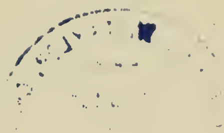
CLAYS OF ECONOMIC VALUE

IN

NORTH DAKOTA



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NORTH DAKOTA.

BY

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ISSUED BY

H. T. HELGESEN,

State Commissioner of Agriculture and Labor.

BISMARCK, N. D.:

TRIBUNE, STATE PRINTERS AND BINDERS.

1892.

NORTH DAKOTA CLAYS.

Two years ago, Prof. E. J. Babcock, of the State University, did some valuable work for the benefit of the State, which was presented under the title, "Coal and Sugar Beets," in the first biennial report of this office. Several months ago he informed the Commissioner that he had been engaged for some time in an investigation of the clays of the State, and that if a report of his work was desired for this department he would prepare one for publication, in a manner similar to that in which his papers on coal and sugar beets had been published. He was assured that such a paper would be appreciated by the present Commissioner, and, if approved by the governor, as provided in Chapter 99 of the Laws of 1891, would be published separately as well as incorporated in the report of this office. The following valuable paper is the result of his work, and for which he is entitled to the gratitude of the State.

H. T. HELGESEN,
Commissioner of Agriculture and Labor.

UNIVERSITY OF NORTH DAKOTA,
GRAND FORKS, N. D., Nov. 1, 1892.

Hon. H. T. Helgesen, Commissioner of Agriculture and Labor for North Dakota:

SIR:—I herewith place in your hands for publication, if it shall seem to you worthy, a report on the clays of North Dakota. There is no appropriation for work of this character, but having become much interested in the clays of the State, I determined to make a preliminary investigation of the subject, at my own expense if necessary. This has been done without the expectation of personal remuneration. I regret that lack of time and means has rendered it impossible to make these investigations more thorough and extended, and in many ways more satisfactory. It is hoped, however, that what has been done may help in the development of the natural resources of North Dakota. I have the honor of presenting to the State the result of my investigations.

Very respectfully,
E. J. BABCOCK,
Department of Chemistry and Geology,
State University of North Dakota.

CLAYS OF ECONOMIC VALUE IN NORTH DAKOTA.

The object of the following pages is to call attention, in a simple way, to some of the clays of North Dakota. So far, practically nothing has been done toward the utilization of the clay, excepting the manufacture of common brick in a few localities. It is with the hope of making known the value of some of the clays of the State that this little report is published.

In order to get a better idea of the clays of our own State, the local descriptions will be preceded by a few general statements in regard to the source and distribution of other clays and the composition and characteristics required for various uses.

ORIGIN AND DISTRIBUTION.

The geographical distribution of clays is very extensive, yet this is true only of material adapted for the manufacture of common brick and coarse products. Deposits of clay fit for the finer uses are by no means common.

The geological horizon of clays suited to different uses varies widely from the earliest to the latest formations. Especially is this true with reference to the clays used for the manufacture of COMMON BRICK and other ARCHITECTURAL material. Coarse clays suited for these purposes are frequently found in drift-covered districts where the underlying deposits are free from sand, pebbles and excess of limestone. This is how some of the brick clay in Northern Minnesota and Dakota occurs. This material is also often found as lake and river deposits which have been formed by the disintegration of surrounding or distant gneissic or feldspatic rock or from shale. It can readily be seen that clays of such origin are not likely to be of high grade on account of contamination by objectionable foreign matter.

A better grade of coarse clay is often found with the fine clays of the Cretaceous and Tertiary formations. From this some excellent brick, terra cotta, and drain pipes may be made. Some of the coarse clays of central and western North Dakota are of this kind and will doubtless prove their worth. It would naturally be inferred that material so different in its origin varies also in its composition and characteristics and so produces articles of widely different values. The essentials in every case are a sufficient proportion of true clay basis or kaolin element to produce a plastic, workable body, freedom from pebbles and from an excess of sand and fusible material. Variety in the color of brick generally results from varying proportions of iron and the intensity of the heat to which the brick is exposed. Hard, dense, semi-vitreous brick result usually from clay with much fluxing material, such as the alkalies and iron.

FIRE CLAY is a clay sufficiently refractory to withstand extremely high temperatures without disintegration or vitrification. Such clays are extensively used for the manufacture of linings for furnaces and fire places, in gas works and potteries, for brick and other architectural material that is liable to be subjected to great heat. For such purposes the clay must be very free from the fluxing constituents, iron and the alkalies. Good fire clay is not very common. It is found and used extensively in parts of England and in some localities on the European continent. In America it is found in New Jersey, Missouri, and some of the other states. Doubtless an excellent material exists in North Dakota, as will be seen from succeeding pages.

As to the geology, it may be said that most of the fire clays are found in the under clay of the coal measures and in the Cretaceous and Tertiary deposits. They often underlie the lignite coal beds. It is probable that the fire clays of North Dakota were part or all under the lignite, (probably in the Laramie group), although in some localities, as near Dickinson, there is no evidence of coal having been over the clay. This, however, may have been the case, the lignite having been removed from over the clay in certain spots by action of water during the great erosion to which these places have been subject.

The term POTTER'S CLAY is very wide in its signification as it may mean any plastic clay from the finest porcelain and dish clay to that used for the manufacture of coarse jugs and jars. It is evident that potter's clay fit for a good white earthenware, as well as that of lower grade for jugs, jars and the like, exists in North Dakota. We shall here consider particularly the geology of the finer clays for earthenware, etc. While clays fit for common brick and drain pipes, tiles and fine terra cotta, and even yellow dish ware are quite widely distributed, fine fire clays and white earthenware and porcelain clays are by no means common. Clays fitted for some of the finer purposes just mentioned are found and used principally in China, in central Europe, in England and in the United States in New Jersey, Missouri and one or two other localities.

China clay, also known as Kaolin, porcelain clay, etc., is plentiful in certain localities in China. Material used for the same purpose is also found in parts of Germany and France. In England a similar clay, known as Cornish clay from Cornwall and Devon, is the basis of the great pottery and porcelain industry of Staffordshire, England.

Most of the clays used for the production of fine earthenware and the better whiteware are probably derived from the Cretaceous and Carboniferous formations, and the most extensively worked deposits of this kind in the United States are those of New Jersey.

The clay from this State forms the basis of a great industry centering at Trenton. The ware produced is of excellent quality, and the clay used is that of the Cretaceous.

While potter's clay is found to exist in several regions where not particularly mentioned, and will doubtless be found in other localities, it is very certain that the finest clays, especially those fit for porcelain, will continue rare.

The clays of North Dakota, which, from this report, are shown to be suited to the production of finer grades of whiteware, are found about Dickinson, and are probably in the Laramie deposits. The best clays in this locality occur in elevations from 150 to 200 feet above the surrounding valleys. These clay knolls have escaped much of the erosion to which the surrounding country has been subject. If these deposits ever extensively covered the plain far east of Dickinson, they have probably been mostly or entirely removed by the longer action of the receding post-glacial waters as they narrowed to the present basin of the Missouri river. The ultimate source of these deposits can only be conjectured, but when we remember the ease with which fine sediment in water is transported to great distances from its original home, it does not seem impossible that the parent rock, whose disintegration formed the basis of this clay, may have been from the feldspatic rocks occurring to the west and northwest along the flank of the Rocky mountains.

GEOLOGICAL SUMMARY OF NORTH DAKOTA CLAYS.

Post Tertiary—	Post-Glacial .. Glacial	Yellow and blue brick clays of the Red River Valley; probably largely washed from the adjoining Cretaceous.
Tertiary—	Laramie	Plastic Clays. White earthenware and fire clays and coal of Dickinson. (Leaf prints etc., about Dickinson, probably Laramie.) Clay and coal at Minot and at Plenty Mine, Mercer county, probably Laramie, also.
Cretaceous—		The upper non-fossiliferous shales about Park river, Langdon, etc., are probably Cretaceous (Fort Pierre), as well as the under fossiliferous and hydraulic cement marl of the Pembina Mountain district.

CHARACTERISTICS AND COMPOSITION.

All varieties of clay originate from the disintegration of feldspatic rock. The parent rock, subject to the action of weather and water, and finally to chemical agencies, is broken, ground and separated into sand and clay. The harder pure quartz of the rock remains in coarser grains as sand and the softer feldspar, by the further wearing and chemical action, is reduced to an impalpable state and finally deposited as a bed of clay. Clays naturally partake of the character of the parent rock. For example, a rock containing much iron or alkaline matter, would be likely to form a clay containing a considerable proportion of these constituents, while a rock quite free from such ingredients, would, unless contaminated by foreign matter, produce a comparatively pure clay. Impurities are often added to clays during the time of transportation and deposition. After deposition the character of the clay is often if not always subject to a modification corresponding to the make-up of the superimposed material. Water percolating through an overlying deposition is almost sure to find some soluble constituent such as lime, iron, or alkalies, which it carries with it till it reaches the underlying clay, where, on account of the compact nature of the deposit, the water passes very slowly and so allows a portion of the elements which it holds in solution to be deposited in the clay. Thus we have another cause of the varieties of clay.

In some cases, water percolating through clay does not add impurities, but probably tends to purify it. This may be the case when coal, especially pure lignite, overlies the clay. Under such conditions the lignite probably acts much like charcoal, as an absorption filter, to remove matter in solution in the water. The water thus being left quite free from the lime, iron, alkalies, etc., instead of contaminating the under clay might, whatever works its way through, serve as a wash to carry off some of the soluble matter of the clay. Whatever the cause, it is a fact that the purest clays very commonly underlie coal seams.

Variations in the character of the rock from which clay is derived, and variations to which the clay is subject during and after deposition, are sure to produce clays of decidedly different character. So it is that we have clays of all grades ranging from those so impure and mixed with sand and pebbles as to be unfit for the coarsest uses, to those so pure that from them can be made the most beautiful and delicate porcelain wares.

Among the more important uses to which the coarser clays are put is the manufacture of BRICK and other ARCHITECTURAL MATERIAL. Clay fit for this purpose is quite common, especially for the inferior grades. The characteristics of clay suited to such production, are not necessarily very closely defined. In general it may be said that a good material must be free from pebbles and from too great a proportion of sand, lime and alkalies. For the common article there is not likely to be any difficulty in finding clay sufficiently free from iron or even alkalies, though a combination of these elements in too large a proportion often occurs. An excess of lime may have a tendency to give a brittle product at a low heat, or fusion at a high heat. Some clays, however, which contain a considerable amount of lime and alkalies, if properly handled, produce an excellent material where resistance and abrasive qualities are sought rather than power to withstand intense heat. As in all cases, the clay must be sufficiently plastic to work well, and must be tempered, if need be, so as to prevent too great shrinkage.

Cavities and fusion spots are often produced when the material used contains lime or pyrite nodules or fragments of organic matter. This can be largely overcome by careful grinding and mixing. The color is dependent principally upon the amount of iron present and the degree of heat to which the clay is subjected. A small proportion of iron, or, in other cases, a strong heat may produce a lighter color than would be the case with much iron or a low heat. It should be remembered that the greater portion of the produce of this class is not of the best grade. Where a superior quality can be made there is an enormous advantage to the manufacturers on account of the greater demand and higher price secured. The best grades of brick, terra cotta and drain pipes are made from inferior fire or potter's clay.

Fire clay is the term given to designate those clays which possess great fire-resisting properties. The best of these clays are quite rare, though low grades are somewhat common. These clays may vary much in their original appearance from a nearly pure white to a slaty gray color. But they should bake to a white or cream color without fusion. The essential qualities of fire clays are plasticity, great freedom from lime, and the fusing constituents, iron, and the alkalies, soda and potash. Iron may exist in clays in several forms; for example, as peroxide, protoxide, sulphate and sulphide. But, in whatever form, unless in small quantities, it is revealed by the ordeal of heat in the coloration and the tendency to melt. The amount of iron which a fire clay can stand depends largely upon the lime, potash and soda it has. A clay containg only traces of these fluxing constituents may have from 3% to 5% of iron and still possess considerable fire-resisting power. If, however, a small proportion of lime and alkalies is added, the clay is useless as fire clay. The accompanying two analyses of the celebrated Stourbridge fire clay will show the variation in iron and alkalies. Analyses by Prof. F. A. Abel.*

Sample.	Silica.	Alumina.	Fe_2O_3	Alkali. Waste, etc.
No. 1	66.47	26.26	6.63	0.64
No. 2	63.40	31.70	3.00	1.90

Sample No. 2, containing so much less iron, is superior to No. 1, the refractory character of which may be doubted. Lime and magnesia evidently exert a considerable influence upon the fusibility of clay. There has been some difference of opinion among chemists on this point. It has been said that the best foreign fire clays seldom contain more than one per cent. of lime and magnesia together. Potash and soda are doubtless the most powerful fluxing constituents commonly found in clays. They unite

*Wagner's Chemical Technology, p. 295.

readily with silica, forming the alkaline silicates which bring down the fusing point to a much lower temperature. There is some difference of opinion in regard to the amount of alkalies a good fire clay will stand. Snelus says that about one per cent. (of potash) is sufficient to render them unsuitable at high temperatures." Bischof found that four per cent. of potash, in a silicate of alumina without any other bases, could be fused at the melting point of wrought iron * * * Clays containing from two to three per cent. of potash are said to stand well at high temperatures. The most carefully made analyses of the more noted and best fire clays of this country and Europe, do not generally show more than two per cent. of alkalies." From the analyses of the fire clays of New Jersey it appears that "those which are found to have one and a half to two per cent. and upwards of potash have not proved to be good fire clays."†

The amount of alkalies admissible in a fire clay depends largely upon the purity, and probably upon the physical condition of the clay. Clays having much lime and magnesia or iron, can stand but little potash and soda. In a general way it may be said that a fire clay should not contain above five per cent. of iron and alkalies together. A pure open body or coarse clay will probably stand more alkalies than it would if in other condition. What has been given may be regarded as covering the most essential characteristics of fire clays. The only way to get a safe determination of the nature and value of a given clay is to consider the clay as a whole, the resultant of the action of all its properties.

The following table of analyses will give an idea of the composition of a number of fire clays in different localities:

†New Jersey Geological Survey, 1878, "Clays," p. 295.

ANALYSES OF FIRE CLAYS FROM VARIOUS LOCALITIES.

CONSTITUENTS.	No. 1.—New Jersey. (Used extensively).	No. 2.—Dowlais, South Wales.	No. 3.—Newcastle-on-Tyne.	No. 4.—Newcastle-on-Tyne.	No. 5.—Stourbridge, England.	No. 6.—Frankenthal-on-Rhine, Germany.	No. 7.—Cheltenham, Missouri.	No. 8.—New Jersey. (Middlesex district.)	No. 9.—Cornwall or Devonshire fire brick.
Silicon	74.30	67.12	69.25	48.55	53.40	50.00	50.80	45.60	73.50
Aluminum	18.11	21.18	17.90	30.25	31.70	31.69	31.53	38.40	22.70
Iron oxide	1.09	1.85	2.97	4.06	3.00	2.54	1.92	1.20	1.70
Calcium	0.11	0.32	....	1.66	....	....	....	0.22	*2.10
Magnesium	....	0.84	1.30	1.91	*1.90	....	trace.	0.25	
Potassium	0.76	2.02	....	....		2.22	0.40	0.59	
Sodium	0.20	....	....	....		....	....	....	
Water and volatile matter	5.90	7.11	7.50	10.67	....	12.65	13.80	13.80	....
Other matter	....	....	....	....	....	.90	1.50	....	....

*Alkalies, waste, etc.

EXPLANATION.—No. 1. New Jersey fire clay, used extensively for fire brick, retorts, etc.—N. J. Clay Report, 1878, p. 248.

No. 2. Fire clay from Dowlais, South Wales, considered the best fire clay Dowlais.—N. J. Report from Percey's Metallurgy.

Nos. 3 and 4 are, according to Muspratt, fire clays from Newcastle-on-Tyne.

No. 5 is, apparently, the purest of several samples of Stourbridge, Eng., fire clay, analyzed by Professor Abel.—Wagner's Chem. Tech., p. 295.

Nos. 6, 7 and 8. Analyses from N. J. Geol Report (clays), '78. No. 8 is considered a No. 1 fire clay, and is, perhaps, a fair sample of the New Jersey fire clays.

No. 9 is the analysis of a remarkably refractory fire-brick of the Cornwall or Devonshire Kaolin. Wagner's Chem. Tech , p. 321.

PORCELAIN AND EARTHENWARE CLAY.

Clays fit for the manufacture of a high grade porcelain or china are among the rarest clays used. For such purposes, material of the utmost purity is required. The clay should be sufficiently plastic to be readily shaped and handled; when baked it must be pure white, or nearly so, and possess reasonable strength. To give these results it must be extremely free from iron and all foreign matter that would effect color. So great freedom from alkalies is not required of porcelain and china clays as for some other purposes, since incipient fusion is necessary to produce the translucency, a characteristic of this kind of ware.

Clays of this kind are found in a few localities only and are then usually mixed with other carefully prepared ingredients. Material is extensively prepared artificially for porcelain and china. Clays of a slightly inferior grade are those used for the production of the earthenware which constitutes the most of our common white dish ware. The best earthenware clays, though not so rare as the china clays, are not very common.

It is upon this kind of clay that the great pottery industry of Staffordshire is built. Some New Jersey and other clays are now much used in making earthenware. The seat of this industry in New Jersey is at Trenton, in Ohio, at East Liverpool.

Clays for good earthenware must, besides being plastic, be as free from iron as possible, and sufficiently free from alkalies to stand high heat. They should bake white and give a strong solid body. Most of the requisites are those of a first class white, plastic fire clay. The special differences are that an earthenware clay should be freer from iron than it is necessary for a fire clay to be, and that a fire clay should be freer from alkalies than it is needful for an earthenware clay to be. For the action of the various constituents of earthenware clays refer to the discussion of fire clay characteristics.

"Clay which is pure white in color and entirely free from oxide of iron may be intimately mixed with ground feldspar or other minerals which contain potash enough to make them fusible, and the mixture still be plastic so as to be worked into forms for ware. When burned, such a composition retains its pure white color, while it undergoes fusion sufficient to make a body that will not absorb water. And its surface can be made smooth and clean by a suitable plain or ornamental glaze. Ware of this kind is porcelain or china.

"The large portion of plain white and decorated wares now sold as C. C. and white granite wares are intermediate between the old earthenware in which the body was of clay unmixed and the porcelain in which the body is of mixed earths that undergo incipient fusion when burned at a high temperature. The fine earthenwares of both kinds mentioned above are being improved in quality and appearance each year and approaching nearer in real excellence to porcelain."

Earthenware clays vary from those approaching nearly to china clay to those so impure (especially from iron) as to be unfit for white ware and called stoneware clays. "Clay containing oxide of iron in sufficient quantity to make it partially fusible in the heat required to burn it, when made into forms and burned is called stoneware clay. The heat is carried far enough to fuse the particles together, so that the ware is solid and will not allow water to soak through it; and the fusion has not been carried so far as to alter the shape of the articles burned. The oxide of iron by the fusion has been combined with the clay, and instead of its characteristic red has given to the ware a bluish or grayish color. Stoneware may be glazed like earthenware, or by putting salt in the kiln when its vapor comes in contact with the heated ware and makes with it a sufficient glaze." Clay of this kind is used largely for finer grades of jars, jugs, etc.

A considerable variety of products may be gotten by a judicious mixture of fine and inferior clays. The following table of analyses will show the composition of a number of china and earthenware clays from different localities :

CONSTITUENTS.	New Jersey ware clay.	New Jersey ware clay.	Clay used in a Trenton pottery	China Clay, Cornwall, Eng.	Dorsetshire clay, used in Staffordshire potteries.	Impure or unrefined Cornish-stone clay.	Porcelain Berlin.
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Silicon	45.45	43.40	69.03	66.20	46.38	35.65	66.60
Aluminum	38 75	37.56	23.89	24.11	38.[illegible]4	32.50	28.00
Iron	1.15	1.04	0.45	0.79	1.04	1.65	0.70
Calcium	....	....	0.29	....	1 20 }	trace	0.30
Magnesium	0.11	....	0.05	....	trace }		0.60
Potassium	0.17	0 35	....	0.96			3.40
Sodium	....	0.37	....	....		30 05	
Water and volatile matter	13.05	15.40	7.46	7.20	13.44 }		
Other matter	1.32	1.40	....	0.20		{ loss 0.15	

Nos. 1 and 2.—From New Jersey Clay Report of 1878.

No. 3.—From analysis made of clay from a Trenton pottery, mixed and proportioned ready for use.

No. 4.—From Williams' Applied Geology.

No. 5.—Muspratt gives this analysis by Mr. Higginbotham, of clay used in Staffordshire potteries.

No. 6.—From Muspratt; Cornish stone clay so extensively used in fine white ware and china clay, in the impure state.

No. 7.—From Muspratt, Laurent, analyst, (supposed to be from the ware, not the clay.)

From what has been said it will appear that the better grades of earthenware clay are occasionally found of sufficient purity to be used in the manufacture of china, porcelain and semi-porcelain wares, while the inferior qualities run gradually into clays used for stoneware, etc. Those clays not sufficiently pure for high grade stoneware may be used in the manufacture of Rockingham and other ware. Stoneware clay may also be used for a very fine quality of drain pipe; but for much of the common drain pipe propably no better than common brick clay is used. Earthenware clay may also be used as a fire clay in many cases and fire clays may in turn be used for earthenware. In fact the very best fire clays of some districts are practically the same as those used for fine earthenware.

In considering the characteristics, etc., of clays, only three divisions have been made, viz: (1.) Coarse clays used for bricks and terra cotta, etc.; (2.) Refractory clays used for fire-brick, furnace linings and various other purposes where exposure to great heat is necessary; (3.) Earthware clays used for the manufacture of white dishware.

Without going into a further study of the varieties of clays, we may take the three groups already considered as central types, to which may be referred, as modified forms, most other clays suited to uses we have not considered.

LOCAL DESCRIPTIONS.

BRICK CLAY.—Clays suited to the manufacture of brick are, fortunately, very widely distributed. The quality, however, varies much, and gives rise to products varying greatly in value.

North Dakota is remarkably well supplied with good brick clays. They are so well known that but little need here be said in regard to them. Fair brick clays may, I think be found in most parts of the State. Over a considerable district in the eastern part, these clays appear in two distinct beds; i. e., the upper, usually yellow clay, immediately under the soil, and the deeper blue clay. In most if not all cases in this district, brick is made from the yellow clay. Still it is quite probable that a judicious and thorough mixture of the blue and yellow clays would produce a better article.

In the north central portion of the state, there are near the surface, shale deposits of considerable thickness which would doubtless in many cases make excellent brick and drain pipe.

In the western portion of the state there is a variety of clays. In many localities the poorer coal clays may produce fine brick, drain and sewer pipe and terra cotta. The coal clays of medium qualities in some places will produce exceedingly fine facing brick and fancy architectural and decorative material.

It is probable that the shales about *Park River*, *Milton*, *Langdon*, etc., along the Great Northern railroad to the north, will produce good brick and drain pipe if properly utilized. They would be likely to produce a firm siliceous red brick.

Near *Minot*, *Ward County* and *Williston* on the main line of the Great Northern railroad, there are clays that will make a fine dense brick and drain pipe in color from light cream to red.

Near *Bismarck* there are two or three layers of clay fit for excellent red brick. On the bank of the Missouri river, north of the Northern Pacific railroad bridge, near Bismarck, two layers appear well suited to this use as well as to the production of good drain and sewer pipes. One of these clays is a rather sandy gray clay; under this is a dark carbonaceous clay somewhat plastic and apparently adapted for making strong, dense drain pipe, roofing tile, brick, etc.

About *Dickinson* the great variety of fine clays afford abundant material for the finest kind of brick, terra cotta, pipe material of different kinds, etc. The best of these clays run into fine fire clay and earthenware clay, and seem too valuable to be used for common brick. They will be further considered under the head of fire and earthenware clay.

In the *Red River Valley* the yellow clay immediately under the soil affords material for a first class cream brick. It is the clay used extensively at Grand Forks, and if thoroughly mixed and formed by a high pressure machine, will undoubtedly produce a superior brick.

The following are analyses of several North Dakota clays which may be used for brick, etc.†

CONSTITUENTS.	Grand Forks.	Bismarck.	Williston.
Silicon ($Si\ O_2$)	51.27	58.73	57.80
Aluminum ($Al_2\ O_3$)	9.33	14.98	9.47
Iron Oxide ($Fe_2\ O_3$)	3.52	5.63	3.16
Calcium ($Ca\ O$)	11.15	2.10	7.91
Magnesium ($Mg\ O$)	2.31	0 74	2.84
Sodium ($Na_2\ O$)	2.08?	0.988	?
Potassium ($K_2\ O$)	0.50?	0.16	?
Water and Volatile Matter *	....	16.672	?
Other Matter	....	....	?

* By Subtraction. All very moist.

REMARKS.—No. 1, clay used at Alsip's Brick Works. No. 2, not used; found on bank of Missouri River near Bismarck. No. 3, not used; associated with coal near Williston. In the laboratory furnace, No. 1 baked cream; No. 2, red, very firm; No. 3, cream.

FINE ARCHITECTURAL AND SEMI-FIRE MATERIAL, TILE, DRAIN AND SEWER PIPE, ETC.—Most of the coarser grade of tile, drain and sewer pipe may be made from common brick clay, but the best of such material is a little more exacting in its clay used, although it is very often classed with brick clay. Under brick clay, some places were mentioned where doubtless fair tiling and pipe clay may be found.

Clays fit for high grade articles of this kind should possess sufficient plasticity and tenacity to be readily moulded into varied shapes, and strength to resist too easy crushing. They must have enough quartz material to prevent cracking and shrinking, and for many purposes should be quite refractory since they are baked at strong heat and may in after use be exposed to high temperatures.

A considerable difference in the product may be made by the use of a good plastic clay and varying proportions of sand.

At *Minot, Ward county*, on the main line of the Great Northern Railway, one or two very good clays are found associated with the coal of that locality. A few miles northwest of Minot coal is mined from the bluffs that rise from the old valley of the Souris river. At Colton's mine the coal is found in a nearly horizontal layer, probably 8 to 12 feet thick and about 12 feet below the top of the bluff. Most of the covering material above the coal appears to be clay and sand. Just above the coal there is a layer of fine clay of a slaty gray color and a smooth greasy feel. The

†The analyses of North Dakota clays used in this report have been made in the chemical laboratory of the State University. In making the analyses the author has been assisted by Mr. Myron W. Smith, B. S., who has been a post graduate student in this University. The alkalies, in all cases, were determined by the writer.

layer appears to be several feet thick. This clay would probably make an excellent architectural material for the finer ornamental purposes. It seems to possess some refractory power, and with a proper admixture of sand would be likely to make a fine drain and sewer pipe and a fair semi-fire brick. In the laboratory it bakes to a light reddish cream and becomes very firm. Its composition is shown by the following analysis :

Silicon ($Si O_2$)	56.86
Aluminum ($Al_2 O_3$)	25.03
Iron Oxide ($Fe_2 O_3$)	6.11
Calcium (Ca O)	0.71
Magnesium (Mg O)	0.76
Potassium (K_2 O)	0.50
Sodium (Na_2 O)	0.016
Water and volatile matter / Other matter } By subtraction	10.014

It will be seen that there is a rather large proportion of iron for a high grade fire material. But its composition is apparently all right for the purposes mentioned, i. e., drain and sewer pipe, semi-fire, ornamental material, etc.

In *Mercer county* at the *Plenty coal mine* on the Missouri river, a clay is found associated with the coal which is very similar to the Minot clay just described. It has about the same texture, color and feel and after being baked looks much the same. It could therefore be used for the same purposes as the Minot clay. The analysis of this clay is as follows:

Silicon ($Si O_2$)	60.79
Aluminum ($Al_2 O_3$)	16.23
Iron Oxide ($Fe_2 O_3$)	4.49
Calcium Oxide (Ca O)	0.65
Magnesium Oxide (Mg O)	1.02
Potassium Oxide (K_2 O)	0 19
Sodium Oxide (Na_2 O)	0.28
Water and volatile matter.... / Other matter by subtraction	16.35

Northeast of *Langdon*, in the *Pembina Mountains*, in the vicinity of *Olga* village, a remarkably fine white clay is found in thin layers outcropping along the hill. The layers which have been seen by the writer are probably not of sufficient thickness to be of use, but from the reports of others there seem to be thick deposits. An illustration on page 31, shows how the thinner layers occur. This clay is very white, of a soapy feel, and very fine in texture. It is also acid to the taste and to litmus, and bakes to a hard, strong body of a pinkish color. The acid element is sulphuric and may partially exist as a natural alum. This clay would doubtless by washing be well fitted for the manufacture of semi-fire brick, fine drain pipe, ornamental material of various kinds and for finer stoneware. An analysis of this clay gives the following results:

Silicon ($Si\ O_2$)	50.45
Aluminum ($Al_2\ O_3$)	17.57
Iron Oxide ($Fe_2\ O_3$)	2.80
Calcium Oxide (Ca O)	0.25
Magnesium Oxide (Mg O)	1.79
Potassium Oxide (K_2 O)	0.07
Sodium Oxide (Na_2 O)	0.86
Water and volatile matter	22.55
Other matter and errata	3.66

At *Bismarck*, along the bank of the river near the Northern Pacific railroad bridge, there are two layers of clay both of which may be used for the purposes described in this section. These two clays occur about 50 feet above the river. The upper layer is several feet thick, is of a dark grayish color and mixed with a little finely pulverized sand. Just under this is a finer, more plastic, chocolate-colored clay of uniform texture. The color is due in part to the presence of carbonaceous matter. On burning, it becomes a light red. When baked, it posseses a hard, compact, ringing body. The thickness of the layer is not known, but of the two layers there is probably a deposit of not less than six or eight feet. There is but little doubt that this clay would be value able for several uses. It could be mixed with the clay above in which is much like it and would then make an excellent drain and sewer pipe and a good ornamental building material. An analysis of this clay shows:

Silicon (Si_2 O)	58.73
Aluminum ($Al_2\ O_3$)	14.98
Iron Oxide ($Fe_2\ O_3$)	5.63
Calcium Oxide (Ca O)	2.10
Magnesium Oxide (Mg O)	0.74
Potassium Oxide (K_2 O)	0.16
Sodium Oxide (Na_2 O)	0.988
Water and volatile matter Other matter, by subtraction	16.672

It is quite possible that the shales seen near *Park River* and *Langdon* along the Great Northern Railway may prove suitable for drain pipe.

About *Dickinson* there is a great variety of clays, some of which being too poor for earthenware and fine refractory material, will make good semi-fire-brick and other inferior refractory articles, besides tiles, pipes, and the finest ornamental building material. By mixing the clays found in this vicinity, material can be had for a large number of uses. A mottled clay, said to occur in large quantities, seems remarkably well suited to the manufacture of terra cotta and ornamental material. This clay appears very much like some of the mottled clay from Martha's Vineyard. It has a fine white body dotted with patches of red. It is all very free from grit aud when ground makes a uniform body of a light red color. It is very plastic, but stands heat well without cracking or warping. The following is an analysis of this clay:

Silicon ($Si\ O_2$)	56.03
Aluminum ($Al_2\ O_3$)	24.23
Iron Oxide ($Fe_2\ O_3$)	9.46
Calcium Oxide ($Ca\ O$)	.....
Magnesium Oxide ($Mg\ O$)	0.31
Potassium Oxide ($K_2\ O$)	0.088
Sodium Oxide ($Na_2\ O$)	0.72
Water and volatile matter	9.39

This clay will be seen to be remarkably free from all fusing constituents excepting iron. By properly mixing with the fine white clay found in the same locality (described under fire and earthenware clay) a fairly refractory material would be gotten, fit for some grades of fire brick, saggars and many other purposes.

A few miles east of Dickinson, at the *Lehigh* mine on the Northern Pacific Railway, the clay which underlies the coal may, without doubt, be used for some of the purposes mentioned in this section. At this place lignite coal is quite extensively mined. The nearly horizontal layer of coal outcrops from the side of a bluff, about 100 feet or 250 feet below the top, and is from 8 feet to 15 feet or more in thickness. It is mined by a tunnel from the side. The coal is capped by a layer of pure gray clay 5 to 10 feet thick, which may be used for common brick, and will probably do well for terra cotta, drain pipe, etc., where not subject to strong heat. The analysis of this clay gives:

Silicon ($Si\ O_2$)	55.77
Aluminum ($Al_2\ O_3$)	12.15
Iron Oxide ($Fe_2\ O_3$)	4 27
Calcium Oxide ($Ca\ O$)	5.92
Magnesium Oxide ($Mg\ O$)	1.90
Potassium Oxide ($K_2\ O$)	0.256
Sodium Oxide ($Na_2\ O$)	0.992
Water and volatile matter, etc., by subtraction	18.742

This clay bakes to a buff color, stands low heat well, but shows a tendency to fuse at high temperature.

The clay under the coal is of better quality than that above. It is dark colored and of a soapy feel. The dark color appears to be due to the large amount of carbonaceous matter. When baked it takes on a light gray color.

The following illustration will give an idea of the formation. The outcrop which appears in this cut is some distance from the mine. It shows only a small portion of the layer of coal and none of the under clay.

The following is an analysis of the under clay after burning to remove carbon:

Silicon (SiO_2)	71.25
Aluminum (Al_2O_3)	21.94
Iron Oxide (Fe_2O_3)	3.67
Calcium Oxide (CaO)	0.74
Magnesium Oxide (MgO)	0.83
Potassium Oxide (K_2O)	.....
Sodium Oxide (Na_2O)	.....
Water and volatile matter, by subtraction	.....

About *Dickinson*, higher grade clays abound which are too valuable to be used for the purposes named in this division. These will be considered under fire and earthenware clays.

For comparison, we insert the following analyses of clays of this character found in other localities, and used for the purposes we have just considered:

CONSTITUENTS.	No. 1.—Wakerley Buff Clay.	No. 2. — Watcombe Red Clay.	No. 3.—Brosley Red Clay.	No. 4. — Dunfermline Red Clay.	No. 5.—Saggar Marl Staffordshire Potteries.	No. 6 — Rockingham and Brick Clay.
Silicon	69.59	57.83	64.06	64.14	54.38	58.07
Aluminum	20.04	20.55	20.60	13.34	26.55	27.38
Iron	3.37	7.75	7.16	7.57	8.38	3.30
Calcium	3.16	1.68	0.12	1.90	....	0.50
Magnesium	3.18	0.97	0.04	....	....	....
Potassium	....	3.87	0.91	1.54	....	10.30
Sodium	....	.56	0.44	....	....	
Water, organic matter and loss	....	6.52	5.85	....	7.28	
Other constituents	....	0.90	0.71	....	3.14	....

Nos. 1, 2, 3 and 4 are terra cotta and tile clay analyses taken from Spon's Encyclopedia of Industrial Arts, and are said to stand fire well and to be much used.

No. 5, Staffordshire saggar clay, "Burns light buff, a fire brick," from Dobson's Brick and Tile, p. 115.

No. 6, "A yellow midland counties clay, used for brick and Rockingham pottery," Dobson's Brick and Tile, p. 264.

The following are analyses of North Dakota clays thought fit for tile, terra cotta, drain and sewer pipe, etc.:

Soil, Sand, and Clay.

Clay (upper).
Thickness, 12 to 16 feet.
(Page 17.)

Coal (lignite).
Showing a portion of the layer.

NEAR THE LEHIGH COAL MINE.

CONSTITUENTS.	No. 1.—Minot, above Coal.	No. 2.—Plenty Coal Mine, Mercer Co.	No. 3.—White Clay, Pembina Mts. near Olga.	No. 4.—Near Bismarck, on Bank of Missouri River.	No. 5.—Dickinson Buff Clay.	No. 6.—Upper White Clay, Lehigh Coal Mine.	No. 7.—Under Clay at Lehigh Coal Mine.
Silicon ($Si O_2$)	56.86	60.79	50.45	58.73	56.03	55.77	71.25
Aluminum ($Al_2 O_3$)	25.03	16.23	17.57	14.98	24.23	12.15	21.94
Iron ($Fe_2 O_3$)	6.11	4.49	2.80	5.63	9.46	4.27	3.67
Calcium ($Ca O$)	0.71	0.65	0.25	2.10	......	5.92	0.74
Magnesium ($Mg O$)	0.76	1.02	1.79	0.74	0.31	1.90	0.83
Potassium ($K_2 O$)	0.50	0.19	0.07	16.672	0.088	0.256	
Sodium ($Na_2 O$)	0.016	0.28	0.86	0.988	0.72	0.992	?
Water and volatile matter, etc.	10.014	16.35	22.55	0.16	9.39	18.742	
Other matter and errata	......	......	3.66	......	......	......	

By a comparison of an analysis of these clays with the preceding analyses given of clays from England and other localities, used for the purposes under consideration, it will be seen that with one or two exceptions the North Dakota clays are of considerably better quality. In nearly, if not all cases, the clays are easily mined. In most cases they are found immediately associated with coal or where it can be had at small cost. This is a great advantage to North Dakota clays. The fuel question is one of paramount importance, since it is one of the largest sources of expense in the manufacture of clay products. The abundance of fuel, which can be gotten for a mere trifle where most of these clays are found in North Dakota, will aid wonderfully in making the manufacture of clay articles an extensive and profitable industry.

FIRE CLAY, ETC.—We now come to the consideration of one of the rarest and most valuable of clays. Fire clay is sought for a number of important uses for which ordinary clay is far too poor and for which no other kind can be satisfactorily used. The following are some uses to which a good fire clay is put, viz., for fire, brick, retorts for gas works, glass works and metal works, for crucibles, for special use in fire-proof buildings, and in furnaces, ovens, flues, fire-proof safes, etc., etc.

The essential characteristics of fire clay have already been considered. (See pages 8-11.) In the last section we mentioned or two clays which may be regarded as fire clays, but they are of inferior quality. The finer fire clays are not essentially different from fine earthenware clays and are often extensively used for pottery. There is only one locality in North Dakota known to the writer where the finest grade of fire clay is found.

About *Dickinson, Stark county*, there are several clays which may be considered first quality fire clays. The origin of these clays can only be guessed. It has already been stated that they are found in the Laramie formation. The finest clays in this locality occur in elevations 100 feet or more above the surrounding valley. These clay knolls have escaped much of the erosion to which the surrounding country has been subjected. If these deposits ever extensively covered the plain far east of Dickinson, they have probably been mostly or entirely removed by the longer action of the receding water, glacial or post-glacial, as it narrowed to the present basin of the Missouri river. The ultimate source of these deposits is a matter for conjecture. It is not impossible that they were once feldspatic rocks occurring to the west and northwest along the flank of the Rocky Mountains.

The clays of this character which the writer has examined, about Dickinson, outcrop from near the top of high bluffs. (See cut on page 27.) In some cases the surface soil and clay seems to have been entirely washed away and the white fire and earthenware clay is left capping the bluff. This is the case with a deposit of very fine clay which occurs about one mile south of Dickinson. At this point the bluff is about 100 feet high. The base appears to be principally of sand and clay. Above this is a very thick layer, probably from ten to fifteen feet of fine white fire clay; above this is a layer perhaps four feet thick, of still purer white clay, which caps the hill where not washed away. This upper clay is intimately mixed with a small amount of sand, which gives it a rough feel. As taken from the layer, the lumps are soft enough to be crushed in the hand. When baked it produces a hard body which shows a tendency to fuse. The color becomes a pure white, purer than before baking, which indicates that a small amount of carbonaceous matter was present in the unbaked material. An analysis of this clay shows the following:

Silicon ($Si O_2$)	72.66
Aluminum ($Al_2 O_3$)	17.33
Iron ($Fe_2 O_3$)	1.05
Calcium ($Ca O$)	0.13
Magnesium ($Mg O$)	....
Potassium ($K_2 O$)	0.36
Sodium ($Na_2 O$)	0.38
Water and volatile matter / Other matter	9.35

From the analysis it will be seen that this is a very pure clay. The silicon appears rather high in proportion to the aluminum, but this is due to the presence of a small amount of sand which, if necessary, could be removed with little trouble. For most purposes the silicon does not appear too high. The iron, it will be noticed, is very low, while there is scarcely more than a trace of calcium, and the alkalies are also low. In all respects this clay seems to be an exceedingly fine fire clay.

The clay, as has been stated, found immediately under this, is a layer about ten feet thick. It is very fine and free from grit, and can be dug with a spade and pulverized in the hand. Its color when dug is grayish white, probably due to a slight amount of carbonaceous matter, but after baking it becomes a pure white. It has a very firm homogeneous body, and when baked becomes very hard with a clear, sharp ring. This clay has been subjected to intense heat in the laboratory furnace and stands perfectly without cracking or warping. The analysis of a sample taken from a surface exposure gives—

Silicon (SiO_2)	64.84
Aluminum (Al_2O_3)	24.31
Iron (Fe_2O_3)	1.60
Calcium (CaO)	0.11
Magnesium (MgO)	0.24
Potassium (K_2O)	trace
Sodium (Na_2O)	0.32
Water and volatile matter } Other matter }	8.58

This analysis shows a very pure clay and one well proportioned for immediate use. The fluxing constituents are so small in amount as hardly to need notice. The iron is also small for an *unwashed, surface* specimen. The surroundings are all that could be desired. At the foot of the bluff where the clay is found there is a small stream which would furnish water to a factory. The deposit is probably not more than one and a half miles from the main line of the Northern Pacific railway, so a spur track could easily be run to it. Coal is mined within a few miles and can be had at very low rates. There is no doubt but what this clay, as well as the one mentioned before it, is unusually well suited for the highest grade of fire material, and there seems to be an abundance of it.

There are doubtless several other deposits of excellent fire clay in this vicinity although the writer has not visited others. However, samples of a number of excellent clays have been secured and analyzed. In most cases these samples are much the same in general appearance as the ones just described. One or two samples show a very slight cream tint after baking. They generally bake white and very hard. An analysis of a sample furnished by Mr. E. F. Messersmith gave the following results:

Silicon (SiO_2)	64.22
Aluminum (Al_2O_3)	17.22 (?)
Iron (Fe_2O_3)	2.09
Calcium (CaO)	trace
Magnesium (MgO)	0.37
Potassium (K_2O)	0 21
Sodium (Na_2O)	0.34
Water and volatile matter	10.29

In the *Pembina Mountains* there is found a fine white clay which may be regarded as a medium fire clay. The extent of this clay is not known, but from reports which have come in, it seems to be in abundance. As dug, it is quite white. When baked at a high temperature in the laboratory furnace, it assumes a slightly pinkish tint. This clay would probably require careful washing. It appears to be slightly impregnated with alum. An analysis of this clay is as follows·

Silicon ($Si O_2$)	50.45
Aluminum ($Al_2 O_3$)	17.57
Iron ($Fe_2 O_3$)	2.80
Calcium (Ca O)	0.25
Magnesium (Mg O	1.79
Potassium (K_2 O)	0.07
Sodium (Na_2 O)	0.86
Water and volatile matter	22.55
Other matter and errata	3.66

This sample was found near *Olga.* An idea of its occurrence may be gotten by referring to cut on page 31. Fire clays of this quality may be found in other localities, but they are not known to the writer. For the purpose of comparison, the analyses are given of a number of fire clays found in different parts of the world, and extensively used for various refractory purposes.

TABLE "A."

Analyses of Fire Clays from Various Localities.	No. 1.—New Jersey, Used Extensively.	No. 2.—Dowlais, South Wales.	No. 3.—Newcastle-on-Tyne.	No. 4.—Newcastle-on-Tyne.	No. 5.—Stourbridge, England.	No. 6.—Frankenthal-on-Rhine, Germany.	No. 7.—Cheltenham, Missouri.	No. 8.—New Jersey (Middlesex District.)	No. 9.—Cornwall or Devonshire Fire Brick.
Silicon	74.30	67.12	69.25	48.55	63.40	50.00	50.80	45.60	73.50
Aluminum	18.11	21.18	17.90	30.25	31.70	31.69	31.53	38.40	22.70
Iron	1.09	1.85	2.97	4.06	3.00	2.54	1.92	1.20	1 70
Calcium	0.11	0.32	....	1.66	....	....	....	0.22	
Magnesium	....	0.84	1.30	1.91		....	Trace.	0.25	†2.10
Potassium	0.76	2.02	....	....	*1.90	2.22	0.40	0.59	
Sodium	0.20	....	....	....		....	....	....	
Water and Volatile Matter	5.90	7.11	7.50	10.67	....	12.65	13.80	13.80	....
Other Matter	....	....	....	....	....	0.90	1.50	....	....

* Alkalies, waste, etc.

† Alkalies and waste.

No. 1. New Jersey fire clay, used extensively for fire brick, retorts, etc. N. J. Clay Report, p. 248.

No. 2. Fire clay from Dowlais, South Wales, considered the best fire clay in Dowlais. N. J. Report from Percy's Metallurgy.

Nos. 3 and 4 are, according to Muspratt, fire clays from Newcastle-on-Tyne.

No. 5 is, apparently, the purest of nine samples of Stourbridge, Eng., fire clay, analyzed by Prof. Abel. Wagner's Chem. Tech., p. 295.

Nos. 6, 7, and 8. Analysis from N. J. Geol. Report (Clays), '78. No. 8 is considered a number one fire clay and is, perhaps, a fair sample of the higher grade fire clays of New Jersey.

No. 9 is an analysis of a remarkably refractory fire brick of the Cornwall or Devonshire Kaolin. Wagner's Chem. Tech., p. 321.

TABLE "B"—NORTH DAKOTA FIRE CLAYS.

CONSTITUENTS.	No. 1.—Dickinson (upper).	No. 2.—Dickinson (under No. 1).	No. 3.—Dickinson.	No. 4.—Pembina Mt.
Silicon ($Si\ O_2$)	72.66	64.84	64.22	50.45
Aluminum ($Al_2\ O_3$)	17.33	24.31	17.22?	17.57
Iron ($Fe_2\ O_3$)	1.05	1.60	2.09	2.80
Calcium ($Ca\ O$)	0.13	0.11	Trace	0.25
Magnesium ($Mg\ O$)	....	0.24	0.37	1.79
Potassium ($K_2\ O$)	0.36	Trace	0.21	0.07
Sodium ($Na_2\ O$)	0.38	0.32	0.34	0.86
Water and volatile matter	9.35	8.58	10.29	22.55
Other matter and errata	....	....	....	3.66

In making comparisons of the analyses of the clays it must be remembered that in all cases the North Dakota clays were unwashed, and in most cases as dug from surface exposures. By reference to the tables of analyses it will be seen that sample No. 1 of North Dakota clay corresponds quite nearly to No. 1 of the other list which is a New Jersey clay, extensively used for a fine fire clay. The advantage, however, appears in favor of the North Dakota clay, since it contains less iron and alkalies. It also seems superior to any of the other foreign clays of list "A," with the possible exception of No. 8. North Dakota sample No. 2 corresponds most nearly to No. 2, and No. 9 of table "A," clays from Dowlais, South Wales, and from Devonshire and Cornwall, Eng. The North Dakota sample again appears superior on account of its greater freedom from iron and alkalies.

Sample No. 3 of North Dakota clays, though probably not quite so good a clay as Nos. 1 and 2, is, however, of fine quality and doubtless superior to the most of the clays in table "A."

No. 4, of North Dakota clays, that from Pembina Mountains, is probably a medium grade fire clay. It appears to have less iron and alkalies than several of the foreign clays extensively used for refractory purposes.

When we consider the quality of the clays, the ease with which they can be mined, the abundance of the clay and the almost inexhaustible supply of cheap coal near the most of it, the surrounding markets and the means of transportation at hand in most cases, there seems to be no reason why these clays should not become the basis of an extensive and profitable industry.

POTTER'S CLAY.—The term potter's clay is very loosely used to designate a great variety of plastic clays. For convenience, we shall in this article make but two divisions of potter's clay, viz., stoneware and earthenware clays. These two clays are those used most extensively for common dishware; the stoneware being the poorer quality and the earthenware, the finer white dishware, largely used for tableware.

STONEWARE CLAYS.—The essential requisites of this class of clays are: Plasticity, fineness, freedom from an excess of impurities such as iron and alkalies, ability to stand heat well and to produce a strong, impervious body. There is a wide variation in stoneware clays. The poorer grades are but a little better than a good brick clay, while the finest approach very close to earthenware clays. The typical stoneware clays bake to a strong, sonorous and sometimes semi-vitrified body. They are usually not so fine nor so homogeneous as the earthenware clays. The ware, after baking, is opaque and commonly of a gray or yellow color, due largely to the presence of a considerable quantity of iron. The coarser stoneware is usually salt-glazed, but the finer quality may be decorated and glazed similar to earthenware. Stoneware may be used for common yellow and gray ware, for jugs, jars, plumber's ware, a cheap quality of dishware and for many other purposes.

In North Dakota there are several localities where stoneware clay is found. In nearly all cases the material is from fair to fine in quality.

Near *Minot, Ward county**, a layer of clay is found over the coal, which is apparently well adapted to the manufacture of stoneware. The clay as dug is of a bluish gray tint; when baked at high temperature it takes a creamy tint. It is very fine and has a greasy feel. On baking it becomes very firm and hard, and shows but little tendency to crackle. An analysis of the clay shows the following:

Silicon ($Si\,O_2$)	56.86
Aluminum ($Al_2\,O_3$)	25.03
Iron oxide ($Fe_2\,O_3$)	6.11
Calcium Oxide ($Ca\,O$)	0.71
Magnesium Oxide ($Mg\,O$)	0.76
Potassium Oxide ($K_2\,O$)	0.50
Sodium Oxide ($Na_2\,O$)	0.016
Water and volatile matter / Other matter, by subtraction	10.014

In the *Pembina Mountains*, near *Olga*, a fine white clay is found which would doubtless make good stoneware. This clay is found outcropping along the bluff. (I repeat the description given on page 21.) The layers which have been seen by the writer were probably not of sufficient thickness to be of use; but from the reports of others there seem to be thicker deposits. An illustration may be seen on page 31 which will show how the thinner

*This clay is also mentioned on p. 14.

layers occur. This clay is very white, of a soapy feel, very fine in texture and is acid to the taste and to litmus. It bakes to a hard, strong body of a faint pink color. The acid element is sulphuric and may in part occur as a natural alum. By washing, this clay would probably do well for stoneware and for several other purposes. The following is an analysis of this clay:

Silicon ($Si O_2$)	50.45
Aluminum ($Al_2 O_3$)	17.57
Iron ($Fe_2 O_3$)	2.80
Calcium ($Ca O$)	0.25
Magnesium ($Mg O$)	1.79
Potassium $K_2 O$)	0.07
Sodium ($Na_2 O$)	0.86
Water and volatile matter	22.55
Other matter and errata	3.66

At the *Plenty Coal Mine* in *Mercer county*, a clay is found associated with the coal, which would doubtless make an excellent stoneware. The thickness of this deposit is not known. This clay is very much like the Minot clay just described. Like that, it is fine in texture and of a bluish gray color. When baked in the laboratory furnace, it becomes very hard and strong, and takes a creamy tint. An analysis shows the following:

Silicon ($Si O_2$)	60.79
Aluminum ($Al_2 O_3$)	16.23
Iron ($Fe_2 O_3$)	4.49
Calcium ($Ca O$)	0.65
Magnesium ($Mg O$)	1.02
Potassium ($K_2 O$)	0.19
Sodium ($Na_2 O$)	0.28
Water and volatile matter, by subtraction	16.65

About *Dickinson*, there are several clays which will make excellent stoneware. But the best of these clays are too good to be used for anything but the highest grade white stoneware, which is the next thing to earthenware. These clays will be described under earthenware clays.

For the purpose of comparison, the following analyses are given of clays used for stoneware in various localities in other parts of the world.

1.—*Unglazed stoneware, Baltimore, very fine white body.

Silicon	67.40
Aluminum	29.00
Iron	2.00
Calcium	0.60
Magnesium	.....
Potassium / Sodium	0.60

*From Muspratt.

2. According to Salvetat,* fine yellow wedgewood ware consists of:

Silicon	66.49
Aluminum	26.00
Iron oxide	6.12
Calcium	1.04
Magnesium	0.15
Alkalies	0.20

3. From analyses of stoneware by the same as No. 2, the following results are secured:

Silicon	from 62	to 75	per cent.
Aluminum	from 19	to 29	per cent.
Iron oxide	from 1	to 8.5	per cent.
Calcium	from 0.25	to 1	per cent.
Magnesium	from 0	to 0.9	per cent.
Alkalies	from 0.50	to 1.5	per cent.

Most of the stoneware clays of New Jersey seem to be of superior purity, especially with reference to iron. By comparing the analyses of stoneware clays from various localities with those of the same class in North Dakota it will be seen that, as far as chemical analyses show, the clays mentioned from this state are apparently of very fair quality.

There can scarcely be any doubt but what these clays will produce an article fully equal to the average of this class of ware.

Earthenware Clays.—The purest, finest stoneware clays grade insensibly into earthenware clays.

Earthenware clay possesses the general characteristics of fine stoneware clay. A good earthenware clay must be highly plastic, very free from iron and excess of alkalies, and must bake to a strong, compact white body.‡ Such clay is the material used for most of the white tableware. The comparative rarity of this clay and the large number of uses to which it can be put, on account of its purity, add much to its value.

As has already been said, clay of this kind is found in England and extensively used in the great pottery industry of that country. In the United States, the fine clays of this quality form the basis of the great pottery industry of New Jersey.

In North Dakota there is at least one district where there are large deposits of clay apparently well suited to the manufacture of earthenware. These clays are found in the southwestern part of the state, in the vicinity of *Dickinson, Stark county.*

These deposits have already been mentioned in connection with the fire clays. The description of some of these will be repeated in this section. The clays of this class (white earthenware clays) found about Dickinson, outcrop near the top of high bluffs. In

*Beckwith's "Pottery" pamphlet. P. 24

‡See the general remarks under Characteristics.

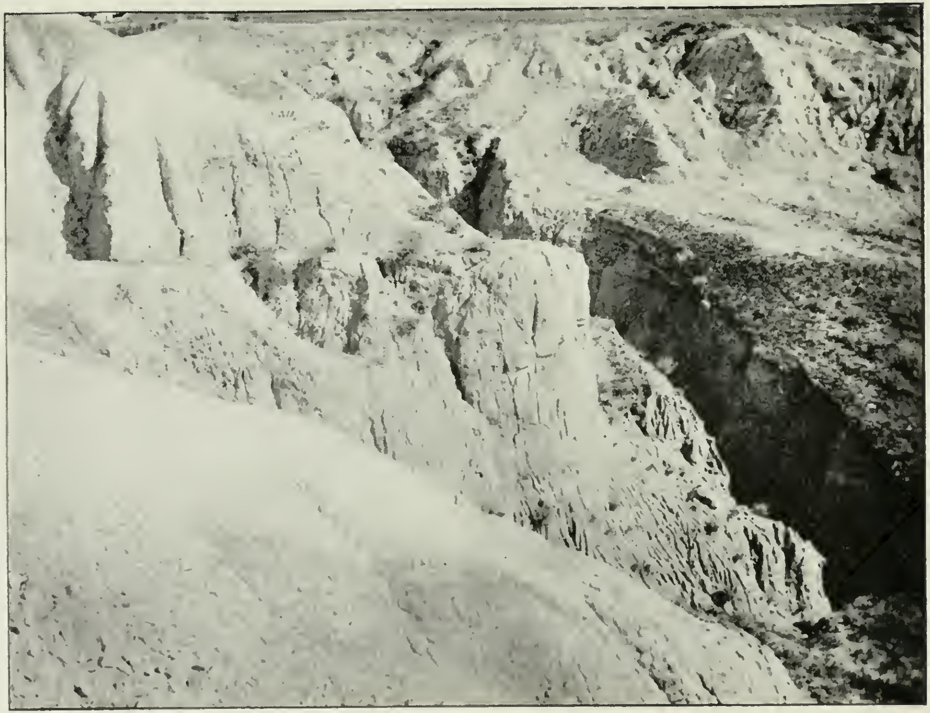
White Fire and Earthenware Clay.
Probably 3 to 5 feet.
(See analysis, p. 27.)

Fine White Earthenware and Fire-Clay.
Probably 10 to 15 feet thick.
(See analysis, p. 27.)

Sand and Clay.

Soft Sandstone.

Sand and Clay.



Probably 100 feet or more in height.

NEAR DICKINSON (about 1 or 2 miles south).

(See page 26.)

some cases the surface soil and clay seem to have been entirely washed away and the white clay is left capping the bluff. This is the case with a deposit of very fine white clay about a mile south of Dickinson. At this point the bluff is probably 100 feet or more high. The base of the bluff appears to be chiefly of sand and clay. Above this is a very deep layer, probably from 10 to 15 feet thick, of fine, white earthenware clay. This seems to be covered by a layer, perhaps 4 feet thick, of very pure but slightly sandy clay. A cut of this deposit is given on the opposite page.

This upper clay as found is of a very light color, but bakes still whiter. It produces a hard body showing little tendendency to fuse. An analysis of this clay, as dug, is as follows:

Silicon ($Si O_2$)	72.66
Aluminum ($Al_2 O_3$)	17.33
Iron ($Fe_2 O_3$)	1.05
Calcium ($Ca O$)	0.13
Magnesium ($Mg O$)	.....
Potassium ($K_2 O$)	0.36
Sodium ($Na_2 O$)	0.38
Water, and volatile matter	9.35

It will be seen from the analysis that this is a very pure clay The silicon appears rather large in proportion to the aluminum, but this is due to the presence of a small amount of sand which, if necessary, could be removed probably with very little trouble. The iron, it will be noticed, is very low for a surface specimen unwashed. The amount of alkalies is small. Withal this clay would, probably, with proper treatment make excellent earthenware material suited for common white tableware, etc. The clay which it has been said is found immediately under this, is a layer perhaps from 10 to 15 feet thick. This clay is very fine and free from grit.

It can be dug with a spade and the lumps can be powdered in the hand. The color of the clay as dug is a grayish white. probably due to a slight amount of carbonaceous matter. After baking, it is pure white. It has a very fine homogeneous body. When baked it becomes very hard and has a clear sharp ring. It stands heat well without warping or cracking. An analysis of a sample taken from a surface exposure, and *as dug*, gives:

Silicon ($Si O_2$)	64.84
Aluminum ($Al_2 O_3$)	24.31
Iron ($Fe_2 O_3$)	1.60
Calcium ($Ca O$)	0.11
Magnesium ($Mg O$)	0.24
Potassium ($K_2 O$)	Trace
Sodium ($Na_2 O$)	0.32
Water and volatile matter, etc. by subtraction	8.58

This analysis shows a very pure clay and one which, when washed and purified, seems well proportioned for the potter's use. The fluxing constituents and the iron are not high for an unwashed surface specimen. This clay has been formed into small dishes and baked at high temperature in the laboratory. The bisque came out a very fine, white, compact body. It had a good ring and showed no tendency to crackle or warp.

A sample of clay which had been cleaned and mixed and tempered ready to be formed, just as used, was taken from one of the large *Trenton* potteries and analyzed with the following results:

Silicon ($Si O_2$)	69.03
Aluminum ($Al_2 O_3$)	23.89
Iron Oxide ($Fe_2 O_3$)	0.45
Calcium Oxide ($Ca O$)	0.29
Magnesium Oxide ($Mg O$)	0.05
Water and volatile matter	7.46
Potassium ($K_2 O$) } Sodium ($Na_2 O$)	?....

By comparing this analysis with the last mentioned from North Dakota, it will be seen that there is, in some respects, a considerable similarity in composition. The North Dakota clay is a little higher in iron, but it must be remembered that the sample from the Trenton pottery had been washed and thoroughly prepared for ware, while the sample from North Dakota was just as dug. There is but little doubt that this clay is well suited for white table ware and the like uses. The supply of the clay is evidently abundant. The surroundings are all that could be asked. At the foot of the bluff where the clay is found, there is a small stream which would furnish water for the factory. The deposit is probably not more than a mile and a half from the main line of the Northern Pacific railway. So a spur track could be easily run to the deposit. Coal is found in great abundance and is mined within a few miles and can be gotten at a very low price. There is plenty of material for saggars in which to bake the ware.

There are doubtless other good earthenware clays in this vicinity although the writer has not visited any such deposits. However, samples of one or two other fair clays have been received and analyzed. The analysis of a sample from about Dickinson, furnished by Mr. E. F. Messersmith gave the following results:

Silicon ($Si O_2$)	64.22
Aluminum ($Al_2 O_3$)	17.22 (?)
Iron ($Fe_2 O_3$)	2.09
Calcium ($Ca O$)	Trace
Magnesium ($Mg O$)	0.37
Potassium ($K_2 O$)	0.21
Sodium ($Na_2 O$)	0.34
Water and volatile matter	10.29

Good earthenware clays may be discovered in other parts of the State; but no such deposits are known to the writer. For the purpose of comparison, analyses are given of a number of earthenware clays found in different parts of the world, and extensively used for the manufacture of whiteware, etc.:

CONSTITUENTS.	No. 1.—New Jersey Ware Clay.	No. 2.—New Jersey Ware Clay.	No. 3.—Clay Used in a Trenton Pottery.	No. 4.—China Clay, Cornwall, England.	No. 5. — Dorsetshire Clay, Used in Staffordshire Potteries.	No. 6.—Impure or Unrefined Cornish Stone Clay.	No. 7.—Porcelain, Berlin.
Silicon	45.45	43.40	69.03	66.20	46.38	35.65	66.60
Aluminum	38.75	37.56	23.89	24.11	38.04	32.50	28.00
Iron	1.15	1.04	0.45	0.79	1.04	1.65	0.70
Calcium	....	....	0.29	....	1.20	Trace.	0.30
Magnesium	0.11	....	0.05	....	Trace		0.60
Potassium	0.17	0.35	....	0.96	....	30.05	3.40
Sodium	....	0.37	....	....	....		....
Water and Volatile Matter	13.05	15.40	7.46	7.20	13.44		....
Other Matter	1.32	1.40	....	0.20	... .	Loss 0.15	....

Nos. 1 and 2. From New Jersey Clav Report of 1878.
No. 3. From analysis made of clay from a Trenton pottery, mixed and proportioned ready for use.
No. 4. From Williams' Applied Geology.
No. 5. Muspratt gives this analysis, by Mr. Higginbotham, of clay used in Staffordshire potteries.
No. 6. From Muspratt, Cornish-stone clay, so extensively used in fine white ware and China clay, in the impure state.
No. 7. From Muspratt; Laurent, analyst. (Supposed to be from the ware, not the clay.)

Hydraulic Cement Clay.—Besides the several kinds of clay that have already been mentioned as found in different parts of North Dakota, there is found, also, in at least one locality, natural hydraulic cement clay. The writer has not had the time or means to make a very careful investigation of this subject, so it will not be possible to speak as fully or as definitely as would be desirable, regarding this deposit. It is hoped, however, that enough may be said to interest some to investigate the formation further.

Hydraulic cement, also known as water lime cement, hydraulic lime, etc., is usually understood to mean a mixture of lime and clay which, after burning, will form a mortar or cement capable of hardening and retaining and increasing its hardness under water. Such a cement is either natural or is prepared artificially by burning a proper mixture of certain rich limestone and a suitable clay.

A widespread and growing demand for hydraulic cement and the fact that first-class natural cement deposits are not widely distributed, have led to a considerable manufacture of artificial cement. When, however, a good natural cement can be found, it is likely to be first sought.

There are many varieties of cements varying in character and value in different localities, and even in the same deposit. The two most distinctly different kinds are those that set slowly but eventually become very hard, and those that set rapidly but never become so firm and hard as the slow setting kind. The first variety is best where great strength is required to sustain enormous pressure. The second variety is better where it is necessary that the mortar should harden immediately but where the pressure is not so great.

Hydraulic cements of different kinds are used extensively for cisterns and wells, sewers, bridges, lighthouses, walls, foundations of heavy buildings, cellar floors, sidewalk paving, manufacture of artificial stone, etc.

The difference in behavior between common and hydraulic lime may, perhaps, be in part accounted for in the following way. "Common lime is burned from carbonate of lime or carbonate of lime and magnesia as nearly pure as can be obtained; and the hardening of the mortar made from it is due in part to the reformation of lime carbonate, in part to the crystalization of hydrate of lime upon the grains of sand and probably in part to the slow formation, during ages, of lime silicate, in virtue of which a good mortar grows harder with age. Hydraulic lime, on the other hand, is burned from limestones notably impure, containing, as analyses show, from twenty to about fifty per cent. of silica, alumina and iron oxide; it either does not slack at all with water or slacks very slowly and with great difficulty, needing therefore to be ground to a fine powder before being used; and its hardening in mortar is due to a chemical combination of lime, or lime and magnesia, with silica and alumina partially effected during the burning, and partially by the agency of water, forming hydrated silicates and aluminates of lime and magnesia, which are insoluble in water."

Hydraulic limes are found in a number of localities in Europe and are extensively used. In the United States, there are, fortunately, several regions containing deposits of natural hydraulic lime, found at different horizons.

"The lowest of these horizons is in the calciferous group, which at Utica, in La Salle county, Ill., and at several points in Maryland and Virginia, furnishes hydraulic limes of satisfactory quality, and may be expected to do the same at points on the same range in eastern Pennsylvania. The water-lime group, at the base of the lower Helderberg, with some kindred limestones belonging just beneath it in the geological series, furnishes nearly ninety per cent. of all the hydraulic lime and cement produced in the United States, being largely burned in Ulster county, New York, furnishing the esteemed Rosendale cement, also in Oneida, Madison, Onondaga, and Erie counties, and near Sandusky, in Ohio; while the well-known Louisville cement is obtained according to Prof. James Hall, from beds of the Corniferous period belonging just above this in the geological series. A limited outcrop of rocks of the Hamilton period at Milwaukee, Wis., furnishes the Milwaukee cement. The St. Louis limestone, of the sub-carboniferous, is said to give promise of hydraulic properties at several points in Illinois while impure limestones of the coal-measures furnish "Parker's cement," in Belmont county, Ohio, and the "Johnston cement," in Cambria county, Pa.*

In *North Dakota*, a natural hydraulic cement clay is found in what is known as the *Pembina Mountain* district. This clay, as well as the shales of the district, probably belongs to the upper Cretaceous period.

About twelve or fourteen miles north of *Milton, Cavalier county*, near *Olga*, an outcrop of hydraulic clay is found. This outcrop occurs in a deep ravine making into the valley of the Pembina river. This deposit of calcareous clay is probably about 350 or 400 feet below the level of the surrounding prairie and within a few feet of the bed of a small creek. The clay appears to form a small ridge or hogback near the foot of the bluff. This ridge, which is quite free from trees, shrubs and grass, which cover so thickly most of the hillside, has been so washed as to show something of the lower formation of that part of the valley. The following figure may give some idea of the occurrence of this deposit. The position, nature and thickness of the layers marked in the figure are only approximately correct.

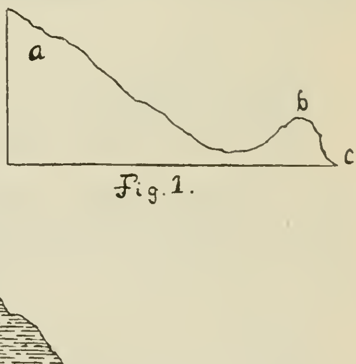


Fig. 1.

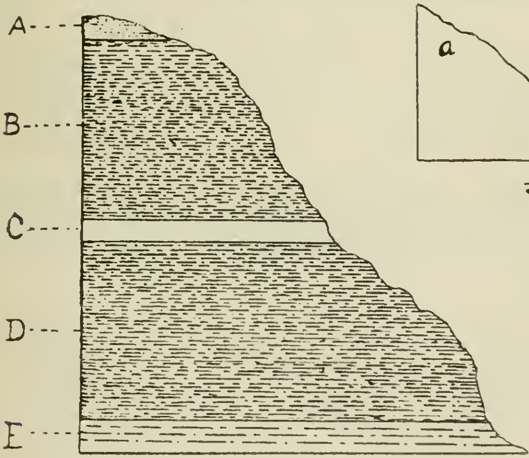


Fig. 2.

Fig. 1 is a section showing the side of a valley. The Top, "a," is about 400 feet above the bottom, "c," where there is a small creek. And "b" is the ridge from which the hydraulic clay appears.

Fig. 2 is a section of the knob "b" of figure 1.

In figure 2, "A" is about 5 ft. of soil and shale.

"B" is about 30 ft. of black carboniferous clay, impregnated slightly with sulphur and alum.

"C" is about 2 to 3 ft. of very fine white clay, of slightly acid taste. (Stoneware and probably medium grade fire clay.)

"D" is about 30 or 40 ft. of black clay. "E" is about 3 to 6 ft. (?) of hydraulic cement clay.

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*Williams' Applied Geology, p. 99.

It is impossible at present to state what is the extent of this layer of cement clay, but there seems to be no reason why it should not prove extensive. The clay can be easily picked out in lumps, which are sufficiently firm to bear handling, but which split into thinner layers that can be rubbed to a fine powder in the hand. The clay is of a leaden gray color and very homogeneous. Occasionally, where splitting occurs, there may be seen impressions of small shells, but the softness of the material makes it difficult to preserve these forms perfect. This clay seems to be Cretaceous and probably is in the lower portion of those beds which Warren Upham regards as of the Fort Pierre subdivision.*

The writer has analyzed this clay and has also given it an actual test by burning it to hydraulic lime and then using it under water. The burning gave a rather quick setting cement. It forms, apparently, a very strong and hard body. No tests were made for tensile or crushing strength. A sample of the clay was sent to one of the eastern cement factories for examination, the report of which examination gave a good hydraulic cement. The fact of its being so easily mined and prepared would much lessen the expense of production. This advantage will be appreciated when it is understood that much, if not most, of the natural cements of many localities is in rock form, which requires an extra expenditure to mine and crush. An analysis of this clay before calcination gave the following:

Silicon ($Si\ O_2$)	18.52
Aluminum Oxide ($Al_2\ O_3$)	5.36
Iron Oxide ($Fe_2\ O_3$)	4.08
Calcium, calculated as $Ca\ CO_3$	70.64
Magnesium, calculated as $Mg\ CO_3$	0.76

This analysis shows a material very much like the Kufstein natural hydraulic lime, of Kufstein, Germany, which is said to produce an excellent cement. The composition of the Kufstein marl is as follows :‡

Silicon	15.92
Aluminum	5.94
Iron Oxide	3.98
Calcium Carbonate	70.64
Magnesium Carbonate	1.02
Gypsum	0.34
Potash	0.55
Soda	0.82
Water and organic substances	0.79

* "This reference has been confirmed during the field work of 1886 by the discovery in the shale in this locality and in its continuation southward on the head streams of Park river, of Scaphites Nicolletti (Morton), Scaphites Nodosus (Owen), Baculites Ovatus (Say), and Baculites Compressus (Say); two species of Inoceramus, one of which is I. Altus (Meek)."
[From Warren Upham on "Upper Beaches of Lake Agassiz."

‡Wagner's Chem. Tech.

It is hoped that what has been said on this subject will lead to further observation and research regarding this formation. If this hydraulic material can be shown to exist in abundance and not too far from the railroad, there seems to be no reason why it should not become the source of a flourishing industry.

Conclusion.—From what has been said it may justly be concluded that North Dakota is richly supplied with a variety of valuable clays. The excellent brick clays which are so widely distributed throughout the state are sure, as the country develops and the cities and towns increase in size and number, to become very important factors in growth, in substantiality and in beauty. Sooner or later the superior brick clays of several localities are likely to become known and appreciated and their products sought by cities of neighboring states. Growth and improvement in the cities will also tend toward developing the clays fitted for sewer and drain pipes, for various sanitary and other purposes.

There seems no reason why those districts supplied with good fire clay may not soon become centers of a lively industry in manufacturing fire brick and other refractory material.
There are some excellent stoneware and probably good white earthen-ware clays. The constant demand for articles of these wares may be expected to result in establishing factories for their production. If the deposits of hydraulic cement clay prove to be extensive, they may be used largely, as the source of water lime.
There is little room to doubt that in course of time the clays of North Dakota will become the source of industries that will play no small part in the general development and growth of the commonwealth.

The importance of the clay industry in several foreign countries is somewhat known, but few who have not investigated the subject, realize the magnitude of this business. Several years ago, in one of the shires of England, in Staffordshire alone, it is said that over 100,000 operatives were employed in connection with the clay industry. Likewise in Germany and France, in China and Japan, this is an industry of great importance. In the United States, in those of the older states that possess rich deposits of clay, there has already sprung up a flourishing business in the manufacture of a variety of clay wares. This is especially noticeable in New Jersey and Ohio. The total value of the articles manufactured from clay annually, in the United States, is probably from $65,000,000 to $90,000,000 or more.
North Dakota possesses at least two advantages, viz., location and fuel supply, which would aid greatly in successfully establishing a large clay industry in the state. Its situation is such, with reference to deposits of fine clays in other localities that it would naturally have a large supporting territory. The use of the coal found in such abundance in the close proximity to the finer clays,

would doubtless be a great help in keeping down the cost of manufacture.

The advantage to the state would be those always secured by the introduction of manufacturies into an agricultural community. New industries develop resources before unused, keep at home as well as bring in a large amount of wealth, enlarge the demand for other products, foster other industries, and in many ways add to the general prosperity.

Although the results of these investigations are encouraging, it is not expected that a great industry of this kind will be at once established. That requires time. It is hoped, however, that the value of these clay resources will be appreciated, and that eventually the clays of the state will be extensively used. To this end it is hoped that these investigations may be helpful.

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ANALYSES OF NORTH DAKOTA CLAYS.

CONSTITUENTS.	Dickinson.	Dickinson.	Dickinson.	Pembina Mountains, near Olga.	Dickinson.	Plenty Coal Mine, Mercer County.	Minot; blue.	Minot, black (under coal).	Bismarck.	At Lehigh Coal Mine, near Dickinson (over Coal).	At Lehigh Coal Mine, near Dickinson (under Coal).	Williston.	Grand Forks—Brick clay used at the Alsip works.	Hydraulic Cement Clay, Pembina Mountains, near Olga.
Silicon........................	72.66	64 81	64.22	50.45	56.03	60.79	56.86	53.72	58.73	55.77	71.25	57.80	51.27	18.52
Aluminum ($Al_2 O_3$).............	17.33	24.31	?17.22	17.57	24.23	16.23	25.03	17.78	14.98	12.15	21 94	9.47	9.33	5.36
Iron ($Fe_2 O_3$)..................	1.05	1.60	2 09	2.80	9.16	4.49	6.11	3.85	5.63	4.27	3.67	3.16	3.52	4.08
Calcium (CaO)..................	0.13	0.11	Trace	0 25	....	0.65	0.71	0.81	2.10	5.92	0.71	7.91	11.15	Ca C O_3 70.64
Magnesium (MgO)...............	....	0.24	0.37	1.79	0.31	1.02	0.76	0.50	0.71	1.90	0.83	2.84	2.31	Mg C O_3 0.76
Potassium (K_2 O)	0.36	Trace	0.21	0.07	0.088	0.19	0.50	0.28	0.16	0.256			0.50	....
Sodium (Na_2 O)..................	0.38	0.32	0.34	0.86	0.72	0.28	0.016	1.72	0.988	0.992			2.08	....
Water and volatile matter.........	9.35	*8.58	10.29	22.55	9.39	*16.35	*10 014	21.82	16.672	*18.742			....	....
Other matter and errata..........	....	....	....	3.66	....	....	....	....	....	....			....	....

* By subtraction.

The analyses of North Dakota Clays, given in this report, have been made in the chemical laboratory of the State University. In making the analyses the writer has been assisted by Mr. Myron W. Smith, B. S., who has been a post-graduate in this university. The alkalies, in all cases, were determined by the writer.

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