2O_3 + Fe_2O_3$	25.95
CaO	1.00
MgO	.74
Alkalies	5.54
Water, etc	8.07
Sum	100.00

Analysis No. 10 is also from Alabastine opening, and will be seen to resemble No. 9 strongly. It is of sample No. 20 by A. N. Clark.

ANALYSIS 10.

SiO_2	56.50
Al_2O_3	19.31
Fe_2O_3	5.89
$CaCO_3$	1.00
$MgCO_3$	1.85
Alkalies (K_2O)	5.98
Difference	9.47
	100.00
Ferrous iron as FeO separately	1.34

Another analysis of shale clay made by Prof. Kedzie from this formation north of Saginaw Bay is very similar, but with less alkalies, (?) salt.

*Sixteenth Annual Report of Director U. S. G. S., Part IV, p. 566.

§ 7. Coldwater shales.

The Coldwater shales are perhaps the most extensive in the state, and from the economic standpoint have thus far been the most important, because they are the source of supply of all the Portland, cement factories of Michigan. They have been quarried chiefly at Bronson, Union City and Coldwater, but extensive beds also occur at Quincy. At these three points the shale is fine-grained, soft, and weathers rather easily to the clay-like mass. The composition of that used at Bronson is:

ANALYSIS 11.

	Per cent.
Silica	62.10
Alumina	20.09
Ferric oxide	7.81
Lime	.65
Magnesia	.96
Sulphuric acid	.49
Water and organic matter	7.90
	100.00

The shales of this series show, so far as the tests go, the properties desirable in the manufacture of vitrified wares. They also burn to a good red color, and vitrify at a moderate heat.

Union City.

This shale has been utilized for the manufacture of Portland cement, but is likewise capable of being employed for other purposes.

The shale which (218) is obtained three miles to the southeast of the town is similar to that used at Bronson, at least as far as appearance goes.

It contains little or no carbonate of lime, as it produces no effervescence with hydrochloric acid. Neither does it show much pyrite. In working it up, 25% of water were required, and yielded a moderately plastic mass, whose air shrinkage was 5%. The air dried briquettes had a tensile strength of from 70 to 80 pounds per square inch, which is rather low.

The soluble salt content was also low, amounting to .4%.

The clay burns bright red, which deepens as vitrification is approached. Incipient fusion was reached at 05, and vitrification at 2, the shrinkage at these two points respectively being 9% and 13%. Viscosity occurred at cone 5.

Quincy.

A. sample of shale from the property of H. Bennett (219) and representing the average of his deposit as exposed in the creek mentioned, gave the following results:

The shale when fresh is dense and hard, but weathers down to a clay which is tough and plastic and contains little grit. It does not effervesce with acid, and shows no mica nor pyrite.

Only 19% of water were required to mix it up, and the mass obtained was moderately plastic. The shrinkage of the bricklets in air amounted to 4%, and the average tensile strength of the air dried briquettes ranged from 75 to 80 pounds per square inch.

The soluble salts were only .2%.

In burning to cone 05, the total shrinkage was 6%; at cone 03, 8%; the clay fused incipiently at the last point. It vitrified at cone 3 with 12% shrinkage, and viscosity took place at 6.

Coldwater.

This shale is also used in the manufacture of Portland cement, the portion quarried being the weathered part of the bed. The material is mostly fine grained, containing but little grit, and the lumps slake slowly when thrown into water. The shale yields no effervescence on the addition of muriatic acid, but carbonate of iron concretions are at times found in it.

In working it up for molding, 21% of water were required, and this gave a mass of very fair plasticity and ability to stand rapid drying. The air shrinkage was 7%, and the air dried briquettes had a tensile strength ranging from 125 to 139 pounds per square inch. In burning, incipient fusion was reached at 03 with a total shrinkage of 14%,

the brick burning to a good red color. At cone 1 the brick became deep red and vitrified at 2 with a total shrinkage of 16%. Viscosity was reached at 5.

If heated too fast there was danger of warping the bricklet. The shale contained a trace of soluble salts.

The partial composition of the Coldwater shale is:

ANALYSIS 12.

Silica	53.44
Alumina and ferric oxide	24.80
Lime	.76
Magnesia	.25
Difference	20.75
Sum	100.00

Bronson.

This shale (230), which is obtained from the Cuyahoga formation, like many other deposits found in this state is at present used chiefly for the manufacture of Portland cement. It is being mixed with marl for that purpose. It would seem, however, that it has marked possibilities in other directions and consequently a sample of it was taken from the stock pile of the Portland cement works at Coldwater, and subjected to a physical test, which yielded the following results: The shale itself is dark gray in color, somewhat dense, but not very hard, and when exposed to the water breaks down into a rather plastic clay.

When ground to pass through a 30-mesh sieve it required 31% of water to work it up into a moldable mass which was very plastic. But in spite of its high plasticity large bricks which were made from it and subjected to rapid drying did so without showing signs of cracking. The air shrinkage of bricklets made from this mixture amounted to 6%. In the burning of the material the temperature had to be raised very slowly in order to prevent the brick from cracking and swelling as it contained a high percentage of organic matter.

The following figures show its behavior under fire:

At cone 06, total shrinkage 12%, color red, incipient fusion; at cone 03, total shrinkage 15%, color red, bricklet nearly vitrified, at cone 1, total shrinkage 16%, color deep red, vitrification reached.

At cone 2, viscosity begins.

In spite of its high plasticity, bricks made from this mixture did not show a very high tensile strength, this latter ranging from 100 to 125 to 135 pounds per square inch.

The soluble salts amounted to .5%.

Analysis 11, above, is the composition of this material quoted from "Mineral Industry" Vol. VI:

White Rock.

Excellent exposures of Coldwater shale occur along the shore of Lake Huron between White Rock and

Forestville (Plate I), but they have not thus far been utilized.

The shale forms a line of cliffs, and when fresh appears brittle and gritty; in places, however, it has mellowed down to a tough clay.

The rock is a thinly laminated shale (179), which contains much sand of a very fine nature, and slakes slowly along the layers. It worked up with 19% of water to a mass of fair plasticity. The bricklets had an air shrinkage of 4%, and the briquettes had a low tensile strength of 36 to 42 pounds per square inch.

Incipient fusion took place at 03, vitrification at 3, and viscosity at 6. The total shrinkage when in the vitrified condition was reached was 11%, the color being deep red.

An analysis of this material yielded:

ANALYSIS 13.

Silica	58.70
Alumina	18.31
Ferric oxide	7.19
Lime carbonate	1.80
Magnesium	.98
Alkalies	3.67
Water and organic matter	9.35
	100.00
Ferrous oxide	2.73
Total fluxes	13.64

§ 8. Devonian shales.

Some of the promising shale exposures in the State are those outcropping to the southeast of, and around the village of East Jordan. They weather to a tenacious clay, and burn to a good red color. Like the Branch county Coldwater shales, they show evidence of the presence of considerable soluble salt, and this would have to be looked after in the manufacture of certain grades of clay products.

In part at least they probably belong to the Devonian (St. Clair) shales, but the Berea Grit which divides the Coldwater shales from the St. Clair shales, has not been located in this part of the state.
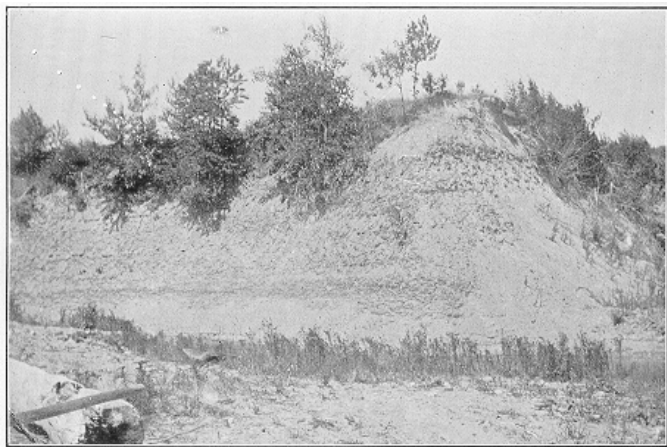

Plate I. Shale at White Rock, near Forestville.

Plate I. Shale outcrops near Forestville.

East Jordan.

Some years ago a shaft was sunk on the property of J. H. Kocher about five miles south of East Jordan, on the W ½ of N. E. ¼, Sec. 30, T. 31 N., R. 6 W.

In the sinking of the shaft which is 105 feet deep a number of shale layers were penetrated, which were mostly of a grayish-black color due to the organic matter which they contained, those near the bottom of the shaft containing considerable quantities of small selenite crystals, but no pyrite was noticeable. While the shale weathers down to a clay on exposure, the fresh pieces slake but slowly splitting along the layers.

The shale (185) contains a high percentage of soluble salts (.8%), which (form a white coating on the surface in drying. In working up the shale for molding, 20% of water was required, and even then the mixture was only moderately plastic. The air shrinkage was 5% and had to be carried on slowly to avoid cracking. The tensile strength of the air-dried briquettes was from 70 to 80 pounds per square inch.

In burning, the clay burned red at 05, with a total shrinkage of 7, but incipient fusion was not attained until 01.

The clay had to be heated very slowly, until all the organic matter had been expelled. Vitrification took place at cone 3 and viscosity at 6.

Another good locality for examining the shale of this region occurs along the road on Sec. 13, between the lumber camp of the East Jordan Lumber company, and the town of East Jordan. There are several outcrops of shale which in places are weathered to a depth of 10 or 15 feet. A sample (177) was taken from the cut in the road near the camp, and the material is a tough reddish clay, which is similar to that being worked in the brickyard at East Jordan.

It is very fine grained and slakes freely in water, but gives no effervescence with acid. It contains .8% soluble salts, which appear on the surface in drying and burning. The air shrinkage was 7%, and had to be

carried on slowly. Incipient fusion occurs at 05, vitrification at 01, and viscosity at 2.

The clay burns to a deep red and makes a very smooth brick. The total shrinkage at vitrification was 13%. The tensile strength of the air dried briquettes was from 80 to 95 pounds per square inch. The following analysis (14) of the material was made by A. N. Clark. No. 15 is also from these shales:

Analysis No.	14.	15.
Silica	55.95	58.60
Alumina	17.43	17.66
Ferric oxide (all iron as)	7.67	7.44
Lime carbonate	2.14	2.14
Magnesium carbonate	1.55	2.19
Alkalies as K_2O	2.86	....
Water, organic matter and difference	12.40	11.97
	100.00	100.00
Ferrous iron as FeO	0.50	....

Norwood.

Along the lake shore about one half mile south of Norwood are extensive outcrops of a dark shale, which is thinly bedded, and traversed by numerous joint cracks. The beds vary somewhat so that by searching along the shore it will be found that the material is softer at some localities than others. A sample (176) was taken from the bluffs along the shore one-half mile south of the landing at Norwood. It works up with 24% of water to a very plastic but not sticky mass, which had an air shrinkage of 6%. The drying had to be carried on slowly to prevent cracking, and in the early stages of the burning, great care had also to be taken. In burning the incipient fusion of the clay was reached at 02, with a total shrinkage of 12% vitrification at 1 with 14% shrinkage and viscosity at 3 which is rather low. The tensile strength of the air dried briquettes was very good, ranging from 135 to 150 pounds per square inch, and the soluble salts were .6%. This is almost certainly the St. Clair shale.

There are, no doubt, many other localities around Charlevoix and E. Jordan, which would yield material suitable for the manufacture of common, pressed or vitrified brick. In addition the intervening lowlands contain beds of clay which have been formed by the wash from the shale outcrops on the hillsides. In some cases these are associated with marl.

Clay also occurs 1½ miles southwest of Boyne Falls on the property of J. F. May, and on the land of Mrs. Powers. The lower layers of the deposit on this latter property it is said, have been tested for pottery purposes, but the upper layers when burned into brick showed a tendency to crack.

Another analysis given below of the St. Clair shale is probably of the fresh material from which the East Jordan and Norwood clays are derived by a process of weathering, involving loss of the volatile combustible. This analysis was given by W. H. Johnson of Alpena and as its form shows was also intended to test the fuel value.

ANALYSIS 16.

Volatile matter	17.96
Fixed carbon	6.49
Ash	75.55
	100.00

ANALYSIS OF ASH.

Silica	70.54
Alumina	15.33
Ferric oxide	5.31
Lime	2.38
Magnesia	.78
Alkalies, etc., by difference	5.56
	10.00

The ratio of silica to alumina is unusually high. That of alumina and iron remains fairly constant in all these shales, at not far from 3 to 1, but here the iron is somewhat in excess.

§ 9. Hamilton (Traverse) shales.

Deep wells passed shale in this group according to many of the records compiled in Vol. V of this report. Much of the so called soapstone is calcareous shale. Such shales are heavily covered with drift in the lower part of the state and no important seams are reported near the surface around Little and Grand Traverse Bay, although the Petoskey and Charlevoix deep wells passed through well marked beds of shale at considerable depths. Only around Alpena do these beds appear to come to the surface in available shape. Out at the end of Third street, Alpena, is a smooth unctuous clay, which effervesces freely with acids and hence is too calcareous for many uses, which appears to come out from under a limestone and to be a calcareous shale which has slaked in weathering.

The Alpena Portland Cement Co., have, however, a clay shale outcropping several miles north of Alpena, and hence probably about the horizon of the Marcellus shale which is between 400 and 500 feet down at Alpena. The dip in that region is about 42 feet per mile to the southwest. From the analysis it will probably be a good clay not only for cement but for high grade brick in general. The analysis is as follows:

ANALYSIS 17.

Silica	61.09
Alumina	19.19
Iron as ferric oxide	6.78
Calcium oxide $= (4.48CaCO_3)$	2.51
Magnesium oxide	.65
Potassium oxide	1.80
Sodium oxide	1.36
Sulphuric anhydride	1.42
Water and CO_2	5.13
	99.93

§ 10. Hudson river shales.

The Hudson river shales, which outcrop abundantly at some points of the Upper Peninsula, especially to the northeast and east of Escanaba, are too highly calcareous and too silicious to be of any value in the making of clay wares.

A series of analyses by Prof. G. A Koenig, of the Michigan College of Mines, of samples from bluffs in this region showed a series of calcareous shales, and argillaceous limestones. Some of the layers had the right composition for natural cement rock, but the composition did not seem to be regular, either horizontally or vertically.

From a well recently put down at St. Ignace, I have samples down to 1,098 feet and I judge that it entered the Trenton limestone, (though the separating line is by no means clear) probably at about 1,044 feet depth. The Niagara seems to

extend from 426 to 788 feet, but between that and the bottom there are no marked shale beds. Brown dolomitic limestones predominate.

See also Geol. Sur. Mich., Vol. I, Part III, pp. 50 to 56, by Carl Rominger. L.

§ 11. Surface clays.

All of the soft plastic clays occurring in the state are of Quaternary age, but still divisible into three types, viz.: morainic or drift clays, lake clays, and river silts.

The former include those deposits of rather local extent, which form masses of often lenticular shape, enclosed within drift material. Among these may be mentioned the occurrences at Lansing, Ionia, Kalamazoo, and possibly Harrietta.

The glacial clays are invariably calcareous, while the lake clays are very frequently so. The river silts are less likely to be calcareous, but are usually gritty. A noteworthy fact is that there is often a division into two members, viz., a lower very calcareous cream burning one and an upper less calcareous one from which the lime has perhaps been leached by weathering, which burns red. This was noticed at Detroit, Lansing, Sebewaing and Minden City, and may hold true at other localities. At most points, however, the deposits are worked only on a small scale and consequently the clay pit seldom extends below the bottom of the upper member.

The number of localities at which surface clays are worked is very great and consequently but a few of them could be visited in the time available.

The calcareous composition of the surface clays is shown by the following analyses, No. 18 being of clay from the Prairie farm near the junction of the Flint and Shiawassee Rivers from C. A. Davis, and No. 19, from near Grayling, No. 20 from Middle Lake; these latter we owe to the kindness of Wm. M. Courtis, C. E.

Analysis No.	18.	Analysis No.	19.	20.
SiO_2	58.50	SiO_2	52.35	55.35
Al_2O_3 Fe_2O_3 }	18.69	Al_2O_3	14.90	17.89
		Fe_2O_3	5.60	6.86
CaO	11.46	$CaCO_3$	15.10	7.25
MgO	1.75	$MgCO_3$	5.75	2.65
CO_2, computed	10.93	SO_3	.34	.86
		H_2O and org	3.95	} 1.25 } 3.75
		Alk. and loss	1.61	4.14
			100.00	

We may also include the analysis of a Marquette clay from Min. Res. Mich. 1889, p. 61.

ANALYSIS 21.

SiO_2	54.62	CaO	13.68
Al_2O_3	12.82	MgO	4.25
Fe_2O_3	2.	H_2O, CO_2 and loss	12.01
			100.48

The analyses of Clippert and Spaulding's clay (30), of some of Shepherd's clay (27, 28, 29), of the Henrietta clay (24), and the slip clays (32, 33), and Nos. (22, 23, 40, 43), are all of the same type. The surface clays have a strong tendency to have from 20 to 40% of carbonates.

The lake clays are those deposited during former extensions of the Great Lakes and often underlie large areas as at Detroit, Pt. Huron, South Haven, Marquette, Saginaw, Escanaba, and many other points along the Lake shores of the lower and even the upper Peninsula.

Detroit Clays.

The region around Detroit forms one of the most important brick making centers in the state, for surrounding the city large areas are underlain by lake clays of two types namely, the upper bed of sandy, calcareous clay and a lower very plastic material. At Wolf's and Clippert's yards for example, the upper bed averages six feet while the under bed is at least four feet thick, the bottom of it not having been penetrated thus far. The lower clay is not equally worked although it is the least fusible of the two.

A sample of both of these was tested with the following results:

Upper clay from Clippert Bros., yard.

This clay shows its calcareous nature by the free way in which it effervesces when a drop of HCl is put upon it. When a lump of it is thrown into water it slakes very fast, falling down to a powdery mass. The clay, while it contains a considerable amount of very fine grained sand, is at the same time highly plastic. Some idea of the fineness may be obtained from the fact that when we wash it through a 60-mesh sieve there remains only a 2% residue, while none remains on the hundred-mesh sieve and on the 150 mesh sieve there was but about 2% residue also. When worked up into bricks this clay required 24% of water by weight. These bricklets in drying had a shrinkage of 4%. When heated to cone 05 the total shrinkage was 6% and the color of the briquette was red; at cone 01 the bricklet showed incipient fusion with a total shrinkage of 14% and the color buff; vitrification occurred at cone 2, the color being reddish buff, while the clay became viscous at cone 4.

The soluble salts in the clay amounted to .6%, and the tensile strength was fairly high, but it was difficult to obtain bricks which were free from flaws owing to the high plasticity of the material, nevertheless the average strength obtained per square inch was from 150 to 190 pounds. This clay is used to a large extent for the manufacture of common building brick. The usual process of treatment is to mix the material with some sand if necessary, although it is not usual. It is tempered out in soak pits which are rectangular in form and rather shallow and after remaining over night in this and becoming soaked with the proper quantity of water it is transferred by means of wire conveyors into the molding machine, which are of the soft mud type. The bricks are with few exceptions burned in scove kilns. One or two of the yards in this region employ stiff mud machinery, and also drawers for evaporating the moisture from the product.

Lower clay, Detroit.

This is an extremely plastic, bluish clay, which contains but little grit. It does not slake .quite as rapidly as the upper clay, but contains a greater proportion of fine clay particles. When mixed with 26% of water it yielded bricklets that had a shrinkage of ?%. In burning these briquettes the incipient fusion occurred at cone 05 with a total shrinkage of 9% and the clay showing a greyish red color. The vitrification occurred at cone 1 with a total shrinkage of 15%. The clay became viscous at cone 5. The tensile strength of air-dried bricks ranged from 175 to 190 pounds per square inch and the soluble salts in the clay amounted to 4%. This lower clay would no doubt yield a denser brick than the upper one, but owing to its dense nature in the raw condition and owing to the low percentage of sand it is much harder to work.

Monroe County.

Prof. Sherzer finds* that the clays used in this county are generally superficial river silts and lake clays, a few feet thick. They burn to a cherry red. There is some trouble with lime pebbles.

*Geol. Sur. Mich., Vol. VII, Part I, pp. 187 to 190.

Ionia.

The glacial drift at this locality contains considerable amounts of calcareous clay and much is also found underlying the valley bottom. Two branches of the clayworking industry are based on this occurrence, viz., a brick yard and a pottery. Although the clays used appear very similar in their raw condition, still that used for the bricks cannot be employed for the pottery.

The pottery at Ionia is operated by Sage & Dethrick, and the product consists of earthenware, flower pots and saucers. The clay used is found on the opposite side of the valley from the town at the base of the hill near the penitentiary. It is a fine grained, highly plastic, blue clay, having very little grit so that most of it passes through a 150 mesh sieve. In water it slakes moderately fast to a flocculent mass. It needed 28% of water to work it up, yielding a mass of high plasticity, and with no grit. The air shrinkage, amounted to 8½%, and the air dried briquette had an average tensile strength of 150 to 170 pounds per square inch. The clay contained .2% of soluble salts.

In burning, incipient fusion occurred at 05 and vitrification at cone 1 to 2. The clay burns cream white, and at incipient fusion is still quite porous.

In manufacturing the earthenware at Sage & Dethricks the clay is brought from the bank and stored in bins ready for use, and then put through a pair of rolls, from which it passes to a pugmill. At the discharge end of the latter there is fastened a heavy wire netting with meshes about one quarter inch, and forcing the clay through this tends to give an additional amount of tempering and also to destroy any lumps that be in it. From the pugmill the tempered clay goes to the molding room.

The larger sized pots and saucers are jollied,* but the small ones are pressed in steel molds.

The kilns are up draft and fired by wood, and the ware is commonly cream colored, being burned at about cone 05.

At the brickyard of F. H. Van der Heyden, the clay forms a high bank, (Plate II) involving the following section beginning at the top:

Sand .... 2 ft.
Fat clay .... 6 ft.
Gravel .... 2 ft.
Sandy clay .... 12 ft.

A mixture of the upper and lower clay is commonly used as it gives the best results. A sample of this was tested (181).

Its fineness is shown by the fact that when washed through a 100 mesh sieve, but a few grains remained on the former, and only 5% of fine sand on the latter. In tempering only 18% of water was required, but this yielded a mass of high plasticity. This shrinks in the air 6%, and at cone 05 incipient fusion was just about reached, with a total shrinkage of 7%, and the color creamy white. At cone 1 the total shrinkage was 12%, and the color buff. Vitrification took place at 2 and viscosity between 3 and 4.

The clay is used for making brick, and owing to its high plasticity tends to laminate when molded in a stiff mud machine. The yard is equipped with two different brick machines, viz., a Wallace stiff mud augur machine with a triple die, and a Creager soft mud machine. The latter is used for the lower sandy clay, while the mixture of the upper and under clay is molded in the auger machine. The soft mud bricks it is said stand the weather much better. The Creager machine has the clay prepared for it in a six foot pug-mill and a pair of rolls.

The yard is also equipped with a hand power repress and the product includes some tile.

For purposes of chemical comparison analyses of the brick clays 22, and the pottery clay 23, by A. N. Clark are here given:

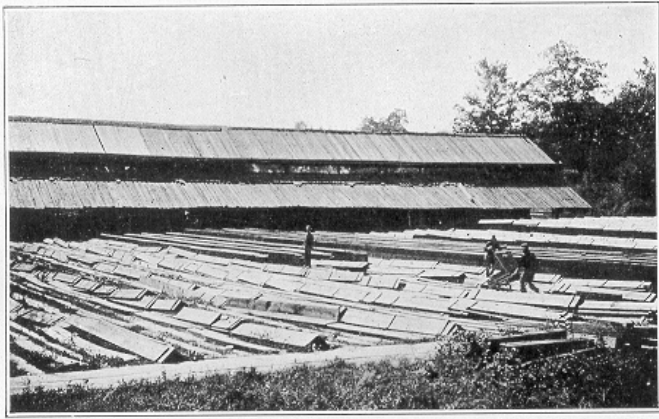| Analysis No.	22.	23.
Silica	44.15	40.15
Alumina	10.00	11.25
Ferric oxide	4.08	4.88
Lime carbonate	24.64	21.43
Magnesium carbonate	1.50	8.93
Alkalies	1.55	2.06
Org. matter	1.95	2.05
Water by difference	12.13	9.25
	100.00	100.00

Plate II. Drying yard, and

Plate II. Clay bank, Van der Heyden's yard, Ionia.

*A special mode of manufacture, in which the ware is turned on a wheel, but shaped in a plaster mold, the inside of the ware being shaped by a scraper, or "shoe." See Geol. Ohio. Vol. VII, p. 102.

Harrietta.

There are two extensive outcrops of clay at this town, the one to north of the Tillage at the brickyard of Geo. Heath, and the other in the ravine near the water tank just east of the railroad station.

The clay used at the brickyard consists of two beds, an upper and a lower member, the former burning buff on hard firing and light red when lightly fired, and a lower member which burned cream.

The clay as a whole is fine grained, tough and contains lime pebbles scattered through it.

A sample of the bottom clay which was tested gave the following results: When thrown into water it slakes rather readily, and most of the slaked mass passes through a 100 mesh sieve. When mixed with 29% of water it gives a very plastic mass, which has a high tensile strength, but owing to its fatness it was hard to mold briquettes from it that were free from flaws, and

while some ran as high as 275 pounds per square inch, the majority did not exceed 175 to 200 pounds.

The air shrinkage of the bricklets made from the clay was 8% and at cone 05, 10 per cent. The clay showed incipient fusion at 1, with a total shrinkage of 17%, while vitrification followed at 3, with a total shrinkage of 22%, viscosity coming at cone 5. The color of the burned clay was as follows, at cone 05 and 1, cream; at 3, greenish yellow.

The upper clay shrinks nearly as much. A determination of the soluble salts in the clay yielded .2%, which is not excessive. Owing to its high plasticity it was hard to dry large bricks of the clay rapidly without having them crack.

The upper clay at this bank is similar to the lower one in its general behaviour. It slakes as easily, but contains slightly more sandy residue. It took 30% of water to work it and gave a very plastic mixture whose air shrinkage was 7%. In burning, incipient fusion began at 04, with a total shrinkage of 11% vitrification at 1, with a total shrinkage of 17% and viscosity at 4. The clay burns nearly white at 05, and buff at 1.

The method of manufacture used at Heath's yard consists in feeding the clay mixture into a pair of rolls, from which it passes to a Kells stiff mud machine. Drying is done on an open yard, and burning in a scove kiln. When burned some of the bricks are buff to cream, while others are red, and a third lot are speckled cream and red.

There is an additional bed of clay a little east of the town, and which is exposed in several ravines. The best one is in a small ravine which is dammed to supply the Ann Arbor R. R. tank, and according to A. C. Lane is opposite to it on the S. E. ¼ of Sec. 7, T. 22 N., R. 11 W. The dam is about at the bottom of the clay which is underlain by a recently formed sandstone. The clay is free from grit is readily fusible, and reddish or greenish in hue. "It lies under a terrace which rises nearly 100 feet above the railroad track, and is cut by the valley which is one of the headquarters of the Slagle river. The clay is overlain by two feet of very fine sand.

The clay is on the property of J. Z. Stanley, who had it analyzed through J. H. Barnes with the following results:

ANALYSIS 24.

Silica	42.85
Alumina	9.87
Ferric oxide	3.43
Lime carbonate	25.55
Magnesium carbonate	13.23
Water, alk., etc.	5.07
	100.00

S. Geijsbeek who has also examined the clay, reports that it is probably best fit for a slip clay.

Saginaw.

Underlying the surface in the region around Saginaw, or at times covered by a few feet of sand are several beds of soft plastic clay, many of which are well adapted for

brick or pottery. In the sinking of a new shaft at the mine of the Standard Mining Co., a bed of blue clay 10 feet thick was struck, (see p. 33) of which the following are the properties (212): The clay is rather fine grained, all of it passing through a 100 mesh sieve. It effervesces slightly with acid, showing the presence of some carbonate of lime, and it also contains some lime pebbles. But it occurs at the base of the drift and the analysis suggests that it may be slaked shale. Analysis No. 10 is probably a fairer representative of the surface clays.

In working it up 33% of water were required, giving a very plastic mass whose air shrinkage was 7%.

Incipient fusion took place at 05, and vitrification at 01, with a total shrinkage of 18%. Viscosity occurred at 3.

The tensile strength is 105 to 110 lbs, and it contains .2% soluble salts.

Its composition is:

ANALYSIS 25.

Silica	47.75
Alumina	17.60
Ferric oxide	9.13
Lime carbonate	2.60
Magnesium carbonate	.70
Alkalies	2.21
Water and organic matter	22.01
	100.00

There are a number of brickyards working surface clays near Paines and making light colored brick.

Clare County.

The following is an extract from a letter from W. H. Shepard concerning some of his clays. Nos. 2, 3 and 4 it will be noticed were the usual surface calcareous clays, while No. 1 is quite different, would make a red brick, and if not gritty might do for Portland cement.

"Enclosed I hand you analyses. Clay No. 1, lies at top of Nos. 2 and 3. No. 4 is from just above or at outcrop of marl on flats and I presume extends under marl for short distance at least. I think I have quite an acreage of the No. 1 clay that will analyze quite uniform throughout the entire strata as I have bored quite a number of 2^ inch holes into it and taken samples. Have a little different clay at tops of some of the highest grounds."

CLAY ANALYSES—SECS. 8 AND 9, T. 17 N., 4 W.—MADE BY H. & W. HEIM, OF SAGINAW.

	26. Clay No. 1.	27. No. 2.	28. No. 3.	29. No. 4.
Silica (SiO₂)	65.05	47.60	45.60	50.40
Alumina (Al₂O₃)	25.	15.	15.85	22.10
Iron (F₂eO₃)	5.80			
Calcium carbonate	2.05	28.29	28.82	24.
Magnesium carbonate	.40	6.00	8.60	.52

Kalamazoo.

In the vicinity of the city there are several occurrences of surface clay, all of them closely resembling each other. They are utilized at present for the manufacture of common brick, but still are capable for making better products in some cases.

One of these deposits is worked at Wait's yard on the western edge of the town. This clay bank is a shallow deposit resting on sand which also forms the hills between which it lies. The clay burns red.

Another but larger deposit is at Leonard's yard along the South Haven branch of the Michigan Central railroad, six miles from the city (Plate III). Here the clay, which is said to be 14 feet thick, is divisible into two benches, viz., a lower one which is quite fat and an upper more sandy one. A mixture of the two is employed for making common brick.

In the manufacture the clay is tempered in ring pits and molded in soft mud machines. The drying is done on pallets and the burning in scove kilns.

A sample of the mixed clays from this deposit was tested (223), and was found to be one of the most plastic of the whole series collected in the present investigation. It took 23% of water to work it up, which is a low amount considering the high plasticity. The bricklets had an air shrinkage of 6%. Incipient fusion began at 04 with a total shrinkage of 14%, the color being bright red. At cone 1 the total diminution in size was 15%, and the clay brownish red; vitrification came at 2 with 17% shrinkage, and viscosity followed rather soon at cone 4. The tensile strength of the air dried briquettes ranged from 135 to 150 lbs. per square inch.

The clay could hardly be used for vitrified ware, but there is probably no reason why pressed brick should not be made from it. The soluble salts amounted to .7%.

Lansing.—Clippert and Spaulding's brickyard obtains its clay from a calcareous glacial deposit, about 2 miles E. of Lansing, on the N. side of the road to the Agricultural College, near the center of the N ½, Sec. 14, T. 4 N., R. 2 W. The clay is curiously located, right in the moraine which passes through Lansing. It is nearly solid clay from the grass roots, though the very top clay is a little stony. At the bottom of the bed, lines of stratification may be seen which are not to be observed in the main mass of the bed. This is shown in Fig. 5. The section is as follows:

Surface. . . .slightly stony.

3 feet. . . .clay, making red brick.

1 foot.... clay, making pink brick.

14 feet. . . .clay, making white to buff brick, uniformly calcareous, analyzed.

1 foot. . . .shaly clay, with layers of fine blue sand, red sandy clay, sandy gravel.

This firm make both red and white, handstock, repressed and machine brick, but only white tile, as they have no red brick clay to spare. The cull tiles sell well at half price, and the broken brick are sold for cistern linings at $1.00 a load. Different grades of sand are used for molding the red brick, and the white brick, and for mixing, though very little sand is added in mixing. Fig. 6 gives a view of the clay bank, and shows the method of

undercutting and blasting down and to the right in the background we can also see the upper bench of red brick clay. The clay does not stand very rapid drying, especially when molded in stiff mud machinery. Its calcareous character is shown by the following composition, which is almost exactly that of the Ionia pottery clay, No. 23:

ANALYSIS 30.

Silica	41.86
Alumina	10.70
Ferric oxide	5.02
Lime	14.33
Magnesia	2.81
Alkalies	2.80
Water	8.00
Carbon dioxide	14.56

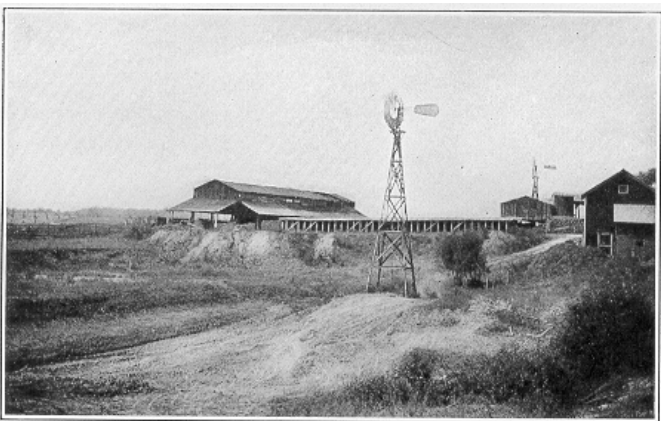

Plate III. Clay bank, and

Plate III. Yard of W. Leonard, Kalamazoo.

Sebewaing.

The surface clay used at the Sebewaing brickyard is a river clay, and is overlain in places by dune sands. The upper two or three feet burns red, while the lower clay in the bank is very calcareous and burns buff. Both clays contain large quantities of lime pebbles, and they are especially numerous in a layer at the juncture of the two kinds of clay. In order to eliminate these from the red burning clay it is treated to a washing process (Plate IV). One puts the clay into a circular sheet iron tank, with

water, and the mixture is stirred by arms attached to a vertical shaft. The effect of this stirring process is to get the clay particles in suspension, while the sand and concretions fall to the bottom of the tank. In front of the machine is a screen with half inch meshes, through which the washed and suspended material is discharged into a trough about 50 feet in length. At the end of this trough is another screen with one quarter inch meshes. After passing along this trough most of the sand is dropped, and the clay and water flow out into the settling tanks which have wooden sides and a sand bottom. The water evaporates from these and leaves the washed clay forming a layer about six inches thick in the bottom of the trough. While the clay is settling and drying on the trough the material being discharged from the machine at a later period is conducted into a second or third trough.
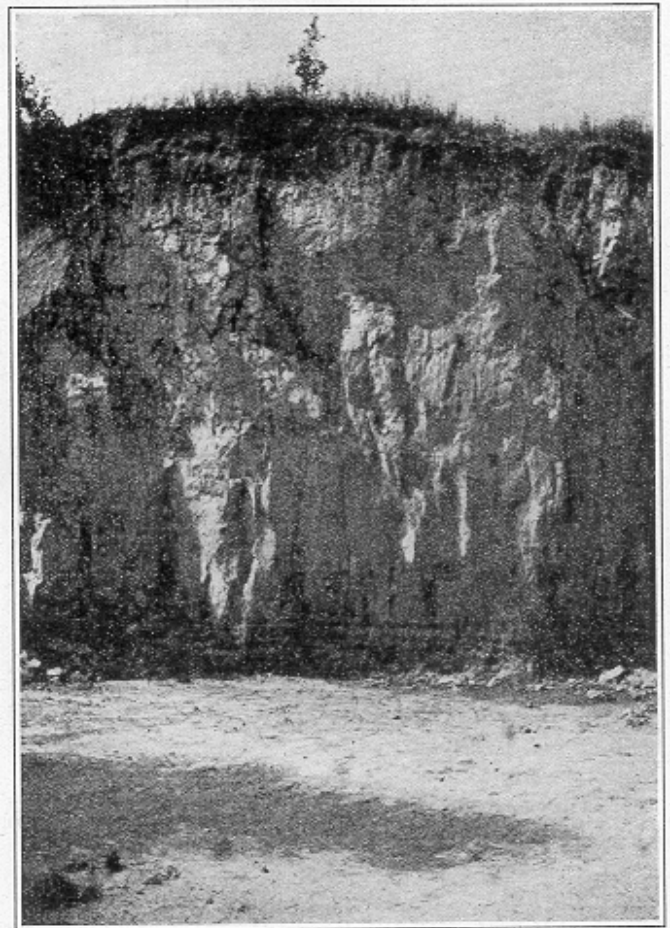
Figure 5. Clay bank at Clippert and Spaulding's brickyard near Lansing.

It is stated that two men can put enough clay for 16,000 bricks through the machine in one day. This ingenious washing process is a highly important one, and could be utilized at many other localities in the state where there are red burning clays containing lime pebbles or concretions. It furthermore removes the coarse sand from the clay and permits of the production of a much smoother brick, a point which is serious when front brick are to be manufactured.

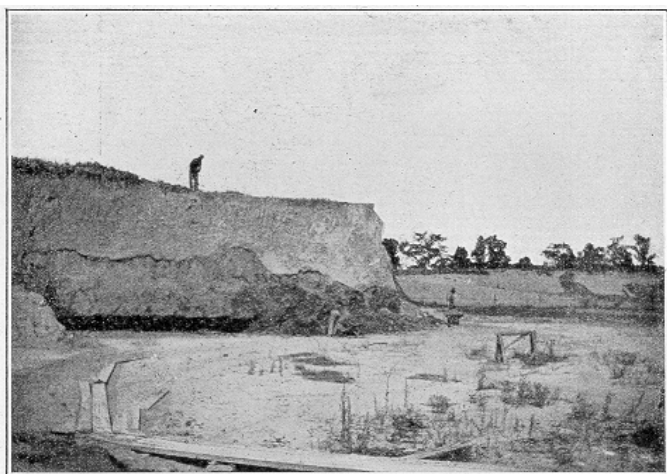Figure 6. Clippert and Spaulding's clay bank, Lansing. To the left the clay has been undercut, and a man is preparing to blast it down. To the right may be seen the upper bench of 3 feet of leached clay which makes red brick.

At the Sebewaing brick works the clays are molded in a Quaker soft mud machine, dried on pallets and burned in scove kilns. While the product is chiefly common bricks still some pressed bricks are made in various shapes and sizes. Their surface is, however, unfortunately roughened by the use of very coarse molding sand.

The lake clays are worked at Badaxe, both red and buff ones being produced. The lower clay bed and the inside of the kiln yield the lighter brick. Soluble salts give some trouble. At Elkton, where a clay from the valley of the Pinnebog is used, we have also a light orange red and a cream colored brick, and limestone pebbles cause some annoyance.

At Croswell, red burning clay is used, while at Minden City both the upper and lower members of the lake clays are employed.

Jackson.

There occurs a bed of potter's clay 5 miles west of Jackson, while at the Adler Brick Co., 3½ miles west, a soft plastic surface clay is employed, which burns red in parts and buff in others. The bricks are molded by the soft mud process and come into competition with the Detroit ones.

The Bennett Tile Co. is located 1½ miles east of town and utilizes a plastic clay, making drain tile and paving brick. They have a clay deposit 7 miles from Jackson, and a narrow gauge road connects it with the works.

At Onondaga the clay is again divisible into a red and a buff burning member. The following is the composition of a clay from G. H. Wolcott's yard, Springport township, Jackson county, from Mineral Resources for 1896, p. 61. Analyzed by Mariner and Hoskins:

ANALYSIS 31.

SiO_2	52.26
Al_2O_3	22.95
Fe_2O_3	8.15
CaO	4.48
Mgo	1.32
Water, etc	10.56
	99.72

This analysis indicates a more or less direct derivation from a coal measure shale.
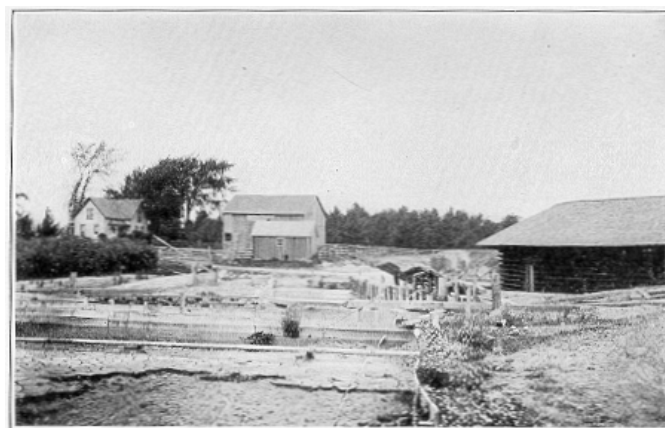

Plate IV. Washing tank, Sebewaing brickyard.

Plate IV. Settling tank, Sebewaing brickyard.

Rockland, Ontonagon County.

Wm. Jeff has a deposit of calcareous lake clay near this locality, which, owing to its fineness of grain, easily fusible nature, and correct composition, forms a natural glaze. The clay possesses very little plasticity, in-fact it acts very much like a fine grained mixture of silica when mixed up with water.

Its composition is as follows:

Analysis No.	32.	33.
SiO_2	52.92	40.12
Al_2O_3	12.25	11.17
Fe_2O_3	6.45	3.81
$CaCO_3$	13.84	11.64
$MgCO_3$	3.55	4.17
$(NaK)_2O$	3.35	3.61
H_2O and organic matter	7.14	19.56
	100.00	97.90

1. Analysis by A. N. Clark.

2. Analysis of Rowley Slip Clay, Orton, Ohio, Geol. Sur., VII (1893), p. 105, 12.85% combined, 31.09 free SiO_2; lime as CaO, magnesia as MgO; CO_2 with H_2O; 2.90% K_2O; .10% phosphoric acid.

Compare these analyses of good slip clays with others.

§ 12. Analyses from miscellaneous localities. L.

The following analyses (34 to 39) were also made by Mr. A. N. Clark. They are all from the surface or Quaternary formations. Many of them will be further referred to in the report on marl. They serve, however, very well here to show the calcareous nature and the proportions of lime and magnesia in surface formations.

Analysis.	34.	35.	36.	37.	38.	39.
(Insoluble in HCl) (SiO_2 and Al_2O_3)............	57.04	75.04	61.10	55.10	65.64	41.94
Alumina and iron................................	4.30	1.90	4.50	6.80	5.35	3.80
Calcium carbonate...............................	22.06	14.02	21.00	25.26	16.60	47.23
Magnesium carbonate...........................	12.45	6.05	11.76	3.10	9.53	3.79
Organic matter and water......................	4.15	2.99	1.64	9.74	2.88	3.24
	100.00	100.00	100.00	100.00	100.00	100.00

34. Field number A.   XII, mostly clay.
35.   "   "   B.   III.
36.   "   "   XIV A.
37.   "   "   XIII.
38.   "   "   XV G.
39.   "   "   XV, clay evidently near by.

The following partial analysis by Prof. F. S. Kedzie is of a clay from the Muskegon valley, which is also a calcareous surface clay:

ANALYSIS 40.

Silica	38.36
Alumina and iron	22.18
Calcium oxide	13.96
Magnesium oxide	8.19
CO_2, etc.	16.45
	99.14

Finally we cite from the report of the State Geologist for 1892, p. 173, some analyses of Upper Peninsula clays:

Analysis.	41.	42.	43.
Silica...	51.05	51.60	67.85
Alumina...	21.42	16.43	2.35?
Iron oxide..	7.81	7.27	
Lime..	1.93	5.40	14.24
Magnesia...	3.73	2.88	1.39?
Difference..	14.06	16.62	14.19?
Sum..	100.00	100 00	....

No. 41 is a red clay from Sec. 8, T. 47 N., R. 37 W.; Arthur Uddenburg analyst. It shows the ferruginous character of the iron country clays.

No. 42 is a brown clay from Sec. 6, T. 47 N., R. 36 W.; same analyst and comment.

No. 43. I have calculated from the data: 67.85% insoluble in H. Cl; 1.49% moisture at red heat; lost 12.7% of its weight after an hour at red heat; 25.43% Ca CO_3. Heated to a white heat for ten minutes, it was entirely fused to a dull gray slag; analyst F. F. Sharpless, location Sec. 23, T. 46 N., R. 24 W.

§ 13. Conclusion by Alfred C. Lane.

The account above given of the uses and properties of our Michigan clay will it is hoped be enough to give one an idea for what uses a particular material may be fitted. For those who wish to go further into the subject, the Annual Report of the Director of the Geological Survey, the part on Mineral Resources of the United states, non-metallic products may be commended. For instance in the sixteenth report (1894) there is a paper on the

Technology of the Clay Industry, in the seventeenth (1895), on the Clay-working Industry. The Engineering and Mining Journal publishes an annual called Mineral Industry which contains valuable papers. The Clay Worker published in Indianapolis is a trades journal of interest.

Among the recent state publications may be named:

Clay Industries of New York by H. Ries, published by the University of New York, price 30 cents.

Clay deposits and Clay Industries of North Carolina Bull. No. 13 of the State Survey, J. A. Holmes, State Geologist, Chapel Hill, North Carolina.

Preliminary Report on the Clays of Alabama, Bull. No .6, Geol. Sur. of Alabama.

Ohio clays are treated by E. A. Orton in Vol. Ill of the Ohio reports.

Missouri shales were treated by H. A. Wheeler in Vol. XI of the Missouri reports.

From these other references may be gleaned.

It is always difficult to tell how far to go in a report on Economic Geology into technology, that is description of manufacturing processes. Many of the reports just cited go more fully into the details in such matters, and any one who really wanted to go into the subject exhaustively would have to go beyond what this report would give in any case. In the same way Prof. Ries omitted details as to the exact methods of chemical analysis and testing, which would be of use only to those who were going to make similar tests, since before making such tests one ought to go to some laboratory where such work is done. There is of course scientific advantage in knowing precisely how things are done, but Dr. Ries has already several times published his methods, and the methods of analysis were those in common use in the State Agricultural College.

Mr. Clark makes the following note:

Some of the alkalies above seem high,—perhaps the clays contain Na as NaCl. The alkalies were usually figured as K_2O. The organic matter and water were sometimes determined by difference which can easily be detected from the exact summation. The iron is all estimated as Fe_2O_3 and in certain cases the FeO has been determined separately. The FeO determinations were made in the absence of a special platinum crucible, and the results are probably low. From two to three analyses were made of each sample except in FeO determinations. The variations were not over 0.2% or if they were, a third analysis was made, except in the case of alkalies where the variation may amount to 0.3%.

No. 36 was also analyzed as a marl would be, by solution in H Cl. which gave less Ca CO., showing that some of the lime is in insoluble form as sulphate or silicate.

I have deemed it the truest economy to confine such matters merely to such description as shall make the results intelligible.

I should add that as Dr. Ries wished to spend some time in studying European practice, he left me a free editorial hand. For the articulation, the insertion and arrangement of many of the illustrations and analyses, the descriptions of the Grand Ledge, Lansing and certain other deposits, and minor notes, I am responsible. From Dr. Ries' work I draw the following conclusions:

1. For use in the manufacture of Portland cement, the shales of the Coldwater (Cuyahoga) series are best adapted. The shales of the Michigan series are also good if not too high in soluble salts. Some of the coal measure shales, which are often too gritty, and some of the clays derived from the weathering of these shales or the Devonian black shales may be suitable. Surface deposits of clay of any size are almost without exception either too calcareous and irregular in composition or too gritty to be desirable.

2. Thick deposits of clay are pretty sure to be calcareous and make white brick except at the upper part, where they are leached.

3. The till clays and many others have limestone pebbles which are deleterious and must be washed out.

4. For vitrified ware, paving brick, stoneware etc., we have a considerable range of clays mainly shale clays or clays derived from shale,—in a few cases perhaps river silts.

5. None of the so called fire clays have proved in the highest degree refractory though some of them fuse only with some difficulty. Their field is rather that of stoneware, paving brick, etc., so far as present tests go.

6. Many of the clays beside that of Jeff No. 32 will probably make excellent glazing or slip clays. Probably a considerable variety of these valuable clays await development.

7. Kaolin and other white ware clays have not yet been found.

8. Before setting up a clay working plant the clay should be tested by several different methods at some reliable clay working plant. If possible precede this by laboratory tests, but do not try to interpret all the properties of a clay from its chemical analysis alone.

ERRATA.

Page 50, line 6 from the bottom, at end of line read 6%.

Page 50, line 12 from the bottom, for drawers read dryers.