CLAYS.

CLAYS OF GARLAND COUNTY, ARK.

By EDWIN C. ECKEL.

General statement.—During the fall of 1905 the writer was detailed, at the request of the Secretary of the Interior, to examine the clays of the Hot Springs Reservation, Ark., and report on the commercial value of such deposits as could be found. In the course of the few days devoted to this work several clay deposits in Garland County, outside the limits of the reservation, were visited and sampled. The following paper is a summary of the principal features brought out by this work.

As the area covered by the Hot Springs Reservation lies entirely outside of the Cretaceous and Tertiary portion of Arkansas, the clays to be found there represent but two types: (1) Paleozoic shales, and (2) recent river and stream deposits. The latter group includes a few small clay beds which in places have been worked on a small scale for the manufacture of common red brick of poor grade. The Paleozoic shales, however, by their leaching and decay in place form a series of light-colored siliceous clays of more importance.

The area within the reservation was examined with some care, and several developed clay properties in other parts of Hot Springs County were visited for comparison. The localities and separate deposits are first described, after which the economic features of the matter are summarized.

Description of clay deposits.—On the southeast side of Hot Springs Mountain, near the road crossing its crest, a series of light-colored clays is exposed. The section shows 6 to 10 feet of these clays, mostly light-gray in color, but with occasional thin reddish bands. The clays are quite free from coarse sand or grit. Their strike and dip are very variable, but a fair average would probably be N. 70° W. and 25° S.

Samples were collected from this locality and analyzed in the Survey laboratory by George Steiger, with the following results:

Analysis of clays from Hot Springs Mountain.

Silica	73.07
Alumina	16.40
Titanic oxide	1.09
Iron oxide	1.12
Lime	.25
Magnesia	.64
Soda	.26
Potash	2.75
Combined water	4.46
Moisture	.36

Across the divide between Hot Springs Mountain and North Mountain a similar series of clays is exposed near the northeast corner of the reservation. At this point 8 feet of gray clay is shown, with no reddish bands, but containing considerable fine sand. Samples collected from this locality and analyzed by George Steiger gave the following results:

Analysis of clays from North Mountain.

Silica	70.31
Alumina	17.27
Titanic oxide	1.00
Iron oxide	1.85
Lime	.23
Magnesia	.91
Soda	.26
Potash	3.51
Combined water	4.36
Moisture	.88

On the south slope of West Mountain, clay beds are exposed at several points. These clays are of the same general character as those shown on Hot Springs Mountain and North Mountain. At the best exposure 5 or 6 feet of gray and red mottled clays are seen. They are, however, full of rather coarse sand and are probably unfit for any use.

Near the northeast end of Sugar Loaf Mountain a series of gray, green, and reddish shales is exposed. These rocks strike N. 40° E. to N. 50° E., and their dip varies from vertical to 70° NW. At some points they have decayed in place and are quite soft clays. The best deposits, however, lie just beyond the reservation limits and have been opened at several points there as well as in pits near the waterworks. At these places the clays have been excavated on a small scale for various purposes.

Analyses of specimens collected from these pits follow:

Analyses of clays from near the reservation line and from near the waterworks.

	A	B		A	B
Silica	73.96	70.29	Magnesia	.49	1.50
Alumina	14.54	16.74	Soda	.80	.08
Titanic oxide	.34	.64	Potash	2.64	2.76
Iro oxide	2.17	2.03	Combined water	3.76	5.00
Lime	.15	.10	Moisture	1.36	1.12

These analyses were made by George Steiger in the Survey laboratory. A is of clay from the pits near the reservation line and B is of clay from the pits of Mr. Arthur Furr, near the waterworks.

The most promising clay deposits of the district lie some distance north of those which have thus far been discussed. On Cedar Mountain, near Mountain Valley post-office, considerable work has been done in opening up large deposits of white clays. Two large cuts and a number of test pits give a good opportunity for the examination of this property

The principal or eastern opening shows 30 to 40 feet of light-gray clay with some interbedded light-yellowish clays and a few layers of light-colored sandstones. This series dips northwest at low angles (10° to 15°). On the south side of the mountain several pits show clay beds interbedded with heavy sandstones. The clays are 6 to 18 inches thick, and the sandstones about the same. These clays are mottled red and gray, but as they have been cut into for only a few feet the colors may change in further work.

The other large opening is about 3,000 feet west and shows 10 feet of light-gray clay overlain by 5 or 6 feet of thin sandstones with thinner interbedded layers of clay.

Analyses of these clays follow: A was collected from the principal east opening, B from the westernmost pit. Both of these were analyzed by George Steiger in the Survey laboratory.

Analyses of clays from Cedar Mountain.

	A.	B.		A.	B.
Silica	74.55	72.06	Magnesia	2.03	2.26
Alumina	13.68	15.31	Soda	.10	.15
Titantic oxide	.73	.95	Potash	3.84	4.53
Iron oxide	1.27	1.24	Combined water	3.63	3.50
Lime	.20	.17	Moisture	.77	.48

Uses of the clays.—So far as known the clays which occur within the limits of the reservation have never been utilized for any purpose. For this reason several opened deposits outside of the reservation were visited and sampled, and the information thus gained is presented in this part of the report.

When the analyses of all these clays are grouped together, as in the following table, it is seen that they are very closely alike in composition:

Analyses of clays, Garland County, Ark.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	73.07	70.31	73.96	70.29	74.55	72.06
Alumina (Al_2O_3)	16.40	17.27	14.54	16.74	13.68	15.31
Titanic oxide (TiO_2)	1.09	1.00	.34	.64	.73	.95
Iron oxide (Fe_2O_3)	1.12	1.35	2.17	2.03	1.27	1.24
Lime (CaO)	.25	.23	.15	.10	.20	.17
Magnesia (MgO)	.64	.91	.49	1.50	2.03	2.26
Soda (Na_2O)	.26	.26	.80	.08	.10	.15
Potash (K_2O)	2.75	3.51	2.64	2.76	3.84	4.53
Water+(100° C.)	4.46	4.36	3.76	5.00	3.63	3.50
Water−(100° C.)	.36	.88	1.36	1.12	.77	.48

1. Hot Springs Mountain, on reservation.
2. North Mountain, on reservation.
3. Sugar Loaf Mountain, on edge of reservation.
4. Arthur Furr's pits, near waterworks.
5. East pit, Worthington property, Mountain Valley.
6. West pit, Worthington property, Monntain Valley.

Specimens collected by E. C. Eckel, and analyzed in the laboratory of the United States Geological Survey by George Steiger.

A fact which is not brought out by analysis is that they differ greatly in the amount of sand contained, and this would have to be taken into account if any attempt should be made to use them. For present purposes, however, the analyses are sufficiently serviceable. Such clays can be used satisfactorily for the following products: (a) pressed brick or flooring tile, (b) second-grade fire brick, (c) body for art pottery.

They will probably all burn to a light-buff or cream color, and will give a dense body at medium burning temperature. At present the Mountain Valley clays are shipped in small quantity to Chicago for use in art pottery. The other clays have been used locally for brick, etc.

So far as the present investigation goes, it may be said that the clays on the reservation are of fair quality for the purposes above named, but that equally good clays occur outside of the reservation. The deposits on North and Hot Springs mountains, moreover, are so located that working them would greatly injure the appearance of the park. If it should be decided to work any of the reservation clays, it would be advisable to explore thoroughly the north flank of Sugar Loaf Mountain with the hope of finding clays there on the Government property; for at that point a clay pit would not injure the appearance of the park system. The clays though useful, are not of such great value as to justify damage to a public park.

CLAY RESOURCES OF NORTHEASTERN KENTUCKY.

By WILLIAM CLIFTON PHALEN.

A general description of the area here considered, as well as a sketch map (fig. 10, p. 260) showing its location, has been given in the paper on Coal Resources of the Kenova quadrangle (pp. 259–268).

All the clays of northeastern Kentucky are transported—that is, they have reached their present position through the agency of water. They may be divided, both as regards age and adaptability, into two classes: (1) The Coal Measures clays, and (2) the recent unconsolidated clays of the river and stream valleys. The former will be considered first. On pages 259–261 of this bulletin a brief description is given of the geology of this region. It is there stated that the lowest subdivision of the coal-bearing rocks in the western part of the field rests on the Greenbrier (Lower Carboniferous) limestone, and has been called the Pottsville formation.

COAL MEASURES CLAYS.

POTTSVILLE FORMATION.

Sciotoville clay.—A few feet above this Lower Carboniferous limestone is found one of the most important fire clays of northeastern Kentucky. This is the celebrated Sciotoville fire clay of the Ohio reports, less widely known as the Logan clay. It has been extensively mined at Sciotoville and in the region around Portsmouth, Ohio. In the Kenova quadrangle of the United States Geological Survey in northeastern Kentucky the horizon of this fire clay is below drainage except at a very few points. On Everman Creek, Carter County, about 1 mile above the residence of Mr. David Childers, 4 to 6 feet of the nonplastic clay show and have been mined. A short distance below Mr. Childers's house the limestone outcrops in the road apparently directly below the massive Sharon sandstone. The fire clay was not observed here. On North Fork of Oldtown Creek the fire clay was reported to George H. Ashley, of the Geological Survey, as being 5 feet thick and resting directly against the limestone and as usually being present without the limestone in the hills east of Tygarts Creek. West of Tygarts Creek the limestone is reported generally present, while little seems to be known of the fire clay.[a] This horizon may be looked for along the western outcrop of the Coal Measures, occurring as it does at the base of this system of rocks. When present it will usually be found a few feet above the Lower Carboniferous limestone and, in the absence of this terrane, occupying a similar position above the Waverly sandstone. Though its outcrop in the Kenova quadrangle is extremely limited, a few miles to the west its horizon is above drainage in nearly the entire valley of Tygarts Creek. At Olive Hill, in Carter County, it is now extensively worked by the Portsmouth Harbison-Walker Company and the Olive Hill Fire Brick Company, and it shows the following section at one of the openings of the former firm:

Section of fire clay at Olive Hill, Carter County, Ky.

	Ft.	in.
Coal		2–3
No. 3 clay	1–9	
Drab flint clay	1–9	
"Semihard" clay	1–5	
"Pink eye"	3	
Blue shale		18–20
Iron ore		4– 8
Top of Lower Carboniferous limestone.		

[a] These statements refer to the territory included within the limits of the Kenova quadrangle.

This order of superposition is usually maintained in this district. It will thus be seen that there may be four distinct varieties of clay present in this noted seam. Of these the nonplastic drab flint clay is by far the most important and becomes the basis of refractory materials of the highest grade. The layer known as "semihard" is on a par with the clay at the horizon of the "Ferriferous limestone"[a] to be subsequently described, though by some of the clay workers the "Ferriferous limestone" clay, at least at some points, is considered superior. The "semihard" is a plastic or No. 2 clay and is mixed with the flint clay in various proportions, dependent on the desired quality of the product. No. 3 clay is also plastic, but of inferior quality to No. 2, while that called "pink eye" may be worked up into bricks, but the product is off color. The following analyses indicate the very high grade of the flint clay at this horizon, the percentages of silica and alumina approaching the theoretical values in kaolinite.

Analyses of flint clay.

	1.	2.	3.
Silica	50.95	48.56	46.75
Alumina	39.49	37.471	38.17
Iron oxide	.....	Trace.	Trace.
Calcium oxide	.....	.112	.17
Magnesium oxide	.28	Trace.	Trace.
Phosphoric acid	.....	.255	.....
Potash	.30	.289	Trace.
Soda		.283	
Water	9.18	[b] 13.030	14.03
	100.20	100.000	99.12

[b] Expelled at red heat.

1. Sciotoville fire clay; N. W. Lord, analyst: Ohio Geol. Survey, vol. 7, p. 58.
2. From ridge between Grassy and Three Prong creeks, Carter County, Ky.; sample collected by P. N. Moore; Robert Peter, analyst: Kentucky Geol. Survey, Report on Eastern Coal Field, vol. C, p. 10.
3. Near Olive Hill, Carter County; analysis furnished by Ashland Fire Brick Company.

Some of the clay from this horizon shows a rather high percentage of alumina, certainly higher than the kaolinite symbol calls for. Such clays are used for kiln brick and have the following composition:[c]

Analyses of high-alumina clays used for kiln brick.

	1.	2.	3.	4.	5.	6.
Silica (SiO_2)	43.38	44.52	43.05	40.30	40.80	42.71
Alumina (Al_2O_3)	40.35	40.81	44.60	45.00	49.00	38.88
Iron oxide (Fe_2O_3)	.85	1.03	2.60	n. d.	n. d.	3.36
Lime (CaO)	.88	.62	.40	n. d.	n. d.	.13
Magnesia (MgO)	.23	.55	.20	n. d.	n. d.	.....
Carbon dioxide (CO_2)	13.41	12.11	9.00	n. d.	n. d.	15.19
Water						
	99.10	99.64	99.85	85.30	99.80	100.27

1,2. Olive Hill, Carter County, Ky.; analyses from Stowe-Fuller Company's catalogue, p. 25½.
3-5. Hayward, Carter County, Ky. Ironton Firebrick Company.
6. Carter County, Ky. Chas. Taylor's Sons. F. W. Clarke, analyst. Specimen selected by E. C. Eckel.

[a] The term "Ferriferous limestone" in this report will be employed in the sense that E. B. Andrews uses it in the reports of the Ohio Geological Survey.

[c] Analyses taken from Eckel, E. C., Cements, Limes, and Plasters, 1905, p. 491.

Other clays in the Pottsville formation.—There are other clay horizons below the Homewood sandstone which, however, have not come into prominence. In the eastern part of the city of Ashland the O'Kelly Fire Brick Company has opened up during the past summer the coal (No. 4) directly below the Homewood sandstone. This seam has the following section:

Section of coal No. 4 in the eastern part of Ashland, Ky.

	Ft.	in.
Roof, massive sandstone.		
Coal		18–19
Fire clay		10
Coal		8– 9
Fire clay	2½–4	

The company is now utilizing the clay associated with the coal at its plant in town with satisfactory results. The same seam with a very similar section [a] also occurs on Catletts Creek. Should the experience of the O'Kelly Company prove satisfactory, there is no reason why the bed on Catletts Creek should not be developed. At other points throughout the area this has proved a prominent clay horizon worthy of careful prospecting by those interested in the development of the clay resources of this area.

In the hills about the head of Johns and Fields branches, Carter County, between 2 and 3 miles northwest of Willard, a few prospect holes have been made on a bed of clay lying a few feet below the Homewood sandstone, and thus similar in position to that just mentioned as occurring in the eastern part of Ashland and on Catletts Creek. The openings have not been driven in far enough to give an accurate idea of the quality, and the clay seen on the outcrop is rather sandy, as would naturally result from the wash from the massive sandstone overlying it. The appearance and thickness of this bed warrant further prospecting. Other clay beds occur in this formation, generally associated with coal. As a rule these are too small to have commercial value.

ALLEGHENY FORMATION.

Clay associated with the "Ferriferous limestone."—As in the formation below the Allegheny, so also in this formation one clay horizon stands preeminently above the rest, as regards quality, distribution, and thickness. This is the fire clay occurring near the horizon of the "Ferriferous limestone" and lying from 10 to 40 feet above the Homewood sandstone. The following sections, one measured by George H. Ashley 1 mile west of Ashland, the other by the writer at Willard, give an idea of the associated beds.

Section of fire clay 1 mile west of Ashland.

	Ft.	in.
Light-brown sandstone	20+	
Coal	2+	
Light-drab clay	2	
Light-brown clay	6	
Dark-drab clay	1	6
Drab clay, with scattered iron-ore concretions ("Ferriferous limestone" horizon)	2	
Light-drab sandy shale	1– 2	
Drab shale		0–8
Dark-drab to black clay, grading into light drab at middle	1	6
Drab clay	3	
Flint clay		1–4
Drab clay	3	6
Dark-drab clay, almost black		3
Drab clay	8	

Four feet from the bottom of the lowest layer is about 1 foot of light-drab flint clay, similar to the best of the Pennsylvania flint clays.

[a] See p. 263 of this bulletin.

Section of fire clay at Willard, Carter County, Ky.

	Ft.	in.
Fire clay		4
Coal		4
Bluish flint clay, reported		4
Dark plastic clay	4	
Light plastic clay, harder than the above	2	
Red iron ore (2 to 4 feet) / Limestone (4 to 6 feet) } "Ferriferous limestone"	10	
Thin band of flint clay, formerly shipped to Olive Hill, Ky., and to Strasburg, Ohio.		

The flint clay shown in these sections is very persistent throughout the quadrangle, on account of its indestructible nature, and will serve as a valuable guide in locating the plastic fire-clay layer. The Willard section differs from that at Ashland in having the workable clay above the limestone, and not both above and below, as is the case in the section measured by Ashley, and also in a section measured by the writer at the fire-clay bank of William T. Johnson, west of Ashland:

Section at the William T. Johnson fire-clay mine, west of Ashland.

	Ft.	in.
Dark clay	4	
Limestone ore (sometimes replaced by 4 feet of limestone), averaging		6
Bone, not always present		2
Light-drab clay	2	

At the opening of the Petersburg Fire-Brick and Tile Company at Coalgrove, Ohio, the fire clay also occurs both above and below the limestone. A section measured by P. N. Moore at Amanda Furnace, about 4 miles northwest of Ashland, is quite similar to that obtained at Willard:

Section of fire clay near Amanda furnace.[a]

	Ft.	in.
Soil	4	
Clay shale	6	
Coal		4
No. 2 fire clay	3	
Pottery clay	4	
No. 1 fire clay	3	
Limestone ore		8
Top of "Ferriferous limestone."		

To the south of Ashland the dips up the Big Sandy carry this horizon below drainage level, but the rise of the beds south of Buchanan brings it again into the hills near Louisa and south of Fort Gay (Cassville), on the West Virginia side, where it has been prospected for on numerous farms on Mill Creek. To the southwest of Louisa it is generally present in the hills. On the farm of Mr. F. R. Bussey, at Busseyville, a good indication was seen 30 feet above the top of the Homewood sandstone, where Mr. Bussey reports 7 to 8 feet of clay. The rapid rise southward carries its horizon above the hilltops at the southern edge of the area. Between Busseyville and Prosperity it is present in most of the hills, and in this region the limestone is generally associated with the clay. To the northwest, on Cherokee and Irish creeks and Dry Fork, it is present, gradually descending to drainage level at Webbville. The basin between Webbville and Willard causes its disappearance between these points, but at Willard it is mined and shipped. The main continuous western boundary of this horizon is found in the hills just east of Little Sandy River, but at the head of Canes, Lost, and Oldtown creeks, in Greenup County, this horizon catches in the hilltops and the iron ore associated with the clay has been mined on the outcrop. In general throughout the area the old benches at this horizon will be a valuable guide in locating this clay, since the red limestone ore at this horizon was one of the most important

[a] Kentucky Geol. Survey, Report on the Eastern Coal Field, vol. C, p. 141.

sources of supply of iron ore in the days of the old charcoal furnaces, and was extensively benched.

Character of the clay.—The clay at this horizon, with the exception of the small band of flint, is of the plastic variety. As worked at Willard and at Ashland, it occurs in two benches—an upper dark bench 4 feet thick, and a lower lighter bench 2 to 3½ feet thick, generally of better quality. Moore's section at Amanda furnace shows an intermediate layer of potter's clay. At the Weaver Pottery Company's works, north of Catlettsburg, from 6 feet of clay the upper 3½ feet are worked, the lower portion being thought too sandy to work satisfactorily. The presence of pebbles of limestone has also caused the company some annoyance. The following analyses indicate the character of this clay. For comparison an analysis of the No. 1 or flint clay is appended.

Analyses of clay associated with the ferriferous limestone.

	1.	2.	3.	4.	5.
Silica	50.95	40.14	56.40	60.16	50.35
Alumina	39.49	43.72	28.00	25.55	33.07
Iron oxide	.....	1.98		1.89	1.43
Lime	.....	1.60	1.30	.00	.30
Magnesia	.28			.00	.15
Potash	.30	.....	.....	[a].08	.....
Soda					
Water	9.18	12.56	14.30	12.37	14.30
	100.20	100.00	100.00	100.05	99.60

[a] By difference.

1. Sciotoville fire clay; N. W. Lord, analyst: Ohio Geological Survey, vol. 7, p. 58.
2. Upper stratum of clay at "Ferriferous limestone" horizon, Ashland, Ky.; Dr. Robert Peter, analyst. Furnished by the Ashland Fire Brick Company.
3. Lower stratum of same. Furnished by the Ashland Fire Brick Company.
4. Clay near Cassville, W. Va.; Laboratory of the mining department, Ohio State University; W. W Bornesberger and R. W. Mercer, analysts. Furnished by Charles Barnell, Cassville, W. Va.
5. Clay near Cassville; analysis by Norfolk and Western Railway. Furnished by Charles Barnell, Cassville W. Va.

Applications.—The clay at this horizon is a plastic or No. 2 clay and is used principally in the manufacture of fire brick, and to a less extent for blast-furnace crucibles, boshes, inwalls, coke-oven brick, etc. For the first purpose it is utilized by the Ashland Fire Brick Company and the O'Kelly Brick Company at Ashland and by the Petersburg Fire Brick and Tile Company at Coalgrove. The product mined at Willard by the Willard Fire Clay Company and the Fraley & Rice Company is shipped, that of the former goes to Olive Hill, where it is mixed with the flint clay to make No. 1 fire brick. The companies about Ashland import flint clay to mix with their product. To make a first-class refractory brick, from 67 to 80 per cent of flint clay is used, dependent on the uses to which the brick is to be put, the remainder being No. 2 or plastic clay. For a second-grade product these proportions are reversed. This clay is also locally suitable for pottery, and is being used for this purpose by the Weaver Pottery Company north of Catlettsburg. The product obtained near Amanda Furnace has been shipped to Cincinnati for the same purpose.

Other Allegheny clays.—In a cut on the Chesapeake and Ohio Railway, about a mile north of Louisa, 8 feet of sandy fire clay, or ganister, occurs at the level of the railroad track. This bed lies 18 feet below a layer of fire clay 1 foot thick, associated with which are limestone nodules, possibly the "Ferriferous limestone." At any rate the ganister occurs but a few inches below a fossiliferous horizon known to be lower Allegheny in age. This

ganister bed was also noted in a cut on the Norfolk and Western Railway north of Fort Gay in a similar stratigraphic position. It does not seem to have attracted any attention, but its appearance is such as to indicate that it may have value.

Near North Kenova, Ohio, a clay was worked thirty years ago and hauled to Burlington and South Point, where it was utilized for pottery. The old workings are entirely fallen shut. The clay is found 25 feet above No. 8 coal and directly below a massive sandstone, thus occupying a position near No. 9 coal. This correlation is strengthened by its interval of about 85 feet above the Sheridan coal. This is the only known occurrence in the area of a workable clay at this horizon.

Other clay horizons locally workable undoubtedly exist, and many shale beds throughout the Coal Measures also appear promising and will probably be used in the future for paving bricks, sewer pipes, and for other purposes where inferior clays and shales may be utilized.

RECENT CLAYS.

The recent clays are found in the flood plains of the rivers and streams of the area and are very widespread, even the smallest streams having in some cases extensive deposits. The deposits worked at the present time are confined solely to the valley of Ohio River in the vicinity of Ashland, where there is local market and cheap coal and where transportation facilities are at hand. The flood-plain clay at the present time is used chiefly for ordinary red building brick, though it is adapted to the making of tile, shingle, etc. It is made into brick at the Means Russell plant west of the town, and by the J. J. Gates Company and the O'Kelly Brick Company in the eastern part of the city. Most of the brick is used in town, though some is shipped into other parts of eastern Kentucky and the adjoining State of West Virginia. The smaller flood plains contain clays which perhaps will not compare in quality with those of the larger river valleys, but which may be worked up into material suitable for local country use. Mr. F. R. Bussey has utilized such material from the flood plain of Harriet Branch of Little Blaine Creek. The deposit here is only 4 feet thick, but it illustrates the possibilities existing on all the smaller creeks. The flood plain deposits along Big Sandy and Little Sandy rivers have not even been prospected. Undoubtedly valuable deposits of clay exist along both these streams, which may be utilized later for common and pressed brick, roofing and drain tile, paving brick, sewer pipe, etc. Experiments having in view the adaptability of these flood-plain clays for the various purposes enumerated above should certainly be carried out.

CLAYS OF WESTERN KENTUCKY AND TENNESSEE.

By A. F. CRIDER.

INTRODUCTION.

During September and October, 1905, the writer was engaged in studying the stratigraphy of the embayment area in western Kentucky and Tennessee and in correlating the formations found there with those recently mapped in Mississippi. The most important products of the area are the extensive deposits of clays. The quality of some of these clays ranks in importance with the ball clays of Maryland, New York, and Ohio.

Common brick and stoneware have long been made in various parts of the district, but until recently little attention has been paid to the rich deposits of fire brick and ball clays. In fact there are now but two fire-brick plants in the entire district, and all the ball clays now being mined are shipped to potteries in Ohio, New York, and other States to be converted into the finished product.

LOCATION.

The area discussed embraces all that part of Kentucky and Tennessee lying west of Tennessee River and includes about 13,237 square miles (see map, Pl. XIII). It is a part of the Gulf embayment and is separated from the older and harder rock district on the east by Tennessee River. Ohio River forms the northern boundary from Paducah, Ky., to Cairo, Ill; Mississippi River forms the western boundary from Cairo to Memphis, Tenn., and the Tennessee-Mississippi line forms the southern boundary.

TOPOGRAPHY.

The region is a dissected plain with a maximum elevation along the southern border of about 600 feet above sea level. There is a low swell extending from north to south, parallel to and about 15 to 25 miles west of Tennessee River. The streams west of this divide flow west and empty into Mississippi River; those on the east side flow eastward and northward into Tennessee River. Throughout a large portion of the distance the divide is along the contact between the Cretaceous and the Tertiary, and it will be of interest to note that the great number of valuable clay deposits occur along the western slope of the divide near the crest.

GEOLOGY.

The oldest formations of this area belong to the Paleozoic rocks, which outcrop in all the streams east of Tennessee River and in a few places west of it. They become more deeply buried to the west beneath the Cretaceous and later deposits, and at the western edge of the area wells bored 1,200 feet deep fail to strike the Paleozoic rocks.

The deposition of the Cretaceous in this region therefore followed a period of deep erosion in which a great trough was scoured out at least 1,200 feet deeper than the basin now occupied by Mississippi River. This pre-Cretaceous trough extended in width from the Paleozoic hills in eastern Arkansas and Missouri to the present location of Tennessee River in Tennessee and Kentucky.

Cretaceous.—The Cretaceous is the oldest of the Gulf embayment deposits. It is a series of interstratified sandstones and clays in the lower part and limestones, marls, sandstones, and clays in the upper part. It occupies a narrow area on the east adjacent to Tennessee River. The area is widest to the south, where its width is about 31 miles. North of this it gradually narrows, and at Paducah, Ky., it is not more than 8 miles wide.

Tertiary.—Above the Cretaceous are the stratified sands, clays, and limestones of the Tertiary, with a total thickness of 2,000 feet or more. The lowest member of the Tertiary is an impure limestone and marl of Midway age, which outcrops in the southeastern section of the Tertiary area near the Mississippi line. North of this the marine deposits disappear or are covered so deeply by later deposits that they do not come to the surface. Immediately above the limestone noted above is the Porters Creek, a very persistent body of dark, slaty, nonfossiliferous clay which occupies a belt 2 to 6 miles wide and extends across Tennessee and Kentucky in a direction roughly parallel to Tennessee River. It forms the most easily recognized and important geologic horizon in the entire area. Except in the extreme south it forms the division between the Cretaceous and the remaining Tertiary and makes it possible to determine the age of the rich clay deposits of the district.

The Tertiary strata above the Porters Creek beds consist of interstratified sands, clays, and lignites. The sands predominate in the lower portion. The fine deposits of white, stoneware, and ball clays occur in these stratified Tertiary sands immediately overlying the Porters Creek clay.

Quaternary.—Over the entire Tertiary and Cretaceous areas is a thin veneer of Lafayette and loess which rests unconformably on the older strata. On account of these overlapping formations it is often difficult to obtain good exposures of the Tertiary and Cretaceous and the exact division line between them is in places impossible to determine. These surficial deposits are thickest on the bluffs adjacent to Mississippi River, where they reach a maximum thickness of 100 feet. They gradually thin to the east and at Tennessee River the maximum thickness is less than 25 feet and they are often wanting.

The large rivers and many of the streams in the interior have extensive bottoms which are covered with recent deposits.

DISTRIBUTION OF CLAY DEPOSITS.

CRETACEOUS CLAYS.

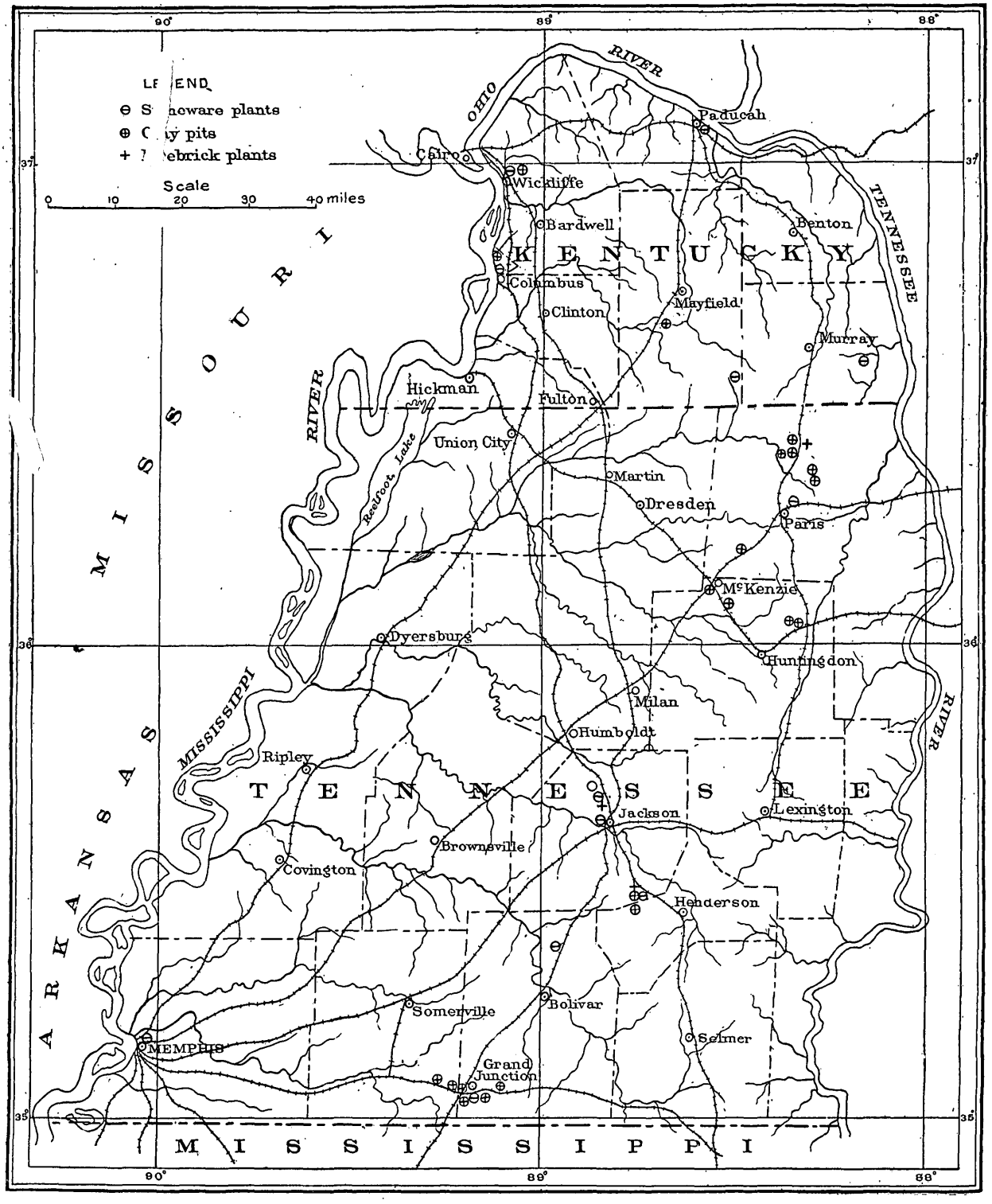
Clays belonging to the Cretaceous in this area are easily fusible and are usually of a dark or bluish color. They occur interbedded with sharp, fine-grained, micaceous sands.

Few of the Cretaceous clays have been developed. This is partially due to the fact that the deposits are generally too far removed from transportation facilities to be of value.

KENTUCKY.

Pottertown, Calloway County.—The Pottertown stoneware plant is located 6¼ miles east of Murray, at Pottertown. Common jugware, churns, and crocks are the principal products. Only one turner is now employed, who turns about 50,000 gallons yearly. A small updraft kiln is used for burning ware. The ware burns to a beautiful cream color on glazing with Albany slip. The green ware can be put in hot sunshine after two days of drying in the shade.

The clay comes from a pit 200 yards east of the former post-office. It occurs in irregular lenses in the Cretaceous and is overlain by 3 to 6 feet of Lafayette. The clay varies in color from a cream white to a gray, purple, and black. It is underlain by a fine-grained, micaceous, variegated sand and is not used as it comes from the pit, but is mixed with the underlying sand in the proportion of five parts of clay to one part of sand. The principal market for the ware is at Murray and the small stores and farms throughout the country.



MAP SHOWING CLAY-PRODUCING LOCALITIES OF WESTERN TENNESSEE AND KENTUCKY.

The following analysis of the Pottertown clay was made by A. M. Peter:[a]

Analysis of Pottertown clay, Kentucky.

Silica	57.840
Alumina	30.340
Iron peroxide	1.180
Lime	.011
Magnesia	.050
Potash	.618
Soda	.519
Water, etc	9.442
	100.000

TENNESSEE.

Hollow Rock, Carroll County.—About 2 miles west of the town, near the railroad, is a small pit of white, lean, siliceous clay. It is found in horizontal layers and if taken out when dry it breaks along the bedding plane. An area 25 by 40 feet has been opened up.

One mile farther west is another pit, in which occurs a bluish-pink, highly plastic clay free from grit. It is shipped to Nashville. The clay is exposed in a gully 30 feet long and 50 feet wide, and is overlain by 3 feet of Lafayette and, above this, by 2 feet of Columbia loam.

TERTIARY CLAYS ABOVE THE PORTERS CREEK.

The valuable clays which occur in great amount and variety in the Gulf embayment area of western Kentucky and Tennessee are principally found in the lower Tertiary. In Tennessee the area is restricted to a narrow belt of country 10 to 20 miles wide lying just west of the Porters Creek clay belt and can be traced across the State by a line of stoneware and fire-brick plants and pits which ship clays elsewhere to be made into the finished product.

In Kentucky the clays extend over a much wider belt, but they are confined within the limits of the lower Tertiary

KENTUCKY.

The Tertiary clays of Kentucky are still practically undeveloped. Most of the clays now being mined are shipped out of the State.

Dr. R. H. Loughridge,[b] who made a comprehensive study of the Jackson Purchase region of Kentucky, gave in his report the analyses of 41 different clays. Tests of the most important were made in the Rookwood Pottery, of Cincinnati, Ohio, and the results are given in the right-hand columns of the table of analyses (p. 420).

Wickliffe, Ballard County.—One of the most extensive clay deposits of Ballard County outcrops in the ravines and along the new railroad east of Wickliffe. Similar clay is exposed in the river bluffs between Wickliffe and Laketon. Near the surface it is gray, but it becomes whiter below. It makes a good fire brick and fancy decorated brick.

The thickness of the deposit is ascertained in the railroad section 1 mile east of Wickliffe. The section is as follows:

Section of clay deposit 1 mile east of Wickliffe, Ky.

	Feet.
Loess	30
Lafayette sand and gravel	20
Black, rotten clay, containing fragments of lignitized wood, bark, and logs	½
White plastic clay	30
Fine quicksand	3
Sand rock, bottom of cut.	

Samples of clay from this horizon have been made into fire brick and tested in the iron furnaces at Birmingham, Ala., where they are said to have stood a higher degree of heat than any other brick used at the furnaces.

[a] Jackson Purchase region: Kentucky Geol. Survey, p. 107.
[b] Jackson Purchase region: Kentucky Geol. Survey.

Analyses of Tertiary clays from Kentucky[a] and Tennessee.

No.	Description and locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Potash.	Soda.	Water.	Color when burned.	Shrinkage (per cent).
1	White clay, 1 mile east of Wyatt's schoolhouse, Calloway County, Ky.	46.020	38.980	Trace.	0.773	0.136	0.309	0.172	13.610	Brown, white when glazed.	.....
2	Howard's pottery, Rock, Graves County, Ky.	56.980	32.160	2.160	Trace.	.209	.838	.111	7.542	Cream	.....
3	.....do.....	62.680	25.880	2.900	Trace.	.319	1.147	.928	6.146	White, unglazed	10
4	Panther Creek, 6 miles east of Mayfield, Graves County, Ky.	75.550	16.751	1.198	Trace.	.144	1.094	.216	5.047	Salmon	.....
5	Fire clay, Wickliffe, Ballard County, Ky.	73.240	15.760	1.920	.325	.519	1.467	.147	6.622	Buff	.....
6	Bluish-white clay, southwest of Blandville, Ballard County, Ky.	74.460	18.070	1.633	.314	.245	.940	.210	4.317	Buff	15
7	White plastic clay, Cane Creek, 2 miles north of Wickliffe, Ballard County, Ky.	63.840	26.040	.740	Trace.	.137	.714	.207	8.322	.....	.....
8	Purplish-gray clay, Laketon, Ballard County, Ky.	67.501	23.051	2.109	.257	.065	.412	.020	6.585	.....	.....
9	Four miles south of Blandville, Ballard County, Ky.	71.940	20.700	Trace.	.370	.350	.630	.000	6.200	White	.....
10	Plastic clay, 4 miles northeast of Milburn, Ballard County, Ky.	76.540	14.820	.960	Trace.	.331	.926	.229	6.194	Light gray	.....
11	Bluish plastic clay, 3 miles east of Blandville, Ballard County, Ky.	71.180	20.800	1.780	Trace.	.101	.247	.291	5.601	.....	.....
12	Purplish plastic clay, 3 miles east of Lovelaceville, McCracken County, Ky.	66.320	22.930	1.190	.437	.209	1.107	.470	7.377	.....	.....
13	Stiff plastic clay, 3 miles south of Wingo, Graves County, Ky.	75.120	15.960	1.420	Trace.	.317	1.351	.245	5.587	Brown	7½
14	Plastic clay, north of Boaz, Graves County, Ky.	61.920	30.060	.300	Trace.	.064	1.602	.239	5.815	Milk white, unglazed	.....
15	Plastic clay, bluff above Columbus, Hickman County, Ky.	85.180	10.260	1.120	Trace.	.064	.954	.146	2.276	.....	.....
16	.....do.....	84.918	10.560	1.102	.572	.108	.651	.000	2.089	Light cream color	.....
17	Clay from "chalk banks," 2 miles below Columbus, Hickman County, Ky.	76.360	14.951	2.109	.325	.173	1.171	.125	4.786	.....	.....
18	Greenish sandy clay, 1 mile north of Hickman, Fulton County, Ky.	71.340	17.190	2.770	1.612	.209	.925	.232	5.722	Light gray buff	.....
19	Greenish sandy clay in Hickman, Fulton County, Ky.	83.380	9.800	2.120	.963	.187	.617	.118	2.815	Light brick color	.....
20	Greenish indurated joint clay, lower part of bluff at Hickman, Fulton County, Ky.	77.960	13.970	2.390	.134	.163	.797	.124	4.462	Brownish buff	.....
21	Indurated clay, 45 feet above low water, Hickman, Fulton County, Ky.	64.800	21.070	5.270	1.400	.050	.646	.202	6.562	Light buff	.....
22	Slate-colored, refractory joint clay, Hickman, Fulton County, Ky.	74.100	16.460	2.700	.358	.187	.559	.135	5.501	Light brown	.....
23	Green, refractory clay, underneath clay No. 22, at Hickman.	83.500	9.940	2.500	.358	.173	.539	.109	2.881	Light brick color	.....

[a] Rept. Kentucky Geol. Survey, pp. 100–118.

A small amount of the clay is shipped to the Union City Tile Company at Union City, Tenn., where it is mixed with common surface clay for making drain tile.

Nos. 15 and 16; Columbus, Hickman County.—These clays came from the bluff above Columbus, 65 feet above low water. They are highly siliceous, containing 85.18 per cent of silica and 10.26 per cent of alumina. The plasticity is due to the fine division of the silica.

One mile up the river from Columbus, at the point where the river leaves the bluff, is a lens of chocolate-colored plastic clay containing numerous leaf impressions and fragments of lignite. The clay is embedded in the coarse sand which outcrops along the bluff from this point to Columbus. It is used at the Rucker stoneware plant at Columbus.

No. 19–23; Hickman, Fulton County.—The bluff at Hickman rises about 180 to 200 feet above the river and contains about 105 to 115 feet of greenish joint clay and clay stone. This is overlain by 10 to 20 feet of Lafayette sand and gravel, and this in turn by 65 to 70 feet of loess.

The clays vary from a highly siliceous clay stone to a plastic joint clay. Clays Nos. 19, 20, 22, and 23 are quite refractory before the blowpipe.

The clays were analyzed by Dr. A. M. Peter,[a] who says:

> It is quite evident that the Tertiary bluffs from which these clays were collected offer some valuable materials to the industrial arts. Some of these are quite refractory, especially Nos. 19, 20, 22, and 23 [of this report], and would probably make good fire bricks, etc. Others could be employed for terra-cotta work and other forms of pottery, while some of these abundant deposits might, no doubt, be used with advantage in mixture with the more calcareous soft material found in some of these beds in the manufacture of hydraulic cement of the character of the celebrated Portland cement.

None of the Hickman clays are being worked.

Pryorsburg, Graves County.—The largest output of clay from any of the Kentucky deposits comes from the Kentucky Construction and Improvement Company's pit, 1 mile north of Pryorsburg. The clay was first discovered in a small outcrop on the north side of a small hill near the main line of the Illinois Central Railroad. A bed 20 feet thick and with a strong dip to the south is now being worked by open pit and tunnel. Holes have been bored into the clay to a depth of 100 feet without penetrating the deposit.

The clays consist of fine white ball and sagger clays used for making chinaware, insulators, and decorated tile. A large per cent of the output is shipped to East Liverpool, Ohio. Mr. M. B. Cooley is general superintendent.

Rock, Graves County.—A small stoneware plant is located at Rock, in the southeast corner of Graves County. Only the common ware, such as jugs and churns, is made here.

The clay used at this plant comes from a pit near the former post-office. These beds occur in lenses about 100 feet long, 40 to 50 feet wide, and 2 to 15 feet thick. There are usually a large number of lenses near together. The clay is very low in silica and high in alumina, and burns to a white-cream color. The ware is burned in updraft kilns. The owners of the plant are W. B. Howard & Sons.

PORTERS CREEK CLAY.

In Kentucky and the larger part of Tennessee the Porters Creek clay, commonly called "soapstone," forms the lowest visible member of the Tertiary. It consists of a black, stiff joint clay, containing a large amount of fine sand and mica. It carries a high per cent of iron and burns to a pink color. In speaking of this clay Dr. R. H. Loughridge[b] says:

> Tests made at the Rookwood Pottery indicate that it can not be used for glazed ware because of the shivering of the glaze. It might be successfully used in the manufacture of water jars, which require no glazing. The unglazed biscuit is pink in color. When mixed with an equal weight of the white plastic clay from Russell's pottery (Pottertown) east of Murray, it receives a good glaze and makes a light chocolate-colored ware, dotted with black specks from the mica particles.

---

[a] Jackson Purchase region: Kentucky Geol. Survey, p. 100.
[b] Op. cit.

TENNESSEE.

Peryear, Henry County.—A new fire-brick plant is now being built at Peryear by the Dixie Fireproof Brick Company, of which Mr. Thomas H. McElrath is superintendent. The clay is ground in a machine run by steam and mixed with crushed brick in the proportion of two-thirds clay and one-third grog. The plant is fitted up with an artificial drier, but in the summer and fall the bricks are dried on covered racks in the open air. It requires about eight to ten days for air drying and twenty-four hours to dry by steam. One round down-draft kiln has been completed and preparations are being made to add two or three other kilns.

The pit from which the clay is obtained is about 200 feet west of the railroad track on the south side of the town. The plant is built on the east side of the railroad track. The clay is reported to be 65 feet thick, and is divided into different beds. The following beds have been analyzed and tests have been made of each:

Clay beds at Peryear, Tenn.

	Feet.
First stratum from the top	3- 6
Second stratum from the top	4½- 5
Third stratum from the top	12–13
Fourth stratum from the top	4
Fifth stratum from the top	4
Sixth stratum from the top	3
Seventh stratum from the top	3½

Clay from stratum No. 1 is a fine ball clay. Besides being used for making fire brick it has been shipped to Chicago, Ill., Milwaukee, Wis., and Columbus, Ohio, for use in the manufacture of asbestos cloths, etc., and also to Iola, Kans., for making retorts. The clay is gray when fresh, but becomes white when dry.

Experiments have been made with the clay for making a hard enamel for decorated tile. The following formula has given the best results:

Formula for making enamel for decorated tile.

	Pounds.
Ball clay	17
Red lead	3
Whiting	10
Flint	20
Feldspar	50
Sal soda	1
Zinc oxide	15

When made according to the above formula, one pint of the mixture should weigh 32 ounces. It requires 2,200° to 2,300° F. to fuse the mass, and it will stand 2,900° F.

Whitlock, Henry County.—Three large clay pits located in Henry County are owned and operated by Mr. I. Mandle, of St. Louis, Mo. The "Mandle pit" is located about 3 miles west of Whitlock. It was opened in 1897 and has been worked constantly since that time. The clay is hauled to Whitlock in wagons, and shipped to East Liverpool, Zanesville, and Cincinnati, Ohio; Covington, Ky.; and Victor, N. Y. This pit furnishes the Tennessee ball clay No. 1 and No. 3, used for making chinaware and decorated tile.

The clay is worked by an open pit, which is now 250 feet long and 200 feet wide. Thirty-five feet of coarse red and yellow sand are now being removed from above the clay. Twelve teams and scrapers are used to excavate the sand, which is carried back into the pit from which the clay has been removed. The following is a section of the pit:

Section in Mandle clay pit, Henry County, Tenn.

	Feet.
9. Columbia loam	5
8. Red semistratified sand	5
7. Stratified white and yellow sand, very coarse, with an occasional lens of impure gray clay	30

	Feet.
6. Pink plastic clay	½– 1
5. Black to chocolate-colored rotten clay containing small particles of iron pyrite, fragments of lignitized wood, and a few leaf impressions	½– 2
4. White ball clay which is considered the strongest clay in the pit	2
3. Black rotten clay similar to No. 5	1– 2
2. White ball clay, very plastic, and similar to No. 4	8–12
1. Gray clay similar to the above except that it contains a slightly larger amount of free silica	4

The clay is assorted in the pit into four classes. The finest ball clay is found in beds Nos. 4 and 2.

The Monroe pit, owned by Mr. I. Mandle, is located one-fourth mile west of the railroad and 3 miles north of Whitlock. A side track has been put in, and the clay is hauled from the pit in wagons and loaded into the cars. The section is as follows:

Section in Monroe clay pit, Henry County, Tenn.

	Feet.
Lafayette gravel and sand	8
Red stratified sand	10–12
Yellow semiplastic, stratified, sand clay with thin bands of rock one-fourth to one-half inch thick	5
Gray plastic clay	10
Black clay similar to the black rotten clay near the top of the clay deposit in the Mandle pit 3 miles west of Whitlock. This is mixed with the other and shipped as a sagger clay	12

The clay lies in horizontal strata. The principal use is for wads and saggers.

The Claxton clay pit, of which Mr. I. Mandle is owner, is located three-fourths of a mile east of India. It was opened in 1898. The clay, which has a strong dip to the south, was first discovered in the road. The formation of the clay is very similar to that at the Mandle pit 3 miles west of Whitlock. The area now opened is in two chambers. The east-west opening is about 100 by 100 feet, and the north-south opening 50 by 100 feet. The section on the south side of pit is as follows:

Section in Claxton clay pit, Henry County, Tenn.

	Feet.
Red Lafayette sand	15
Thin band of black rotten clay	1
White ball clay containing stains of iron oxide	6 – 7
Black rotten clay same as upper clay layer 1½ feet thick at north end of pit, but thickening to 2½ feet at the south end	1½– 2½
Gray, tough ball clay, white when dry, 4 feet thick at north end, and 5 feet thick at south end	4 – 5
Thin band of black rotten clay	⅓– ½

A well recently bored about 100 yards south of the pit struck the clay at a depth of 16 feet and passed through it at a depth of 32 feet. Coarse yellow sand was found below the clay and a fine stream of water was struck at a depth of 60 feet.

The three Mandle pits in Henry County furnish Tennessee ball clay No. 1 and No. 3, besides sagger, wad, and stoneware clays. These various kinds of clays occur in the same pit. The ball clays are found in the upper part of the deposit, which gradually grades into the wad and more common clays below.

The ball clays are used by white-ware and art potteries, encaustic tile manufactories, electric and porcelain works, and enameling, stamping, and terra cotta concerns.

Tennessee ball clay No. 1.—This is a highly plastic clay, which mixes well with water, and when washed through a 120-mesh sieve leaves but little residue. The clay fuses at Seger cone No. 8 and has a total shrinkage of 15 per cent, or about one-seventh. At this heat it burns to a white-creamish color.

The rational analysis of Tennessee ball clay No. 1 is as follows:

Analysis of Tennessee ball clay No. 1.

Clay substance	86.20
Feldspar	2.70
Flint	11.10

Tennessee ball clay No. 3.—This clay has a brown color when dry, mixes well with water, and will pass through a 120-mesh sieve without residue. By passing it through a 175-mesh sieve it leaves 10 per cent residue, which consists mainly of fine sand.

The shrinkage at cone 1 is 12.5 per cent, or one-eighth; at cone 8 the shrinkage is 18 per cent, or about one-sixth. The color of the clay at cone 0.010 is white; at cone 1 the color is still white, and at cone 8 it fuses to a gray body.

The rational analysis of Tennessee ball clay No. 3 is as follows:

Analysis of Tennessee ball clay No. 3.

Clay substance	91.35
Feldspar	2.70
Flint	5.95

The location of the Peryear pit and of the three Mandle pits described above throws much light on the age of the fine deposits of ball and sagger clays in this section of the State.

The lowest member of the Tertiary which has been recognized in Henry County is the Porters Creek clay or "soapstone." It occurs in the deep ravine at Conyersville, 3 miles east of Peryear. According to barometric measurement, the Porters Creek clay at Conyersville is 50 feet lower than the clay pit at Peryear. Wells 100 feet deep at Peryear get water before reaching the Porters Creek clay. The dip to the west is therefore at least 30 feet per mile. The Mandle pits, located 3 miles west and north of Whitlock, are at least 5 miles west of the Porters Creek outcrop, and are therefore in the lower Tertiary. The age of the ball clay near India is not so certain. The Porters Creek clay outcrops in the deep ravine just east of Paris and along the railroad for 3 or 4 miles to the southeast. A line drawn from Paris to Conyersville would pass near India. This line, however, represents the western edge of the Porters Creek clay, which is usually 3 to 4 miles wide. The elevation of the India pit is 400 feet above sea level, barometric reading, or about 20 feet lower than the most western outcrop of the Porters Creek clay at Paris.

Paris, Henry County.—A small stoneware plant is located 1½ miles east of Paris on the Louisville and Nashville Railroad. It is owned and operated by John T. Currier. The clay is ground and tempered in a 2-horse pug mill with a capacity of 11,000 pounds per day. The clay is used as it comes from the pit. Twelve hours after turning the ware can be placed in the sunshine without checking. Two kilns are in use, with a combined capacity of 5,000 gallons. The ware is glazed with Albany slip.

The clay comes from a pit one-half mile northeast of India, on the west side of the road. It underlies 4 to 5 feet of Lafayette sand and gravel. The clay has but little grit, is gray to light chocolate in color, and contains very small flakes of mica.

Hico, Carroll County.—White stoneware clays are dug from pits 3 miles southeast of McKenzie and shipped to potteries at East Liverpool and Akron, Ohio, and Louisville, Ky. Similar clays occur along the Louisville and Nashville Railroad just south of McKenzie.

Gilmore, Madison County.—The Southern Tile and Brick Works has the largest and most complete brick plant in the State. The plant is located at Gilmore station, 5 miles north of Jackson, on the Mobile and Ohio Railroad. Mr. X. B. Wickersham is general manager. It has been in operation since 1903. Fireproof, dry press, and stiff-mud bricks are manufactured.

The clay for the fire brick is ground in a Wallace pug mill and molded in a side-cut stiff-mud machine. Common clinker is used instead of grog. The clinker completely burns up and leaves the bricks porous and thus permits them to expand on heating. The output is 20,000 bricks per day.

The bricks are taken from the machine and placed upon a 30 by 46 inch pallet, which rests upon a stationary frame made over a small steel track. Each pallet will hold 120 bricks or more. When full, a patent brick car is pushed underneath the pallet, and by a patent lever the load is transferred to the car. The car is then pushed on the steel track to the drier, and the pallets are deposited upon a long rack, where they remain until the bricks are dry. After they are dry enough to set in the kiln the bricks are conveyed on the car to the kiln. They are therefore handled but twice before burning.

In the summer and fall months the bricks are dried in the open air on covered racks, about eight days being required for drying. A hot-air drier is used in cold or damp weather. Bricks will dry in the hot-air drier in twenty-four hours.

A steam drier was first used, but the pipes soon began to leak steam, which condensed on the bricks and retarded drying. The hot-air drier has proved much more efficient. Five kilns are in operation—four rectangular kilns, which hold 185,000 each, and one round down-draft with the same capacity. All the kilns are made of fire brick and fire bricks can be burned in them. Wood and coke are used in the kilns until they become red, and coal is used for the heavy burning. It requires about 20 cords of wood, half a car of coke, and 20 tons of coal for burning a kiln of 185,000 bricks.

In addition to the common kind, the company makes various fancy-colored, dry-pressed bricks. The variety of colors is obtained by combining the fine white clays with the common yellow loam in various proportions. Chattanooga manganese is used for making spotted bricks.

The clay used for making fire bricks and fancy-face bricks comes from a pit about 100 yards west of the railroad. It is a gray, highly plastic clay, which belongs to the Wilcox formation of the Tertiary. A thorough investigation of the clay was made before the plant was erected, and it was found to be 30 feet thick and to cover an area of several acres.

The following is an analysis of the clay, furnished by Mr. X. B. Wickersham:

Analysis of clay from Gilmore, Madison County, Tenn.

Moisture	0.98
Silica	77.83
Alumina	16.16
Ferric oxide	2.86
Loess	2.17
	100.00

Combined water substances were unsought.

The white clay is overlain by about from 5 to 10 feet of Columbia loam, which is used for making the common dry-pressed and stiff-mud bricks. Fire bricks are shipped to various places in Tennessee, Kentucky, Mississippi, Alabama, Arkansas, and Louisiana. Fire clay is ground and shipped in small sacks for making the mortar in which the fire bricks are set. It requires thirteen men to operate the stiff-mud machine, and nine men for the dry press.

Pinson, Madison County.—A large plant has been erected near Pinson for the manufacture of fire brick, stoneware, tiles, and common mud brick. It is operated by Messrs. Robins & Henderson.

The fire bricks are made from a mixture of white plastic clay and sand in the proportion of three parts clay to one of sand. Sawdust is used instead of grog. The production is about 30,000 bricks per day.

The stoneware is made from the same clay as the fire brick. The ware is turned on wheels run by steam and is dried on an artificial heater. The Stewart patent down-draft kiln is used. Wood is used for fuel, about 15 cords per kiln being required. The production is 2,500 gallons per day. Albany and Seneca Falls slips are used for glazing ware. The Seneca Falls slip gives a bright-olive glaze. When combined with the Albany slip it gives a pale-greenish tint.

The clay used at the Robins & Henderson plant comes from pits located about 2½ miles southwest of Pinson. The clay occurs in small lenticular bodies with a maximum thickness of 20 feet. A large number of these bodies are found in a small area.

Mr. Henry Weiss operates some clay pits 3 miles southwest of Pinson. Clay is shipped to Memphis and Chattanooga stoneware plants.

The clay used in the Jackson, Tenn., pottery is obtained from pits 3½ miles southwest of Pinson. The pits are operated by Mr. C. M. Morrow.

The white clays in the Pinson district occur in the lower division of the Tertiary. The Porters Creek clay outcrops as far east as Henderson and is overlain by the coarse variegated sands in which the white plastic clays are found. These clays occupy much the same geologic position as the ball clays near Whitlock, Peryear, and India, in Henry County, the white clays near Hico, in Carroll County, and at Saulsbury and Grand Junction, in Hardeman County.

Grand Junction, Hardeman County.—A small stoneware plant, operated by Mr. W. T. Follis, is located in Grand Junction. Two turners are employed, who manufacture 350 gallons per day. The ware is burned in a down-draft 16-foot kiln. Five or six tons of coal are required for each kiln.

The clay used in the Follis plant comes from the Hancock pits, located along the Illinois Central Railroad track, three-fourths of a mile southwest of Grand Junction. It occurs below the Lafayette sands, the lower portion of which is cemented into a conglomerate. The clay is exposed to a thickness of 20 feet and is used as it comes from the pit.

The Irwin Clay and Sand Company has an extensive deposit of white clay and sand 1¼ miles east of the city. Part of the clay is shipped to the Memphis pottery for making stoneware. Molding and glass sands are also shipped.

Stoneware clays have been shipped from the Pinson and Prewitt pits located one-half and one mile, respectively, west of the station. Neither of these pits is worked constantly. White clays are also mined and shipped from Saulsbury, 5¼ miles east, and from Lagrange, 3 miles west of Grand Junction.

PRODUCTION.

There are in the Kentucky-Tennessee district under discussion fourteen plants engaged in the manufacture of stoneware and red earthenware. All of these plants derive their clay from pits in the district. The following is a list of the stoneware plants:

Stoneware plants in Kentucky and Tennessee.

Kentucky:
- J. A. Bauer, Paducah.
- W. K. Russell & Son, Pottertown.
- W. B. Howard & Son, Rock.
- Geo. W. Myatt, Tompkinsville.
- Wickliffe Pottery, Wickliffe.

Tennessee:
- W. T. Follis, Grand Junction.
- Jackson Pottery Company, T. J. Connor, lessee, Jackson.
- C. Sparks, McKenzie.
- Memphis Stoneware Company, Memphis.
- John C. Currier, Paris.
- Pinson Pottery, Pinson.
- Toone Pottery Company, Toone.

The value of the product for 1904 was distributed as follows:

Value of product in Kentucky and Tennessee stoneware plants, 1904.

Tennessee:		
Stoneware	$98,000.00	
Red earthenware	250.00	
		98,250.00
Kentucky:		
Stoneware	84,150.00	
Red earthenware	10,400.00	
		94,550.00

A large per cent of the clay mined is shipped to places outside of the district. The following is a list of the clay miners:

Clay miners, Tennessee and Kentucky.

Name.	Kind of clay shipped.
Prewitt & Hurst, Grand Junction, Tenn.	Stoneware.
R. H. Breedlove, Henry, Tenn.	
J. C. Cleaver, Hollow Rock, Tenn.	Stoneware.
Mineral Springs clay mine, Paris; mine at India, Tenn. John N. Jackson, proprietor.	Stoneware.
L. J. Irwin, Grand Junction; mine at Irwinton, Tenn.	Stoneware.
Andy Pate, McKenzie, Tenn.	Fire clay.
Tennessee Ball Clay Co. of Clarksville; mine at McKenzie, Tenn.	Fire clay.
F. M. Wright, Paris, R. F. D. No. 4; mine at Nobles, Tenn.	
I. Mandle, 3943 West Pine st., St. Louis, Mo.; mines at Whitlock and India, Tenn.	Ball, fire, sagger, and wad clays.
J. L. Roark, Paris, Tenn.	
Peryear Clay and Mining Co., Peryear, Tenn. R. W. Beale & Sons, proprietors.	Ball, fire, and stoneware clays.
Kentucky Construction and Improvement Co., Pryorsburg, Ky. C. P. Henderson, president.	Ball clay.

The total amount and value of clay shipped from the district in 1904 was as follows:

Shipments of clay from Tennessee-Kentucky district, 1904.

	Tons.	Value.
Fire clay	8,695	$8,908.00
Ball clay	21,350	69,225.00
Stoneware clay	11,600	11,175.00
Miscellaneous clays	1,800	2,250.00

BRICK INDUSTRY.

Common building brick forms the largest clay product in the district. There are 43 brick plants, which produced in 1904 62,541,000 common bricks, valued at $400,318; 280,000 fire bricks, valued at $4,600; 200,000 face bricks, valued at $2,000; and $12,700 worth of drain tile. It will be seen from the above figures that the average retail price for common bricks is $6.40 per thousand.

CLAYS OF THE PENOBSCOT BAY REGION, MAINE.

By Edson S. Bastin.

Area covered by field studies.—The field observations on which this paper is based were confined to the coastal region and extended from Bluehill Bay on the east to Pemaquid Point on the west, taking in nearly all of the islands which border this part of the mainland. That portion lying to the east of Thomaston was studied during the summers of 1904 and 1905, while making a detailed geological study for folio publication of the Penobscot Bay and Rockland quadrangles. The coast from Thomaston to Pemaquid Point was studied hastily during a reconnaissance trip in the autumn of 1905, made principally for the purpose of tracing the limits of certain granite areas.

Distribution.—The clays of this district are distributed over the lowlands of the coastal region as a nearly horizontal sheet of varying thickness. So uniform is the material in grain and color that only here and there can a division into distinct beds be recognized. Vertically they are confined mainly to the interval between sea level and the 125-foot level, and while not all the land within this interval is occupied by these deposits it is probably safe to say that they cover fully half of such territory. Areally they find their broadest distribution and penetrate farthest inland along the rivers and tidal estuaries, while along certain bold parts of the coast they may be entirely absent. Along Penobscot River they are well developed as far up as Bangor and along St. George River they penetrate inland a distance of 20 miles to the villages of Thomaston, Warren, and beyond.

General appearance of the clays.—The clays here considered, which are the only commercially important clays of the region, are yellowish gray to blue-gray in color, the former being by far the more common. For the most part they are exceedingly fine grained and except in a few localities are very free from sand or pebbles.

Recognition in the field.—The clays are readily recognized where they have been exposed by the waves or streams and where they have been uncovered in excavations. Excellent natural exposures occur at Sherman Cove, near Camden, along the north side of Rockland Harbor, along St. George River near Thomaston, and at many other localities on the shore, where they have been cut into by the waves and now stand up as benches or terraces rising 10 to 25 feet above the beach. Artificial exposures are common in the railroad cuts and in the cuts and ditches of many of the wagon roads. One of the best exposures is at the brickyard at Thomaston, and other good exposures occur at the quarries west of Rockland, where the clays must be stripped off before the limestone can be reached. Even where sections can not be found, the presence or absence of the clays may usually be recognized from the general appearance of the land surface. Extensive flats or gently sloping plains occupying the lowlands and free from surface bowlders are nearly always found to be built up of these clays. When roads traversing these flats have not been graded with materials brought in from other localities, the clayey character is revealed by the fine light-gray dust which develops in dry weather, the sticky gray mud which forms after a heavy rain, and the absence of pebbles or cobbles.

Depth.—The depth of the clay deposits varies greatly, being in general greatest on the lowlands and least on the higher hill slopes. Depths of 15 to 35 feet are very common, and well records in some cases seem to show a depth of from 50 to 75 feet. The record of a well at the brickworks in Thomaston showed 45 feet of clay resting upon limestone.

Age and origin.—The distribution of these clays with respect to the present coast line at once suggests their marine origin, and such a conclusion is sustained by the presence here and there within the clays of the shells of marine animals. The clays represent, in truth, old clam flats formed at a time when the sea level was considerably higher, relative to the land, than it is at present. Their age is fixed by their relation to the deposits made by the glaciers which covered the State in the Pleistocene period. In several localities they were seen to overlie deposits of glacial bowlder clay, while they were overlain in turn by gravels deposited by streams flowing from the melting ice; they were deposited therefore during the glacial occupation. The streams flowing from the melting glaciers were heavily laden with sediment; the coarser portions, the gravels and sands, were deposited on the land surface or in the ocean close to the shore, but the finer portions were carried farther out and deposited as these beds of marine clay. They differ from the clam flats of to-day only in the greater rapidity with which the muds were deposited.

Present utilization in brickmaking.—These clays, in common with the limestone and much of the granite of Maine, possess the commercial advantage of proximity to the coast, where the manufactured product can be easily and cheaply shipped by water. Plants for the manufacture of common brick are numerous along the lower portion of Penobscot River; near Damariscotta, on Damariscotta River; and at other localities within the area under discussion. Within the Rockland quadrangle there is only one company engaged in brick manufacture; this is the Thomaston Face and Ornamental Brick Company, with a plant in the eastern part of the village of Thomaston. This plant is given special mention because it has been studied by the writer in more detail than other plants, and because its modern equipment seems to point out the lines to be followed in the future development of these deposits. The clay at this brickyard is buff gray in color and free from pebbles or concretions. As it occurs in the banks it is moderately dry. It is dug by steam shovel and transferred in small cars to the disintegrator, where it is dry crushed. The clay is worked by the stiff-mud process, the dry material being carried by a belt from the disintegrator to a Raymond pug mill, where it is mixed with about 20 per cent of water and fed into a Raymond "999" brick machine provided with an automatic down-cut cutting table. This machine has a capacity of 8,000 to 12,500 standard side-cut bricks per hour. The bricks are dried in a 10-tunnel drier having a capacity of 75,000 bricks. The burning is done in an ordinary scove kiln. The bricks show an air shrinkage of one thirty-second of their length and a fire shrinkage of one sixty-fourth, and incipient fusion takes place at about 3,000 °F. The product goes principally to Massachusetts and is shipped by rail, although water shipment is equally feasible. At present the company's product does not correspond to its name, for its whole output is common brick; but the clay is considered to be of too high a grade for use solely for this purpose, and the company is now installing machinery for the production of pressed brick.

Chemical composition.—In the table below are given analyses of clays from three localities within the Rockland quadrangle:

Analyses of clays from Knox County, Me.

	1.	2.	3.
Silica (SiO_2)	62.80	62.33	61.59
Titanium oxide (TiO_2)	.87	.79	.....
Alumina (Al_2O_3)	17.36	17.70	19.10
Ferric iron (Fe_2O_3)	4.40	5.19	7.53
Ferrous iron (FeO)	[a] 2.00	[a] 1.72	
Lime (CaO)	.88	1.00	1.68
Magnesia (MgO)	1.58	1.53	1.87
Soda (Na_2O)	1.48	2.38	.....
Potash (K_2O)	3.05	2.41	.....
Water (at 107° C.)	1.31	1.11	5.51
Water (on ignition)	4.39	3.81	
Carbon dioxide (CO_2)	None.	None.	
	100.12	99.97	97.28

[a] The values reported for ferrous iron are questionable on account of the presence of a small amount of organic matter.

1. Clay from brickyards at Thomaston, Me. W. F. Schaller, analyst, U. S. Geological Survey laboratory.
2. Clay from Hayden Point, near South Thomaston, Me. W. F. Schaller, analyst, U. S. Geological Survey laboratory.
3. Clay on the property of the Rockland-Rockport Lime Company, near Rockland, Me.

Although these three samples were taken at localities several miles distant from each other their analyses are closely similar, a fact which suggests that throughout this region the clays possess a rather uniform composition. From the chemical analyses and also from a microscopic examination it is seen that these are not what could be called "sandy" clays, though the amount of sand is sufficient so that none need be added in mixing for brickmaking. Ries,[a] from a consideration of several hundred analyses of brick clays, finds that the silica percentages range from 34 to nearly 91 per cent, with an average of about 59 per cent. The Penobscot Bay specimens are only slightly above this average. The percentage of iron is fairly constant and is sufficient to give the burned bricks a bright-red color. The average for brick clays is about 5 per cent. The absence of calcium carbonate, shown by the absence of CO_2 in analyses 1 and 2, is a desirable feature, as is also the rather high percentage of alkalies. The latter are the most important fluxing constituents of the clay, and on burning serve to bind the grains together. If, as in this case, their quantity is large, the brick may be burned at a lower temperature than otherwise.

Future utilization in brickmaking.—In the opinion of the writer the high quality of these clays, their abundance, and their favorable situation on the seaboard, warrant a much more extensive commercial development. A factor worthy of consideration in this connection is the possibility of utilizing in brick manufacture some of the water power of the coastal region. At a number of places along this part of the coast long tidal estuaries penetrate inland for considerable distances and are usually much contracted in width at one or more places. Through these narrow portions the tide, both at ebb and at flow, surges with great power, which, if harnessed, could be made to serve a variety of useful purposes. It is along such estuaries that the marine clays are best developed, and the possibility of the application of such power in the manufacture of brick, especially of pressed brick, naturally suggests itself. A good example is the case of Weskeag River, with narrows

[a] Ries, Heinrich, The clays and clay industry of New Jersey: Final rept. State geologist New Jersey, vol. 6, p. 55.

at the village of South Thomaston (4 miles south of Rockland). There has recently been some talk of utilizing the power at this point. Marine clays of fine and uniform texture occur abundantly in this vicinity, the clay of analysis No. 2 being taken from Hayden Point, only 1 mile distant.

Possible utilization in the manufacture of Portland cement.—The lime industry of the Rockland region is discussed by the writer in another part of this bulletin (pp. 393–400), and it is worth considering whether the marine clays may not be utilized with this limestone in the manufacture of Portland cement. These cements are artificial mixtures whose essential constituents are lime, silica, and alumina. The first is generally supplied by limestone or marl, the other two by clay. In burning, the three constituents unite to form complex silicates, and it is essential that they be combined in the proper proportions in order to give the best results.

In clays utilized in the manufacture of Portland cement the silica percentage should lie between 60 and 70 per cent. These clays show 62 to 63 per cent silica. According to Eckel, "the alumina and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_3+Fe_2O_3=\frac{SiO_2}{3}$."[a] In the clay from Hayden Point (No. 2 in the table) this ratio is $\frac{SiO_2}{2.7}$.

In reference to the quantity of clay needed Eckel[b] estimates that there should be in sight at least 1,600,000 cubic feet of clays, a twenty years' supply. This would mean only 3.67 acres excavated to the moderate depth of 10 feet. In view of what has been said of the extent and depth of the clays there should be no doubt as to the adequacy of the supply.

The limestone used should be relatively free from magnesia. Lime made from a highly magnesian limestone has the property of setting under water to a very hard mass. When mixed with clay, however, and burned at high temperatures in a Portland cement, it gives cements of doubtful character. The reason for this is that the carbonate of magnesia, unlike the carbonate of lime, does not ordinarily combine with silica or alumina at the clinkering heat employed in the manufacture of Portland cement. In amounts of less than 4 or 5 per cent, however, magnesia is certainly not injurious. The so-called "soft rock" of this region, being poorest in magnesia, would be the most available for cement purposes. As regards quantity needed, Eckel[b] estimates that at least 3,800,000 cubic feet should be in sight for each kiln established, a twenty years' supply. This would correspond to a vein of rock 100 feet wide, 100 feet deep, and 380 feet long. The amount of limestone in the region is probably adequate to meet these demands.

At present the nearest Portland-cement works are located in the eastern part of New York State, and the opportunities for building up a good local cement market seem to be good. With the same advantages of easy and cheap shipment by water, there seems to be no reason why Rockland cement, like Rockland lime, should not be able to hold its own in the New York market, as well as at other points on the Atlantic coast. In this connection it may be borne in mind that nowhere on this coast south of Rockland do pure low-magnesia limestones occur near the seaboard.

---

[a] Eckel, E. C., Cements, Limes, and Plasters, 1905, p. 354.
[b] Op. cit., p. 305.

CLAYS OF CAPE COD, MASSACHUSETTS.

By MYRON L. FULLER.

INTRODUCTION.

Area treated.—In the present paper Cape Cod is considered as synonymous with Barnstable County, all the land south and east of Monument River, which lacks only a mile or two of reaching from Massachusetts Bay to Buzzards Bay, being included under the term. One or two clay localities lying a short distance outside of the limits thus defined are, however, mentioned.

General distribution of the clays.—Although the clays have been worked at relatively few points on the cape, they underlie a considerable portion of the area and are exposed at the surface at a large number of points, especially on the outer arm from Highland Light, Truro, to Orleans and Chatham. Westward from these two villages the clays are less accessible, though still encountered in shallow wells and occasionally exposed in the lower valleys along the south shore and in the bluffs and along the edges of the marshes on the north shore. At West Barnstable, however, a good exposure, worked many years for brick clays, is found. In the highlands, marked by the morainal ridge and sandy-wash plains lying between the north and south shores of this part of the cape and east of Buzzard's Bay, the clays are too deep beneath the surface to ever be economically available. Along the shore of Buzzards Bay no important clays have yet been found, and it is probable that they are here below sea level.

Field work.—The data relating to the Cape Cod clays were collected in connection with a study of the Pleistocene geology and artesian water resources of southeastern New England. As a part of this investigation it became necessary to trace out the clay beds of the region, during which abundant opportunity to note their economic aspects was presented. The study was made in 1904 and 1905, and during the latter year the writer had associated with him Mr. F. G. Clapp, to whom credit for a material portion of the facts is due.

GEOLOGY.

General features.—Cape Cod is composed entirely of clay, sand, and gravel, with occasionally a bed of till, consisting of a heterogeneous mixture of clay, sand, and bowlders, often known locally as hardpan, and a superficial deposit of scattered bowlders, sometimes of large size. Bed rock is not encountered anywhere on the cape, but is relatively close to the surface near the head of Buzzards Bay, where wells about Onset are said to have encountered it at a depth of from 60 to 100 feet.

Superficially, the backbone of the cape, except the outer arm, appears morainal. Starting at Woods Hole and extending northward along the shore of Buzzards Bay to Monument River is a hummocky and frequently bowlder-covered ridge, with here and there an undrained depression or kettle, often containing a pond of more or less size. Near Monument River the ridge bends at a somewhat sharp angle to the southeast, following the shore of Cape Cod Bay to the vicinity of Orleans, where it crosses the outer arm and is cut off by the sea. To the east of the Buzzards Bay portion and to the south of the remainder of the ridge lies a great flat sandy-wash plain sloping gently to the sea. North of Orleans the outer arm consists superficially at least of fine gravels and sandy plains, which are horizontally stratified in Eastham, but are more irregular in structure and surface topography in the Wellfleet and Truro regions. At the end of the cape, in the vicinity of Provincetown, nothing but sands thrown up by the waves or piled up by the winds as dunes are to be seen.

Geologic section of the Cape Cod region.

System.	Series.	Stage.[a]	Formations, etc.	Character of deposits.
Quaternary.	Recent.	Recent.	Recent deposits.	Salt and fresh water marsh deposits, dunes, sand bars, and spits.
	Pleistocene.	Wisconsin (Glacial).	Wisconsin drift.	Morainal deposits and outwash gravels and sands.
		Peorian (inter-Glacial).	Not recognized. Probably represented by a long erosion period, with land elevated.	No deposits recognized on Cape Cod.
		Iowan (Glacial).		
		Sangamon (inter-Glacial).		
		Illinoian (Glacial).	Unnamed.	Sands and gravels with granite pebbles.
			Montauk drift.	A till made up of brownish, greenish, or gray sandy clay with pebbles and occasional bowlders. Formed by reworking of Gardiner clay and older gravels by ice sheet.
			Herod gravel (often cut out by ice erosion).	Sands and gravels with granite pebbles.
		Yarmouth (inter-Glacial).	Jacob sand (sometimes cut out by ice erosion).	Yellowish, greenish, and brownish sandy clays or clayey sands, alternating with fine gray to buff sands.
			Gardiner clay.	Light to dark gray nearly black clay, weathering to a greenish or brownish color.
		Kansan (Glacial).	Jameco gravel.	Sands and gravels with granite pebbles.
		Aftonian.	Unconformity of erosion.	Deposits are below sea level in Cape Cod region.
		Sub-Aftonian.	Mannetto gravel.	Sand and gravels, largely quartz, but with a few decomposed granitic pebbles. Below sea level in Cape Cod region.
Cretaceous.			White or yellowish quartz sands and gravels, with clays of white, gray, and various other colors. Below sea level in the Cape Cod region.	

[a] Correlations are provisional, and are based on similarity of succession and history of the Glacial deposits of the Long Island and interior regions.

Character of the deposits.—Until recently all the materials of the cape have been considered to have been deposited in connection with the ice which covered the region in the last or Wisconsin glacial stage. It is now known, however, that these Wisconsin deposits, including those of the moraine and outwash plain, are relatively thin and superficial, the mass of the materials being made up of a complex succession of beds of different types, most of which are far older than those of the last ice invasion. These deposits, which belong to a series extending from New York Harbor eastward to the locality under discussion, have been carefully studied on Long Island, New York, and at other points along the coast, and their sequence has been determined. The succession and character of those which occur above sea level or which approach close to that level on the cape are shown in the foregoing table.

OCCURRENCE OF THE CLAYS.

From the foregoing table it will be seen that there are four clays represented in the materials making up Cape Cod. Only the Gardiner clay and the clayey phases of the Jacob and Montauk formations, however, are known to occur above sea level, hence it is with them alone that the present discussion deals. The thick Cretaceous clays which are the foundation for many of the great clay industries of New Jersey and elsewhere are unfortunately, so far as known, below sea level on Cape Cod. They are probably less than 50 feet below tide level at Highland Light, to judge from the low horizon of the glacial deposits exposed at the base of the bluff, and it is possible that they rise above sea level in the inland portion of the cape in the North Truro region, possibly even appearing near the bottom of the deeper valleys, although no such clays have yet been reported.

COMPOSITION AND STRUCTURE OF THE CLAYS.

Character of the Gardiner clay.—The best exposure of the Gardiner clay is in the bluff at Highland Light, Truro, where it has a thickness of about 40 feet. It is a very tough, not very plastic clay, varying from dark gray to dull black in color. The latter variety is most frequently seen in the lower part of the bed and the lighter gray variety in the upper part. The top is sometimes colored a dull grayish to greenish brown, this being due, it is thought, to the action of percolating waters passing along the contact of the clay at the base of the loose overlying sands. The whole is minutely laminated, although this structure is not always clearly visible except on exposed edges etched out by the atmosphere. The lighter-colored types of clay may show a distinct though not strongly developed shaly structure, apparently due to the presence of thin laminæ of very fine sand. An occasional quartz pebble up to one-fourth inch or so in diameter may occur, but no granitic pebbles or layers of quartz pebbles have been seen. The clay does not appear to contain much true kaolin, being rather a quartz flour. No fossils, lignite, or other traces of organic life have been seen.

The Highland Light deposit may be taken as a type of the Gardiner clay in this region. Nowhere else, however, does it attain such a development, being ordinarily much thinner, the thickness being perhaps as low as 5 feet in some places, while in others the clay may even have been entirely removed by the Montauk ice. Its character is fairly constant throughout the region, although, because of local conditions more favorable to weathering, the brown phase is often more conspicuous than at Highland Light. In the bluff sections, where it has been longer exposed to the action of the weather, the clay often appears structureless and may crumble into the small pellets described in other parts of the country as "buckshot."

Character of the clays of the Jacob formation.—In most localities where the Gardiner clay is exposed, and intervening between it and the coarser materials of the Herod formation, are transitional beds of fine material varying from sandy clays to clayey sands. The more clayey phases approach the clays of the Gardiner in composition, the only difference being the presence of a larger percentage of sandy laminæ. At other times the Jacob is much coarser, in which case the contact with the Gardiner clays is quite definite. In color the

clays of the Jacob formation vary from brown and greenish in the more clayey varieties to gray and yellowish in the sandy types.

Character of the clays of the Montauk drift.—Under this head is included the clayey and nearly pebble-free phases of the Montauk drift, which owe their origin to the reworking practically in situ of the Gardiner clay by the Montauk ice sheet. It differs from the unaltered clays in the absence of the minute but highly perfect and regular lamination characteristic of the latter, exhibiting rather an irregular and somewhat indefinite banding, such as might be expected to result from accumulation beneath an ice sheet. The most conspicuous point of difference, however, is the presence of granitic pebbles, either isolated or in layers or pockets, or of an occasional erratic bowlder, indicating a glacial origin in contradistinction to the interglacial origin of the Gardiner clay.

DESCRIPTIONS OF THE CLAYS BY LOCALITIES.

Provincetown region.—West of the bluffs terminating the highland northwest of North Truro the cape is made up of a series of curving wave-built spits which have become connected into a solid mass now covered with dunes rising to heights of from 80 to 100 feet above sea level. Except for the vegetable muck about the marshes and thin beds of mucky silts in the ponds between the sand hills, nothing in the shape of clay is found near the surface in the Provincetown region. The Gardiner clay, as well as the underlying Cretaceous beds, which doubtless include more or less clay, probably once extended over this region, but were subsequently eroded by the agency of waves and shore currents to a depth, according to a recent well boring, of at least 100 feet below the present sea level, before the waves and winds built up the bars, beaches, and dunes constituting the present surface. At a depth of 140 feet a gray clay was encountered which, though probably Cretaceous, somewhat resembles the Gardiner. It is said to be of considerable thickness, but no accurate figures were obtainable.

Truro region.—This term as here used includes the highlands extending northward from Pamet River to the northwest end of the bluff near Moon Pond. The best exposures of clay are found in the bluff near Highland Light, but impure clays or clayey sands occur at a considerable number of other points.

The clay near Highland Light, which is of the typical Gardiner type, first appears at the top of the bluff at a point about one-half mile north of the light-house. It continues along the top for some distance, then gradually sinks as the gentle southward dip brings it nearer the beach. At Highland Light the section shown by the bluff is as follows:

Section at Highland Light, Cape Cod.

	Feet.
Dune sand	5
Yellowish quartz sand, with erratic pebbles near the surface	35
Tough gray to nearly black Gardiner clay, interstratified with sand near top	45
Iron-stained gravel, sometimes partly cemented	15
White sand	15

Beyond the light-house the clay continues with the same southward dip, outcropping with slight undulations for about half a mile, beyond which it is not seen because of the covering of sandy talus for a distance of a mile. At this point about 20 feet of clay are exposed, the top being 40 feet above the beach. It is not seen again to the south, but as the upper part of the bluffs is entirely of sand it is evident that the clay sinks below sea level in this direction. The clay also comes close to the surface on the flats near the highway west of the light-house, where it is reported to be found over a considerable area. Although the clay occurs in vast quantities and is easily accessible from the land side, no material use of it appears to have been made. Similar clays, however, were elsewhere extensively used in the construction of the State roads, and the clays near Highland Light might be used to advantage for similar purposes. Owing to exposure to the open sea, it will probably never be practicable to work the clays from the ocean side. It is not impossible, however, that at some future time, when more accessible deposits elsewhere are exhausted, the clays under

discussion may be worked with profit if connection by tramway or otherwise is made with the inner side of the cape, from which shipments could be made by vessel. It is certain that in thickness, quality, and extent the clays at Truro outrank any of the clays elsewhere exposed on Cape Cod. Occurring as they do, at the top of a bluff, the pits could be readily drained and the cost of stripping would not be excessive, except in the region south of the light-house, where the beds, owing to the southward dip, are overlain by a considerable thickness of sands and gravel.

Along the beach from the point at which the clay bed described disappears little but sand is seen in the bluffs until a point about 1½ miles northwest of the Pamet River life-saving station is reached. At this point a gray to yellowish-brown laminated sandy clay or clayey sand, associated with numerous springs, shows above the beach. It is much disturbed, and detached fragments up to 10 feet in length occur in lumps upon the beach. Outcrops of upturned clays, or possibly large clay "bowlders," show through the sands of the beach between high and low tide level for some distance. The material seems to represent the transition between the Gardiner clay and the Jacob sands. One-fourth mile farther south a few feet of very fine, compact, and somewhat contorted sandy clay of a greenish color, interlaminated with sand, were seen. This clayey sand or sandy clay continues to show along the beach southward for about one-eighth mile, when it again disappears beneath the beach, only to reappear for a short distance about half a mile farther on, or three-fourths of a mile from the life-saving station. The material does not belong to the Gardiner clay, but rather to the Jacob sands, and, although some portions may contain a sufficient amount of true clay for the material to be utilized for brickmaking, very little of the deposit as a whole could be so used.

In front of the life-saving station a greenish and olive clay, full of iron laminæ and concretions, outcrops in the beach between high and low tide mark. It seems most probable that it is associated with the peat which is being undermined by the waves as they cut back into the extension of Pamet River Valley and that it is of post-Wisconsin origin.

No complete traverse of the west coast of the Truro district was made. The gray to orange sandy clay, however, was seen in the bluff about a mile northwest of North Truro, but the bed was only about 2 feet thick. Some sandy clays or clayey sands were also seen in the bluffs 2 miles south of North Truro. Neither of these clays will prove of economic value unless it is for use on roads or other local purposes.

Wellfleet region.—This region includes the high rolling land from South Wellfleet northward to Pamet River, in the southern part of Truro Township. In the work in this district the beaches on both the ocean and the bay side were traversed and all localities which inquiry showed to contain clays were visited.

Southward along the coast from the Pamet River life-saving station clays are first exposed in the bluff about one-fourth mile distant, where a few feet of clay project through the talus at a single point. The clay shows again about one-half mile south of the station, but it is not until a point 1½ miles south is reached that the clay is seen in any considerable amounts. Here, however, nearly 20 feet of clay are exposed along the bluff for some distance. It is of the dark blue-gray type characteristic of the Gardiner clay, but has thin layers of yellowish sand. It seems to be moderately folded and is overlain by 20 to 30 feet of stratified sand and gravel. A few hundred feet farther on the clay dips nearly or quite to beach level, but soon rises again and is seen through the talus at scattered points for about one-fourth mile, beyond which it is again well exposed as a horizontal bed 20 feet thick at the bottom of the bluff at numerous points for another half mile, south of which it is covered by talus. It appears to sink below the level of the sea at a point northeast of Long Pond, but is strongly developed again one-half mile farther south, where it occurs as a strongly folded bed overlain by from 10 to 30 feet of sands and gravels. South of this point talus prevents the clay from being seen; it probably, however, sinks rapidly and goes below sea level, not reappearing anywhere north of South Wellfleet. In addition to the Gardiner clay there are a number of thin beds of sandy clay a foot or two in thickness interstratified with the sands and gravels constituting the bluffs.

The clay, although present in large amounts, can not be readily worked, owing to the thick covering of sand and gravels. The depressions which occur in the bluff from time to time are due to folding, and the clay is little if any nearer the surface in the valleys than in the ridges. The exposure to the open Atlantic will probably always prevent the working of the clays from this side of the cape.

On the bay side of the cape no clay was seen in the bluffs from Pamet River south to Great Beach Hill. On the east side of Great Beach Hill and on the mainland north of Great Island the talus is somewhat darkened, possibly indicating clay beneath the surface. On Indian Neck, south of Wellfleet, and in the bluff on the small point between the neck and the railroad, exposures of clay or clayey sand are found. In the southeastern portion of the bluffs at Indian Neck from 4 to 5 feet of interstratified sand and clay are exposed along the beach for several hundred feet. This probably belongs to the Jacob formation, but it is said that blue clay, presumably Gardiner, was dug from the beach for use on the State road. In the northern bluff at Indian Neck from 6 to 10 feet of blue clay, overlain by fine brown and gray sands, outcrop in an undulating layer for several hundred feet. It is believed that this clay layer belongs to the Gardiner formation, while the overlying sand is Jacob. The clay is blue, somewhat shaly, and jointed. The same or another layer of the Gardiner clay comes near the surface in the fields back of the hill, where a number of pits were opened and considerable clay was taken out during the building of the State road. On the small point mentioned as occurring between Indian Neck and the railroad, a small bed of clay is exposed in a broad arch in the bluff, but the clay here is not reported to have been worked. In the interior of this part of the cape near the level of the swamp, 1 mile north of Wellfleet, clay was seen in a local pit from which material for the State road had been taken. Another pit which has yielded considerable quantities of clay is located on the north side of the same swamp a little over one-fourth mile to the west. Again, on the south side of the swamp, about one-half mile northwest of Wellfleet, there is a pit 20 feet in depth in which 8 feet of brownish clay, becoming greenish toward the bottom, interlaminated with sand, and carrying occasional granite pebbles, are exposed under 2 or 3 feet of Wisconsin till and gravel. Blue clay is said to have been taken out below the portion of the pit now exposed. The pebble content of the clay is believed to indicate that it belongs to the Montauk drift, though doubtless derived from closely adjacent masses of Gardiner clay. Just south of the road leading from Wellfleet Center westward across the railroad there is another pit of similar clay. Clay occurring in alternate streaks of blue, yellow, and brown, with some sand, is also said to outcrop in the woods one-half mile southeast of North Wellfleet. Pilgrim Spring, emerging from the base of the bluff, just east of Indian Neck, may flow from the top of a similar clay layer.

Eastham region.—The Eastham region includes the area between South Wellfleet on the north and Eastham station on the south. The region is mainly one of flat plains, with the exception of the southern portion, which has a rolling topography. A traverse of the beach from South Wellfleet to the end of the bluffs 1¼ miles south of Nauset Beacons failed to show clay, except in the vicinity of the beacons. A little south of this point a small knob about 10 feet in height of bluish Gardiner clay and brown Jacob sands shows in the face of the bluff. Just beyond several feet of folded gray to light-chocolate Gardiner clay outcrop for 100 feet or so along the beach. The clay as here exposed is too thin and would require too much stripping to be of economic value except for local purposes. South of these outcrops no clay appears in the bluffs, although the Montauk drift is at points quite clayey. No clays were found on the bay side of the cape, except near the south side of the mouth of Blackfish Creek southwest of South Wellfleet. At this point a hard blue putty clay without pebbles was found below tide level and was excavated to a depth of 4 feet for use on the State road. It probably belongs to the Gardiner formation. In general the clay is not to be expected above sea level in the Eastham region.

Orleans region.—Under this head is included the area south from Eastham station to Pleasant Bay, Chatham, and west to the vicinity of Brewster. Throughout most of the area the Gardiner clay seems to be below sea level. Three-fourths of a mile east of Tonset,

on the shores of Nauset Harbor, however, 6 or 8 feet of brownish buff sandy clay, either Jacob or Gardiner, are exposed just above beach level. There are also indications of the presence of clay in the hills northwest of Town Cove. Again, 1 mile northeast of Brewster a little sandy clay shows in the beach. Clay is also reported to have been found along the shore near East Brewster. None of the localities, so far as known, are capable of furnishing clay except in very small quantities, and unless other deposits are found no commercial developments are to be anticipated.

Chatham region.—This term is applied to the area included in Chatham and that part of Orleans Township bordering on Pleasant Bay. The area is characterized by a strong development of the Gardiner clays, especially along the shores of the bay mentioned.

One-fourth mile east of the highway, on the north side of Pleasant Bay, a dark clay, presumably the Gardiner, outcrops in a broad, low arch or anticline beneath a thick series of sands and gravels. The clay continues for 100 or 200 feet, then sinks below the beach. In a bluff on the point just beyond the small inlet, one-half mile from the road mentioned, there is another similar anticline of dark Gardiner clay. This is somewhat higher and broader than the preceding, and more clay is exposed. Either of the outcrops could be made to furnish clay for local use without great expense, although considerable stripping would be necessary if the clays were to be worked on a large scale. The most important outcrops of the clays are on Nickersons Neck, on the south shore of Pleasant Bay, beginning about one-third mile from the mouth of Muddy Creek and extending to the bend of the neck, three-fourths mile northeast. The clays outcrop along the beach in a series of gentle folds. From 5 to 30 feet of clay are exposed, all of which could be used for making brick, or similar purposes. The clay, in its lower and less altered portions, is gray to nearly black, but in the upper weathered portions it is greenish or brownish, and weathers into a loose, buckshot-like mass. Thin, ferruginous laminæ and soft iron concretions are abundant in the upper portion. The clay at some points contains a few erratic pebbles, and is elsewhere somewhat sheared, probably owing to the drag caused by the overriding of the Gardiner clay by the Montauk ice, from which the pebbles were also derived. Over the clay there is 30 feet or more of sand and fine gravel, which would make stripping expensive if the clay should ever be worked on a large scale. Amounts sufficient to supply all local needs could, however, be taken from the bluffs with little or no stripping. The islands off the mouth of Pleasant Bay were not visited, but Simpson Island shows rather dark bluffs, which may indicate the presence of clay. The small island southeast of this shows, so far as could be determined from the shore, only gravel. Strong Island, to judge from its elevation, probably contains clay, although it may be entirely covered by sand. On the south side of Nickersons Neck clay is exposed in the high bluff on the north shore of Crows Pond and in a pit just southeast of the highway leading to Nickersons Neck, and near the head of Riders Cove, there is a pit 75 feet in diameter and 15 feet deep, from which considerable clay has been taken in the past. The clay is brown and weathers into small plates or buckshot lumps. It evidently belongs to the upper weathered portion of the Gardiner clay, and agrees very closely in character with the upper portion of the clays in the bluffs on the north side of the neck. Another clay pit is located just west of the State road, as it descends from Nickersons Neck to Riders Cove. The clay varies from light blue and gray in the unweathered portions to brown in the weathered portions, and is very hard and much jointed, as well as folded and sheared. The clay contains a few pebbles, and one bowlder 15 inches in diameter was seen, which would indicate that it is to be referred to the Montauk drift, although doubtless formed from the reworking of Gardiner clay in the immediate vicinity. It bears a somewhat close resemblance to the clay at the brickyards at West Barnstable. Indications of clay were seen on the east side of Riders Cove and near Chathamport. At North Chatham a small pit north of the road shows 5 feet of brownish clays, with occasional pebbles. The same clay rises and shows in the road near by 25 feet higher. It is evidently to be referred to the Montauk drift. No clay was seen in the immediate vicinity of Chatham, and in general it is not to be expected in large quantities, as the region has not been lifted enough to bring the clays above sea level.

Blue clay is, however, reported in considerable amounts near Mill Pond, and near Oyster Pond there is said to be so much brown clay that wells are driven with difficulty. It is not improbable that a few feet of clay may also show above tide level at other points. The clay is not infrequently encountered in the wells.

Harwich region.—The clays in Harwich Township do not appear to occur above sea level in any amount, and only one pit was found in the region, this being in the valley, about three-fourths of a mile west of South Harwich. Inquiry in regard to wells, however, showed that the clays are encountered in many of the wells, and it is said that they can be found at depths of from 6 to 8 feet in some of the hollows. The clay is said to be blue in color and to be extra hard. A very dark reddish clayey sand was seen on the road in the vicinity of Pleasant Lake station, but its source could not be located. Local beds of clayey sand are encountered in the pits at many of the cranberry bogs in this vicinity, but the Gardiner clay has apparently not been found.

Dennis region.—This region is practically coextensive with Dennis Township. It includes the area between Bass River on the west and Harwich on the east, and from Nantucket Sound on the south to Cape Cod Bay on the north. In general, relatively little clay is found, but in one or two localities clay beds are fairly well developed. It is reported that in the vicinity of North Dennis yellow clay, with some erratic pebbles, is encountered below a few feet of gravel or till. The clay is thin and is underlain by a sand layer, below which another layer of blue clay is encountered. The wells, which are from 10 to 35 feet deep, are said to seldom encounter the blue clay. The yellow clay is probably to be referred to the Jacob sand.

At Corporation Landing, on Nobscusset Point, a greenish-gray clay, with pebbles and interstratified sand, is seen in thin layers. A little farther west a greenish-gray sandy clay with ferruginous laminæ comes up above the beach, several feet being exposed for some distance along the beach to the west. At the edge of the marsh, just back of the old wharf, a pit shows 5 feet of gray and greenish clay, with pebbles, presumably Montauk drift, formed by the reworking of the Gardiner clay.

In the vicinity of West Brewster, and to the northeast and southwest, indications of clay are seen in the roadside exposures. Pebbles are generally present, and the clay is most likely a phase of the till. A little blue clay is said to be found in digging for sand at the bogs near West Brewster, but it is not encountered in the wells.

Half a mile southeast of South Dennis, in the bottom of a large gravel and sand pit, is exposed a series of alternating sand and clay layers, becoming bluish at a depth of a few feet. The blue clay is without pebbles, and may represent the Gardiner clay. No clay is encountered in the sand pits at the cranberry bogs in this vicinity, but blue clay is struck in the wells, which are 20 feet or more in depth.

So far as known, the only clay bed worked is that in the pit near South Dennis. Probably none of the clays near West Brewster will yield material of any value except for local use on the roads. At Nobscusset Point and vicinity the clays have been worked in the past, and may possibly be worked again in the future, although over most of the area considerable stripping would be necessary.

Barnstable region.—The area included under this head is practically coextensive with Barnstable Township. At Barnstable blue clay is reported at a depth of 10 to 12 feet in the wells at Finney's store and elsewhere. It is said to form the bottom of the marsh to the north. Traces of clay were seen slightly above marsh level at Calves Pasture Point, northwest of the village. The well water in the vicinity of Barnstable is found on top of the clay. At Harbor Bluff, near Hyannis, there are 5 feet of buff to brown laminated sandy clay, with pockets of sand and small pebbles. It is very tough, and has been worked a little for local purposes at a point where it shows at the surface. It probably belongs to the Montauk formation. No other clay is known in the vicinity. At Hyannis Port clay is said to occur in several of the wells, but it does not appear to reach the surface. Similar conditions exist at Craigville, Centerville, and Osterville. At Cotuit, or Cotuit Port, no clay is known.

Near West Barnstable the only clay deposit which has so far been worked on a considerable scale is located. The pit is about three-fourths of a mile east of the railroad station, at a point where the railroad cuts through a low hill. The clay is quite soft and plastic, and near the surface is of a yellowish color, with a slightly greenish tinge. It is interbedded with lenses of sand and layers of cobbles, and contains throughout the 12 feet exposed in the pit a considerable number of small erratic bowlders, indicating that it probably belongs to the Montauk drift. Toward the bottom of the pit the clay is more bluish, and it is said that a test hole was sunk for a distance of 20 feet through similar material. The clays have been somewhat folded by the ice which has passed over them since their deposition. Stratification is not indicated other than by the sand and bowlder layers mentioned. North of the railroad the clay is said to be of deeper-blue color and to give bricks of a much darker shade. All of the clay is somewhat sandy, but additional sand has to be added in brickmaking.

The clay is reported in the wells in the vicinity of West Barnstable at various depths, apparently having a very irregular surface.

Sandwich region.—An old clay pit is located near the end of Town Neck, northeast of Sandwich, but it is now grassed over and no clay is to be seen. Near by is a house built of the brick from this pit. According to well drivers, the clay occurs all along the shore for a mile or so, both northwest and southeast of Sandwich. It is said to have an irregular surface, varying from a few feet above tide to several feet below. The upper few feet of the clay contain pockets of sand, which often yields water under some artesian pressure. Below these sandy layers the solid blue clay is encountered. It is known to be over 20 feet thick, but the bottom has never been reached, so the maximum thickness is unknown. Clay is also said to have been formerly worked at East Sandwich, where plenty of blue clay was found. In general, however, the clay in the Sandwich district is so near tide level that difficulties in draining would be experienced if extensive pits were to be opened. The clay, however, is of good quality and considerable amounts might be obtained with moderate stripping without going much below sea level.

Falmouth region.—The Gardiner clay has not been seen on the mainland in this region. Near Woods Hole, however, clay is encountered in some of the wells, and can sometimes be found under the beach within a few feet of the surface. So far as could be learned, it is usually of a yellowish or light-gray color, and carries pebbles or bowlders, which indicates that it probably belongs to the Montauk drift. Local beds of more or less clayey sands are also encountered in the sand pits at the cranberry bogs. None of the so-called clays, so far as seen, contain a very high percentage of true clay, and none are likely to prove of any economic value. The Elizabeth Islands were not visited, but the Gardiner clay is known to occur on Nonamesset and others of the islands. It is usually of no great thickness, and is commonly buried to a considerable depth by sand and gravel. Because of the small amounts of the clays and the extensive stripping necessary, it will probably not warrant economic development.

Clays in adjacent regions.—Clay is reported at or near water level in the valley of Monument River, but appears never to have been worked. A yellowish clay was once worked for local purposes on Burgess Point, on the east side of Buzzards Bay, near its head, and some very sandy clays, or, more properly, clayey sands, are found in thin layers in some of the sand pits near the cranberry bogs.

The nearest clay outcrop of consequence is at Indian Hill, between Sandwich and Plymouth. The clays at this point are exposed in the bluffs for a considerable distance, and have a thickness of 20 feet or more. In general character the clays most nearly resemble those on Pleasant Bay, at Chatham. The lower and unaltered portion is of the dark-gray to nearly black type, characteristic of the unaltered Gardiner formation, while the upper portions are of the greenish, brownish, and yellowish types, which everywhere characterize the weathered parts of the same formation. A few pebbles occur in the upper portion of the clay, possibly indicating a reworking by the Montauk ice. The clays at this point are overlain by 20 to 30 feet or more of sands and gravels, which would have to be stripped

before the clay could be worked to any extent. The remoteness of the point from any town or railroad, and the exposed nature of the coast, would offer considerable obstacles to the economic development of the deposits.

SUMMARY.

At the present time the clays on Cape Cod are worked on a commercial scale only at West Barnstable. The works at this point have been in operation over fifty years, and supply the entire demand for common brick on the cape. There is at present, therefore, little demand in the region for additional clay for brickmaking purposes. The building of the State roads, however, created a temporary demand, which caused a large number of small pits to be opened, and it would be greatly to the advantage of the traveling public if its use were to be extended to the common roads, which are often at present little more than sandy trails through the woods.

Although the only commercial development of clay is at West Barnstable, there are several other points where the conditions, other than accessibility to transportation lines, are equally favorable, and at some time in the future the deposits may become of considerable economic value, especially at Highland Light, Truro, Wellfleet, and Chatham.

NOTES ON CLAYS AND SHALES IN CENTRAL PENNSYLVANIA.[a]

By GEORGE H. ASHLEY.

Area discussed.—The following notes are among those collected during the survey of the Houtzdale, Curwensville, and Punxsutawney quadrangles, lying in southern Clearfield County, southeastern Jefferson County, and northeastern Indiana County, Pa. The region covered includes the well-known Clearfield County flint-clay area.

GENERAL DESCRIPTION.

The rocks outcropping in this district belong in the lower part of the Pennsylvanian series of the Carboniferous. They include, first, the Pottsville formation, composed of the Homewood and Connoquenessing sandstones, between which lies the Mercer group of shales, clays, and coals; second, the Allegheny formation, including the strata between the Brookville and Upper Freeport coals; and, third, the lower half of the Conemaugh formation, which overlies the Upper Freeport coal.

The clay materials of this area consist of flint clay, plastic clay, and shale. Flint clay occurs at four horizons—three in the Allegheny, which appear to be of rather limited distribution and minor importance, and a fourth at the Mercer horizon in the middle of the Pottsville formation. In the Allegheny formation flint clay occurs below the Upper Freeport coal in a position possibly corresponding with that of the well-known Bolivar flint clay. It has been found at a number of points in the Little Mahoning Creek drainage. Flint clay has been noted at the horizon of the Middle Kittanning coal at a number of widely separated points, notably about Westover and near McCartney, in Clearfield County. The Lower Kittanning coal is underlain by Flint clay in the Little Mahoning Creek drainage. The Mercer coal is underlain by flint clay, which at present is the principal bed being mined in Clearfield County. It is present throughout a broad stretch of country, ranging from Grampian eastward down the Susquehanna Valley to Clearfield, up the Clearfield Creek drainage to the south and southeast, and over into the Moshannon Creek drainage around Osceola. It occurs to the north and northeast of the area studied, but notes on those occurrences can not be given at this time.

Plastic clay underlies practically all the coal seams of the Allegheny formation, but the clay underlying the Lower Kittanning coal appears to be the most important, and at the time the examination of this area was made it was the only one being worked. It is mixed with flint clay in the making of fire brick.

Shales are very abundant in the area of these three quadrangles, but in most cases they are very sandy. There are one or two horizons of shale which give promise of being commercially valuable. One of these beds is low in the Conemaugh, occurring just above the Mahoning sandstone, and is especially well developed in northeastern Indiana County and southeastern Jefferson County. The other shale deposit specially noted is between the Upper and Lower Freeport Coals.

In the following description the localities at which flint clay was noted are given, and special emphasis is put on deposits not being worked. In the majority of cases the data consisted simply of the discovery of the flint clay in the washing of the road, and little or

[a] See sketch map, fig. 11, p. 272.

no information could be gained of its thickness or character. In the case of the shales the notes are confined to the deposits lying near transportation, which alone can be considered at the present time as of commercial value.

DISTRIBUTION OF FLINT-CLAY DEPOSITS.

Center County.—The rise of the rocks from Moshannon Creek toward the southeast to the Allegheny Front exposes the horizon of the Mercer clay all along the northwestern flank of the mountains facing the creek. Little is known of the clay in this region, except at Sandy Ridge, where it has long been worked. Here there are about 2 feet 6 inches of flint clay, overlain by from 3 to 6 feet of soft blue clay and underlain by from 1 to 3 feet of soft clay. The exposure here is just at the outcrop. The bed dips below the surface to the northwest and may in the future be mined in that direction by shafts, should prospecting prove it to be present and of workable quality and thickness.

Clearfield County.—From its outcrop on the Allegheny Mountains the Mercer clay is carried below drainage under the Houtzdale syncline, containing the Houtzdale coal basin, but it rises again above drainage on the flanks of the anticline which runs from McCartney to near Wallaceton and beyond. This arch is low at either end, but rises so that the Mercer clay is in the hilltops at an elevation of over 2,000 feet above sea level to the northeast of Burly. It is carried down to the northeast by the sinking of the anticline until it is but little above the railroad between Wallaceton and Bigler at elevations of 1,750 to 1,770 feet. Along the crest of the anticline it is exposed at a large number of points and has been mined in every direction from Burly. In this district it ranges from 6 to 8 feet in thickness and occasionally shows 12 or 15 feet. It is also exposed on the roads northwest of Sanbourn at a number of points. It has been mined extensively in the crest of the hill 2 miles west of Blue Ball and outcrops at several points a similar distance west of Wallaceton. Along the Tyrone and Clearfield branch of the Pennsylvania Railroad, and the Beech Creek division of the New York Central and Hudson River Railroad, it is extensively mined between Wallaceton and Woodland, rising above drainage at Wallaceton. In this district it shows a maximum thickness of 10 or 11 feet, though the portion mined and the average thickness will be much less. In most of the mines it ranges from 2 feet 6 inches to 4 feet. The worked stratum is apt to be irregular both in thickness and in quality. It is often overlain and underlain by impure or soft fire clay. On Clearfield Creek its horizon is above drainage from a little north of Madera to the mouth of the creek. It was not seen south of Faunce in the main valley, but it outcrops on North Branch of Upper Morgan Run. At Faunce the clay has a thickness of about 6 feet, but usually only a part of that is workable. It has been worked again at Chase, where the flint portion of the clay is only 2 or 3 feet thick, the soft, sandy clay being both above and below. At these points the clay occurs about 200 feet above the level of the creek, but descends toward the mouth of Little Clearfield Creek. The clay is below water level under all of the Little Clearfield Creek drainage. It rises from water level at Curwensville, being exposed just above the Buffalo, Rochester and Pittsburg Railroad track directly across from town, though of poor quality. It runs up Little Anderson Creek, Biglers Run, and Anderson Creek and has been opened and worked at a number of points. It also outcrops over quite an area on Hogback Run to the north of Curwensville. In this district it shows a maximum thickness of 18 feet, though most of the operations on it do not mine more than 6 or 8 feet, and often less. At Stronach the "nodular" clay is from a knife-edge to 6 feet thick, and the "block" clay below from 2½ to 7 feet thick. There is usually some black shale between the clay and the overlying Mercer coal. On Anderson Creek the clay is from 2½ to 10 feet thick. On Hogback Run the clay is reported to show locally as much as 8 feet of "nodular" clay overlying 11 feet of "block" clay. In places this changes to as high as 11 feet of "nodular" clay over 7+ feet of "block" clay.

Farther up Susquehanna River it again appears above drainage at the mouth of Porter Run and remains above water level to the sharp bend below Bells Landing. The Mercer horizon rises above Susquehanna River just west of Mahaffey and continues for several

miles up the river, but so far as seen this horizon does not yield workable clay in the region about McGees.

In regard to the quality of the clay on the Susquehanna and Roaring Run drainage the best evidence of its excellence is the extensive use that is being made of it. Large mines are in operation west and northwest of Curwensville and along Roaring Run from Woodland to Wallaceton. The clay about Burly and west of Blue Ball is also mined, in a number of cases being hauled by wagon to the railroad.

Flint clay also occurs in this region at what is supposed to be the horizon of the Middle Kittanning coal. It was seen at several points near Westover and a few miles southwest of McCartney. At one opening near Westover the clay measured from 3 to 5 feet. The outcrop near McCartney was noted in the grading of a switch running southwest to a small mine.

Northeastern Indiana County.—Flint clay was noted at a number of points in the northeast corner of Indiana County, though at none of these points could an examination be made to determine either the thickness or quality of the clay. On Little Mahoning Creek flint clay was noted northeast of Richmond, a little north of the old station of Enterprise, associated with what was considered to be the "B" coal. North of Deckers Point it outcrops at several places in the road high up on the ridges, apparently associated with the "E" coal. Southeast of Nashville, on the road toward Gettysburg, is an outcrop near the top of the hill, probably at the horizon of the "E" coal. The clay also occurs a little to the northwest or north of Robertsville within one-half mile of Little Mahoning Creek. Flint clay was again seen near Glen Campbell, on the road from Urey to Ridge along the crest of the hill, and on the south side of Bear Run on the road from Glen Campbell to North Summit.

SOFT CLAYS.

As previously stated, practically all the coal beds of the Allegheny formation are underlain by beds of clay, and in most cases the flint clays noted above have soft clays associated with them. Of these clays the bed underlying the "B" coal appears to be of the greatest thickness and probable value. The "B" coal is above drainage along most of the valleys of the area under consideration, except those lying immediately in the center of the synclines. Prospecting would doubtless reveal clays of commercial thickness and quality at the horizon of the other coals, but as a rule the thickness and character of the clays are not revealed in coal mines. Where the thickness of the clay associated with the other coals was determined, it was usually found to be not over 2 feet. The quality of the clay is unknown

SHALES.

The shales of the eastern portion of this region seem to be uniformly sandy, though possibly not too much so for the successful manufacture of brick or tile. In the western part of Clearfield County and the northeastern part of Indiana County there are many places where the shales immediately over the Mahoning sandstone and immediately below the "E" coal appear to be less sandy in character, and they may warrant careful testing or experimental work. A few of the exposures near the railroads may be noted. These shales outcrop between the "D" and "E" coals at a large number of points around Glen Campbell. A short distance east and west of Burnside the shale above the Mahoning sandstone occurs from 100 to 150 feet above the horizon of the "D" coal. The use of these shales for the manufacture of paving bricks is suggested. Similar shales are found over a broad area in the northern part of this county. To the east of Rossiter the shales between the "E" and "D" coals seem promising. Conemaugh shales are well exposed by the grading for the Buffalo, Rochester and Pittsburgh Railway, though these generally seem rather too sandy for most purposes. Somewhat similar sandy shales are being successfully worked at Punxsutawney on a small scale, being made into common, pressed, and paving brick. A somewhat less sandy shale occurs just south of Punxsutawney, about 150 feet above the valley floor.

BENTONITE OF THE LARAMIE BASIN, WYOMING.

By C. E. Siebenthal.

The variety of clay known as "bentonite" occurs in many localities in Wyoming, and various articles [a] describing its occurrence and character have appeared from time to time. These have been freely drawn on in the preparation of the following paper.

PHYSICAL CHARACTERS.

In color the clay, when freshly exposed, varies from a light yellow to a light olive-green with a waxy luster, but assumes a dull cream color on exposure. In freshly uncovered outcrops it appears as a bedded joint clay, the blocks varying from roughly rectangular or conchoidal shape to long slender pieces. The joints are more or less open and occasionally contain crystals and plates of gypsum and sulphate of soda. The clay is very fine grained, no grit being perceptible to the touch and very little when ground between the teeth. Microscopically it is made up of extremely minute, more or less rounded particles of fairly uniform size and apparently of the same mineral nature, with here and there particles of undecomposed labradorite. The clay has a soft unctuous or soapy feel, but it is quite brittle and is easily quarried. It clings strongly to the tongue. In weathering it absorbs a great amount of water and increases much in volume, forming an intumescent reticulated mantle an inch in thickness, which later melts down to a white powder under the effects of rainfall and frost. Mixed with the proper amount of water it is exceedingly plastic and with the addition of more water it becomes a perfect paste. Tests show that it completely absorbs over three times its weight or seven times its volume of water, and twice as much glycerin as diatomaceous earth will absorb.

COMPOSITION.

Bentonite falls under the kaolin group of hydrous silicates of aluminum, as will be seen from the subjoined table of analyses. Its resemblance to ehrenbergite has been pointed out by Knight, while Read considers it a variety of montmorillonite.

[a] Knight, W. C., Eng. and Min. Jour., vol. 63, 1897, pp. 600-601; vol. 66, 1898, p. 491.
Merrill, George P., Ann. Rept. U. S. Nat. Museum, 1899, pp. 340, 348.
Slosson, E. E., Tenth Ann. Rept. Wyoming College Agric. and Mech., 1900, extract, p. 14.
Read, Thomas T., Eng. and Min. Jour., vol. 76, 1903, pp. 48, 49.
Darton, N. H., Geologic Atlas U. S., folio 107 (Newcastle, Wyo.), 1904, pp. 5, 9.
Merrill, George P., Nonmetallic minerals, 1904, pp. 233, 243.
Fisher, C. A., Bull. U. S. Geol. Survey, No. 260, 1905, pp. 559-563.
Darton, N. H., Prof. Paper U. S. Geol. Survey No. 32, 1905, p. 400.

Analyses of bentonite.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
	Crook County.	Natrona County.	Weston County.	Newcastle.	Taylor.		Linscott.	Cosgriff.		Cassa Mining Co.	
SiO_2	61.08	65.24	63.25	63.25	59.78	58.25	66.5	64.0	64.0	60.18	60.18
Al_2O_3	17.12	15.88	17.62	12.63	15.10	24.70	23.9	22.9	24.0	26.11	26.58
Fe_2O_3	3.17	3.12	3.70	3.70	2.40	2.61	3.1	3.1	3.2		
MgO	1.82	5.34	3.70	3.97	4.14	1.30	1.0	2.0	1.5	2.54	1.01
CaO	2.69		4.12	4.12	.73	1.61	0.5	1.0	.6		0.23
Na_2O	.20	.....	.....	.....	.....	.....	.....	.....	.....	.80	1.23
K_2O	.....	.....	.....	3.55	.....	.....	.....	.....	.....		.....
SO_3	.88	.....	1.53	1.58	.....	.....	.....	.....	.....	.....	.....
H_2O	.....	9.17	.....	6.91	16.26	11.00	5.0	7.0	6.7	10.26	10.26
	86.96	98.75	93.92	99.71	98.41	97.47	100.0	100.0	100.0	99.89	99.49
Sp. gr.	.....	.....	2.132	.....	2.180	.....	.....	.....	.....	.....	.....

I. Analysis by Westfall.
II, III. Analysis by W. C. Knight.
IV. Geologic Atlas U. S., folio 107 (Newcastle).
V. Unknown.
VI. Analysis by H. L. Hodges.
VII–IX. Analysis by John Ogden.
X, XI. Analysis by Thomas T. Read.

USES.

The shipment of bentonite began in 1888, when several carloads were used by eastern firms in the manufacture of hoof packing, a dressing or poultice for the inflamed hoofs of horses. The chief use of the clay so far, however, is to give body and weight in the manufacture of paper, and practically the whole output of the clay for the last few years has been taken by a paper mill in Denver, Colo. Other uses are in antiphlogistine, a proprietary remedial dressing, and as an adulterant in candies and drugs. Though highly plastic it is unsuitable for the manufacture of fire-clay products on account of its low fusibility. It could possibly be used in the manufacture of pottery by mixing with ground feldspar. It is a good retarder for use with the hard cement plasters. Its high absorption of glycerin, as compared with diatomaceous earth, suggests its substitution for the latter in the manufacture of dynamite.

GEOLOGIC OCCURRENCE.

The bentonite deposits of Wyoming vary somewhat in stratigraphic position. In the vicinity of Newcastle one bed occurs near the top of the Niobrara formation, and another in the Graneros shale, the basal formation of the Benton group. In the Bighorn basin the deposits also occur in the Graneros, a short distance below the Mowry submember of that formation. In the Laramie basin the bentonite beds are also in that portion of the Benton corresponding to the Graneros, but they lie a short distance above the Mowry beds. Just above the deposits is a bed of very black shale and in this, at a distance of 15 or 20 feet from the bentonite, are many highly ferruginous septaria. The thickness of the bentonite in the Laramie Basin ranges up to 4 or 5 feet, but in the Bighorn Basin there are beds over 7 feet in thickness and near Newcastle one is reported to have a thickness of 12 feet.

LARAMIE BASIN DEPOSITS.

Taylor's.—This pit was opened in 1888 in the NW. ¼ SE. ¼ sec. 30, T. 22 N., R. 75 W., about one-fourth mile north of Rock Creek station, on the original line of the Union Pacific Railroad, now abandoned. The clay crops out here on the slope of the hillside, with a

thickness of 4 to 5 feet, and dips 4° or 5° to the south with the slope of the hill, the bed being thus exposed over several acres. In working the clay pit the top, consisting of a few inches of weathered débris, is stripped off and the clay is loaded into wagons and hauled 6 miles to Wilcox, the nearest railway station. The clay is shipped loose in box cars, either in lumps, as it naturally comes from the pit, or as the fine loose powder which results from the weathering of the clay.

Linscott's.—About 3 miles southeast of Taylor's a pit was opened in 1897 in NW. ¼ sec. 17, T. 21 N., R. 75 W., near the old line of the railroad. About 20 carloads were shipped before the readily accessible supply was exhausted. Another site was opened up in the SE. ¼ NE. ¼ sec. 14, T. 22 N., R. 76 W., on the north side of Rock Creek, from which about 100 carloads have been shipped. The thickness and relations are analogous to those of Taylor's bank.

Cassa Mining Company.—This claim is located in the N. ½ sec. 10, T. 22 N., R. 76 W. Nothing but development work has been done up to the present time, and only sample consignments have been shipped. The claim takes in a strip a mile in length, the occurrence of the clay being similar to those previously described.

Sam White's.—This property lies in the NW. ¼ sec. 20, T. 22 N., R. 77 W., on the south slope of Como Ridge. This occurrence of the clay is similar to the others except that the dip of the rocks is steeper and a smaller area is uncovered. Only development work has been done.

Cosgriff's.—This claim is located in the NW. ¼ sec. 12, T. 21 N., R. 75 W., near the prominent point locally known as Chalk Bluff. The thickness, geologic relations, and quality of the outcrop are the same as in the occurrences already described. No clay has been shipped.

The foregoing comprise all the occurrences of this clay which have assumed commercial importance in the Rock River region, the type locality. They are strung along the outcrop of the Benton formation for a distance of 20 miles. The bed of clay is probably persistent throughout that distance, though its outcrop is not always apparent. Bentonite has been noted in a few localities elsewhere in the Laramie basin.

Hutton Lakes.—Along the bluff on the northwest shore of the northern of the Hutton Lakes for a distance of 200 yards a bed of bentonite makes a white band in the black shale of the Benton formation. This bed is from 3 to 4 feet thick and dips about S. 85° W. The Mowry beds outcrop to the east and evidently dip beneath the clay. The quality is apparently good.

Sand Creek.—Near the middle of the north side of sec. 2, T. 13 N., R. 75 W., in the east bank of Sand Creek, a 4-foot bed of characteristic bentonite is underlain by 20 feet of soft black shale and overlain by fossiliferous sandstone and light and dark shales. The relation of the bentonite to the Mowry beds is not clear, but the probabilities are that this clay is beneath the Mowry.

Riverside.—On the Riverside ranch, in the NE. ¼ sec. 14, T. 13 N., R. 76 W., a bed of much-weathered bentonite less than 2 feet in thickness lies a few feet above the Mowry beds. In the SE. ¼ sec. 6, T. 14 N., R. 75 W., the bed is reported to thicken to 4 feet.

PRODUCTION AND PRICES.

From 1888 to 1895, inclusive, the output of bentonite averaged about 60 tons annually. From that time it gradually increased until in 1902 it is reported to have been 1,200 tons. With the closing down of the western paper mills the output almost stopped, and in 1905 only a very small amount was shipped.

In the early period from 1888 to 1895 the price averaged $25 per ton, f. o. b. cars. The price then dropped to $5, but later rose to $6 and $7 per ton. The total production to date is approximately 6,000 tons, with a value of $45,000.

SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers listed below, references to clays will be found in the publications listed under the head of "Cements," on page 384.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin No. 143. 114 pp. 1896.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin No. 260, pp. 559–563. 1905.

GOLDING, W. Flint and feldspar. In Seventeenth Ann. Rept., pt. 3, pp. 838–841. 1896.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528. 1892.

——— Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893.

LANDES, H. The clay deposits of Washington. In Bulletin No. 260, pp. 550–558. 1905.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842–880. 1896.

——— The clays of the United States east of the Mississippi River. Professional Paper No. 11. 298 pp. 1903.

SCHRADER, F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 546–549. 1905.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957–1004. 1896.

VAUGHAN, T. W. Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883.

——— Clays of the United States. In Mineral Resources U. S. for 1883–1884, pp. 676–711. 1885.

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904.