CLAYS.

NOTES ON THE CLAYS OF FLORIDA.

By GEORGE C. MATSON.

INTRODUCTION.

Timber is so abundant in the South Atlantic and Gulf States that heretofore wood has been the principal building material in common use. The increase in wealth and the growth of towns and cities, however, have caused an increasing demand for more substantial structural materials. This demand has been met by the use of products manufactured from clay. In some States clay products have been made in a variety of forms; but in Florida little attention has been given to anything except common building brick, though in one locality, near Pensacola, some front and fire brick are produced and a plant was formerly operated for the manufacture of red earthenware. The recent development of subirrigation for truck gardening has created a market for tile, which has been in part supplied by pipes made of cement and in part by ordinary clay tile. Tile of this kind is commonly known as drain tile, but in Florida it is seldom used for drainage purposes.

In addition to the supply necessary to meet the home demand, considerable clay is mined in Florida and shipped to some of the Northern States, being sold under the name of ball clay and used for the manufacture of pottery. Upon his return from a recent trip to Florida Dr. D. T. Day reported that a plant had been established at Jacksonville for the manufacture of pottery.

In Florida the brickmaking industry is most active near the large centers of population where there is a good demand for the product, but small plants are also situated at various localities in the northern part of the State where clay is abundant. The total number of factories in operation is about 27, distributed in thirteen different counties. The factories are most numerous in the counties near the northern line of the State, because the clay deposits are there most

abundant. Clay occurs also in the central part of the peninsula, where deposits suitable for brickmaking are known to exist in Alachua, Putnam, and Lake counties. The most southerly points where brick are manufactured are at Tampa, in Hillsboro County, and near Auburndale, in Polk County. It is probable that brick clays could be obtained in most of the counties which lie in the upland portion of the peninsula. Valuable clays for brick manufacture occur also at various points in the St. Johns Valley from Palatka northward. Ball clays are being mined in Putnam and Lake counties, and it seems probable that the area of workable deposits may extend into some of the adjoining counties.

The rocks of Florida are all either of Tertiary or Quaternary age; and the geologic section of the State comprises representatives of each period from the close of the Eocene to the present time. With the exception of the lower Oligocene, each of the major subdivisions contains more or less clay. A generalized geologic section of Florida is given below.

Generalized geologic section of Florida.

	Approximate thickness (feet).	Character.
Quaternary:		
Recent	10	Sand, peat, muck, marl, and coquina; clay in small areas on the flood plains of some of the streams.
Pleistocene	100	Sand, marl, and coquina; clay not abundant, but good deposits of moderate extent occur locally—for example, near Middleburg, Clay County.
Tertiary:		
Pliocene—		
Clays and sands	20–50	Cross-bedded red and yellow sands with some pebbles; clay is widely distributed in this formation, but is usually sandy; Lafayette formation, doubtfully Pliocene.
Fossiliferous shell marls	20	No clays.
Phosphatic gravels	30	No clays of importance.
Clays	10	Sandy blue clays occurring in depressions in the Oligocene limestone; Alachua clay.
Miocene—		
Clay	25	Plastic bluish or greenish-gray clays; "aluminous" clay.
Fossiliferous shell marls	50	No clays.
Limestones, sands, silex, and clays.	500	Known chiefly from well records; no clay beds of economic importance.
Oligocene—		
Upper	250	Limestones, marls, sands, clays, and fuller's earth. Clays and fuller's earth occur in the upper part of the section, and clays are found locally near the base.
Lower	1,000	Soft white limestone. No clay.

OLIGOCENE CLAYS.

The lower Oligocene is practically all limestone and consequently not important in this discussion. The upper Oligocene includes beds of clay of considerable thickness and fuller's earth beds in both the northern and southern parts of the State. The brick clays are light green to greenish gray in color and very plastic, and although

they are well exposed they are not extensively utilized for the manufacture of clay products. The section in the pit at the Tampa Brick Company's plant shows 2 to 4 feet of white Pleistocene sand resting unconformably upon 10 feet of light-green upper Oligocene siliceous clay containing some nodular beds of carbonate of lime near the base. Scattered throughout the clay are many bowlders and cobbles of chert consisting of silicified corals.

The following analysis represents a sample of clay from the upper Oligocene near Tampa. Although the sample was not taken from the clay pit at the brickyard, it is probably fairly representative of the character of the clay at that locality.

Analysis of clay from Tampa.

[Collected by W. H. Dall; analyzed by L. G. Eakins.[a]]

SiO_2	70.78
$Al_2O_3+Fe_2O_3$	11.33
MgO	-----
CaO	2.18
H_2O	14.55
	100.98

This analysis is incomplete, but shows the general character of the clay. Clay from this horizon is now being used for the manufacture of good building brick, and it might possibly be made into paving brick, an article greatly needed in the peninsula of Florida. However, before attempts are made to use it for that purpose it should be subjected to practical tests to determine its value.

Clay similar to that at the Tampa brickyard outcrops on the shore near Clearwater, and well records indicate that a short distance from the coast it attains a thickness of 8 to 12 feet and is covered by 10 feet of coarse Pleistocene sand. About 1 mile north of Espiritu Santo Springs the following section was noted:

Section 1 mile north of Espiritu Santo Springs.

	Feet.
White sandy loam, Pleistocene	2–4
Slightly indurated dark-brown sand, Pleistocene	1½
Light-green siliceous clay, upper Oligocene	0–5

The clay at this place closely resembles that at the Tampa brickyard. The deposit is favorably located on the shore of the bay, and it might be possible to work the clay and ship the product to Tampa by water.

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 355.

A sample of Oligocene clay was collected from the Sandlin place, about 2 miles southeast of Marion, Hamilton County, and was analyzed with the following result :

Analysis of clay from Sandlin place, 2 miles southeast of Marion, Hamilton County.

[Collected by G. H. Eldridge; analyzed by H. N. Stokes.[a]]

SiO_2	78.23
Al_2O_3	1.85
Fe_2O_3	1.85
FeO	-----
MgO	2.11
CaO	1.60
H_2O at 100°	[b] 8.48
H_2O above 100°	
P_2O_5	Trace.
CO_2	-----
	99.57

The high silica content indicates that this clay is likely to be somewhat refractory, but it should prove satisfactory for the manufacture of ordinary brick. It is very plastic and of light-drab, blue, or greenish color. Similar clay is widely distributed in Florida. It probably lies at about the horizon represented by the clays near Lee and the clays and fuller's earth beds near Quincy, River Junction, and Jamieson. The thickness of individual beds does not as a rule exceed 10 feet; but the clay should prove of value for manufacturing where it is not deeply buried and is situated within easy reach of a suitable market.

Clay of a quality similar to that described above was observed on Suwannee River at White Springs, and it is also reported farther down the same stream. Well records show that light-green clay attains a thickness of about 70 feet near Newmansville,[c] and detailed investigations would probably show that this clay outcrops in some of the counties to the north.

Some clays from the upper Oligocene of Florida were collected by T. W. Vaughan and sent to Heinrich Ries for examination. The results of the tests made, together with Vaughan's notes, are incorporated in a previous report.[d] A sample of white calcareous clay was obtained on a hillside in sec. 1, T. 1 S., R. 4 W., on property owned by W. B. Stoutamire, about 18 miles southwest of Tallahassee.[e]

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 356.
[b] Includes a little CO_2.
[c] Dall, W. H., Neocene of North America; Bull. U. S. Geol. Survey No. 84, 1892, p. 109.
[d] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, pp. 83–85.
[e] Idem, p. 83.

The chemical composition of the clay is indicated by the following analysis:

Analysis of clay from Leon County, Fla.

[Analyst, H. Ries.]

SiO_2	35.95
Al_2O_3	13.23
Fe_2O_3	1.27
CaO	15.00
MgO	5.40
H_2O	10.55
Moisture	
CO_2	18.50
	99.90

Another sample, which is described as brick clay, was obtained on the property of J. D. Stoutamire, in sec. 15, T. 1 S., R. 4 W.[a] This clay burns to a light-buff color and it is thought that a sufficient admixture of sand would make it available for the manufacture of front brick.

Calcareous clay was also obtained on W. W. Williams's farm in sec. 21, T. 1 S., R. 4 W.[a] The outcrop is in the bed of a small creek about one-half mile southeast of Jackson Bluff on Ochlocknee River. The thickness of the exposure of clay is only 2½ feet, and it is overlain by about 6 feet of sandy alluvium. The tests indicated that this clay had too high a shrinkage to be used alone, but it might be suitable for mixture with other clays to serve as a binding material. Its value for this purpose was suggested by the fact that it has a high tensile strength, ranging from 300 to 388 pounds to the square inch.[b] The chemical composition is given below:

Analysis of calcareous clay from land of W. W. Williams, near Jackson Bluff, Ochlocknee River, Florida.

[Analyst, H. Ries.]

Silica	30.83
Alumina	15.40
Ferric oxide	1.40
Lime	13.78
Magnesia	7.50
Alkalies	Undetermined.
Carbon dioxide	20.14
Water	7.16
	96.21

[a] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 84.

[b] Idem, p. 85.

MIOCENE CLAYS.

The Miocene beds which are exposed in Florida consist largely of marl and limestone, but a bed of calcareous clay of considerable thickness occurs above the marls in some localities. This deposit outcrops at Alum Bluff, where it consists of light-gray to greenish-gray clay. The presence of a white efflorescence upon the surface of the clay led to the use of the name Alum Bluff for the exposure at this locality. The use of the term "aluminous"[a] clay appears to be unfortunate, as it is likely to be misleading. So far as now known, no clays of Miocene age are being extensively utilized in Florida, though it appears probable that the deposit described above might prove valuable.

PLIOCENE CLAYS.

Clays of Pliocene age are widely distributed in northern Florida and extend some distance southward along the elevated axis of the peninsula. The clays near the northern boundary belong to the Lafayette formation and those in the central part of the peninsula form the Alachua clay. The clays of the Lafayette formation are probably more extensively used than those from any other geologic formation in the State. The occurrence of the clay beds is very irregular, and the thickness of some of them varies within short distances. The clays are plastic and have a great variety of colors, ranging from nearly white and mottled gray to various shades of blue, red, or yellow. They usually carry a high percentage of rather coarse sand that prevents excessive shrinking on drying, but often gives the burned product a rough appearance and renders it porous. However, when properly mixed and burned the clays of the Lafayette formation make a very good brick for ordinary building purposes.

The Alachua clay is widely distributed, but occurs as discontinuous patches. It is usually plastic, and the color is commonly light gray to bluish gray, except on weathered surfaces, where light yellow or red colors prevail. Like the clays of the Lafayette formation, the Alachua clay is liable to be sandy, and hence is best adapted to the production of common building brick.

The clay of the McMillan Brick Company's pit, one-half mile north of Molino, is referred to the Lafayette, though the thickness of the workable deposit at that locality is unusually great for this formation. The material is very plastic and is utilized for the manufacture of building brick. A section which was roughly measured in the pit southwest of the factory gave 5 to 8 feet of red and yellow stratified sands with laminæ of clay, underlain by 25 feet of very plastic dense

[a] Dall, W. H., and Stanley-Brown, Joseph, Cenozoic geology along the Apalachicola River; Bull. Geol. Soc. America, vol. 5, 1894, p. 157.

blue clay. The clay in this section contains much less sand than is commonly found in the Pliocene clays of Florida, and this fact, together with its thickness, makes the deposit somewhat more valuable than the average.

PLEISTOCENE CLAYS.

The Pleistocene beds of Florida consist largely of sand, but a few local deposits of clay have been discovered. Though most of these clays are sandy, there are a few localities where the beds are exceptionally free from grit. This is the case on Black Creek, in Clay County, where the Union Brick Company is working an extensive deposit of very pure plastic clay, which makes a building brick of good quality. The section given below was roughly measured in the pit of this company. The locality is about one-fourth mile north of Black Creek and 2 miles below Middleburg.

Section in pit of Union Brick Company near Black Creek.

	Ft.	in.
Light-gray sandy loam, Pleistocene		6–8
Very plastic light-blue clay, showing thin lamination, Pleistocene	6–12	
Erosion unconformity.		
Fine white sand with patches of yellow clay at the top	3+	

The light-blue clay shows columnar jointing and is weathered to a bright red along joints near the surface. A few small concretions of lime occur scattered through the deposit.

The analysis given below represents a sample of clay obtained at Melborne Creek. The exact location of the exposure from which the sample was obtained is not known, but the deposit is probably of Pleistocene age.

Analysis of hammock clay from Melborne Creek.

[Collected by N. S. Shaler; analyzed by L. G. Eakins.[a]]

SiO_2	38.04
$Al_2O_3+Fe_2O_3$	27.19
MgO	.46
CaO	10.73
H_2O	10.73
H_2O, including some CO_2	23.61
	100.03

To judge from the analysis, this clay should prove valuable for brick manufacture, provided a large enough quantity could be obtained to warrant the construction of a factory.

[a] Bull. U. S. Geol. Survey No. 228, 1904, p. 355.

RECENT CLAYS.

Some Recent clays are being mined for the manufacture of brick about 1 mile west of Chipley. The deposit at this locality consists of a light-blue alluvial clay which forms the flood plain of the stream. The surface lies very near water level, and hence no attempt has been made to mine the clays to a depth of more than 3 to 4 feet. The full thickness of the beds has not been determined, but they may extend to more than twice the depth of the present pit; if so, the deposit could be worked on a large scale. The absence of overburden makes it possible to mine the clay cheaply, and the presence of water in the pit is the only serious disadvantage. However, the excavation could probably be carried on without serious inconvenience by means of a steam shovel. This clay is sufficiently plastic to be molded by the stiff-mud process, and the burned product varies in color from pale yellow to red, depending on the thoroughness of the oxidation of the iron present. The lighter colors are characteristic of underburning, and dark colors are a sign of imperfect oxidation due to the exclusion of air or to the application of heat too rapidly.

PLIOCENE (?) BALL CLAYS.

In Putnam and Lake counties there are a number of pits that produce a plastic white clay commonly known as "kaolin." This clay bears a strong resemblance to kaolin, but differs from it in origin. According to Ries,[a] the term kaolin is usually restricted to the white-burning clays, of residual origin, which consist of silica, alumina, combined water, and a very small percentage of fluxing compounds. The so-called "kaolins" of Florida are of sedimentary origin, and consequently do not meet the requirements of the above definition. They are known to some extent as ball clays. The deposit in Putnam County consists of a conglomerate or coarse sand with probably 30 to 40 per cent of argillaceous matter. The clay, when separated from the sand and gravel, forms a white fine-grained mass, resembling pure kaolin. It burns white, is very plastic, and is sufficiently free from fluxing compounds to be fairly refractory. The tensile strength of the air-dried clay is sufficient to enable it to retain its form with considerable tenacity. This fact, together with the color and refractoriness, makes it possible to use the clay for the manufacture of white earthenware. The manufacturing is mostly done outside the State.

The area covered by the ball-clay deposits is not very clearly defined. Mining is now being carried on at Edgar, Johnson, and McMeekin, in Putnam County, and at Yalaha, Okahumpka, and Richmond, in Lake County. In Lake County the deposit is said to lie along both sides of Palatkaha Creek for a distance of 25 or 30

[a] Ries, Heinrich, Clays; their occurrence, properties, and uses, 1906, p. 165.

miles. The following description is taken from the unpublished notes of George H. Eldridge:

Kaolin occurs on the property of Dr. J. F. Richmond, not far from Okahumpka. The pits and outcrops lie along the Palatkaha, extending from the doctor's house a distance of 2½ miles upstream and perhaps a short distance in the opposite direction. The beds have been prospected between a quarter and a half mile back from the stream on the east side and about the same distance west of the stream, but in the latter case not so thoroughly as in the former. Pits were examined in the NW. ¼ NE. ¼ sec. 23, T. 20, R. 24; the NE. ¼ NW. ¼ sec. 26, T. 20, R. 24; and the NE. ¼ SE. ¼ and the SE. ¼ NE. ¼ sec. 14, T. 20, R. 24. The material has been used for making pottery and ornamental tile. It was shipped to New York to a factory located on the Hudson River. The deposit occurs in a bluff 2 to 10 feet high along the river. It is essentially a mixture of quartz and clay, both usually white. The relative proportions vary from a nearly pure sandstone or grit to a rather pure clay. The material is said to contain 50 per cent of clay. About one-half mile from the house is a mottled pink or yellowish-white sand with occasional more or less clayey patches. The exact thickness of the clay bed is not known, but it is supposed to be about 20 feet.

The Putnam County ball clays probably occupy a considerable area west of Palatka, and they may extend beyond the boundary of the county. This deposit is reported to have a maximum thickness of about 30 feet. The following section is given by Ries:[a]

Section in clay pit at Edgar, Fla.

	Feet.
Top soil	8
Impure upper clay	8–10
White clay	25
Green clay.	

The thickness of the green clay was not determined. According to Eldridge, this clay was elsewhere observed resting upon limestone, and there appears to be little doubt that it belongs to the Upper Oligocene. The age of the ball-clay deposit has not been definitely determined, but it may be Pliocene.

The following mention of ball clay is contained in a report by Ries:[b]

According to Mr. W. T. Vaughan, of the United States Geological Survey, who has been doing field work on the Tertiary formations of northern Florida and southwestern Georgia, another deposit of ball clay occurs on the land of Mr. Augustus Munroe, sec. 32, T. 10 S., R. 23 E. Mr. Vaughan states that—

"The material is very sandy, but its thickness could not be ascertained from observation. Several auger holes had been sunk, and these indicate a thickness of about 10 feet. The bed is said to be thicker near the summit of the hill. The overburden varies from 4 to 10 feet, and the deposit can be economically worked over an area of several acres. The transportation facilities are good, as the Plant System railway is only a half mile distant."

[a] Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper U. S. Geol. Survey No. 11, 1903, p. 82.

[b] Idem, p. 83.

A weathered deposit of argillaceous sand resembling unwashed ball clay is mined for road metal near Interlachen, and similar material is being obtained west of Palatka. Other deposits of like character are reported at Bartow Junction, Winter Haven, and Arcadia. None of the material from these localities has been tested to determine its value for manufacturing, but the deposit at Arcadia is said to be valuable for road building, and it is probable that the clays from the other localities mentioned might be used for a similar purpose. At Bartow Junction the beds weather to a bright-yellow or mottled color, owing to the presence of iron oxide, and hence the material is probably unfit for use where a white burned product is desired. These beds are covered by the gray Pleistocene sand common to the region. The deposits are ordinarily 10 to 12 feet or more in thickness, and as they are near the surface they can be worked advantageously. Roads treated with the unwashed mixture of gravel and clay are far superior to the sandy thoroughfares common in the region.

Several analyses of Florida ball clays and two analyses of the more ferruginous beds at Bartow Junction are given below.

Analyses of Florida ball clay.

	1.	2.	3.	4.	5.
SiO_2	46.11	45.39	84.41	79.99	79.48
Al_2O_3	39.5	39.19	11.02	10.82	12.14
Fe_2O_3	.35	.45	Trace.	3.25	2.64
FeO				.25	.09
MgO	.13	.29	Trace.	.07	.07
CaO		.51	.20	.23	.31
H_2O at 100°	[a] 13.78	[a] 14.01	[b] 4.25	[b] .90	.86
H_2O above 100°				4.09	4.73
P_2O_5			Trace.		
CO_2				None.	None.
SO_3	.07				
Alkalies		.83			
	99.94	100.67	99.88	99.87	100.32

[a] Stated as "water" in the original publication.
[b] Includes a little CO_2.

Localities: 1, Washed clay from Palatkaha River; 2, washed clay from Edgar; 3, raw clay from Richmond's, 6 miles south of Leesburg; 4 and 5, clay from Bartow Junction.
Sources of analyses: 1 and 2, Ries, Heinrich, Clays of the United States east of the Mississippi River: Prof. Paper, U. S. Geol. Survey No. 11, 1903, p. 83; 3, 4, and 5, collected by Geo. H. Eldridge, 3 analyzed by H. N. Stokes, 4 and 5 by George Steiger; Bull., U. S. Geol. Survey No. 228, 1904, p. 356.

The first two analyses represent the ball clay after it has been prepared for market by washing; the third shows the character of the raw material. It is interesting to note that the difference between the original clay and the washed material is practically all due to a lowering in the percentage of silica. This is brought about by the removal of quartz sand and pebbles in the process of washing.

The samples from Bartow Junction (4 and 5) show a remarkable similarity to the raw ball clay represented by analysis 3. In fact,

the only important difference is an increase in the amount of iron present and a corresponding decrease in the quantity of silica. The ball clay is valued because it is refractory and burns white. The material at Bartow Junction lacks these two characteristics, and hence it could not be used for the production of white pottery. It might, however, be useful for the manufacture of colored ware, and its similarity to the ball clay suggests that it might be worth while to prospect elsewhere for deposits similar to those in Putnam and Lake counties.

METHODS OF MINING AND MANUFACTURING.

The ball clay is mined by dredging. The pit is kept partly full of water, supplied by a flowing well, and a float is used for dredging purposes. On this float are an engine, a scraper, and a pump. The engine is used to operate the scraper, which loosens the material, and the pump, which elevates the loosened sand and clay to the washing troughs. In these troughs the clay is separated from the sand and gravel, and it is then carried to a shed where it is squeezed between circular wooden disks to remove the excess of water. The material obtained in this manner is said to be of excellent quality and is shipped to the factory to be manufactured into pottery.

The brick clays of Florida are all mined by means of open pits, few of which exceed 25 to 30 feet in depth. It is usually necessary to remove the covering of Pleistocene sand that rests on the clays at most localities, but as this deposit is thin the cost of stripping is small. In most of the brickyards the clay is excavated by means of pick and shovel and loaded on small cars which are drawn up an inclined track to the shed where the molding is done. The clay is dumped from the car automatically into the pug mill, where it is thoroughly mixed and forced into the molding machine. In most plants the bricks are made by what is called the stiff-mud process, but in some brickyards the soft-mud process is used. From the molds the bricks are conveyed to the drying sheds, either on small cars or by means of a broad belt which extends from the molding machine across the shed.

After being air dried, the bricks are taken from the sheds and placed in the kiln. In many brickyards the burning is done in temporary kilns that are constructed each time that a number of bricks are ready for burning. In these kilns the heat is supplied by wood fires and is distributed by an upward draft through the openings left between the bricks. In a few yards permanent kilns are used, the heat being supplied in the same manner as in the temporary kilns, except that the bricks are so arranged that there is a downward as well as an upward draft. This method of burning is more economical than the other and gives better results.

Practically all the clays which are now being utilized for brick and tile manufacture burn to a bright-red or yellow color at comparatively low temperatures. However, the products of the kilns frequently show every gradation in color from light buff to nearly black. These variations are usually due to imperfect oxidation of the iron compounds present, the lighter colors resulting from burning at too low a temperature and the darker from lack of sufficient air to furnish oxygen. With clays containing both lime and iron, however, a buff color may result, even when the clays are properly burned.

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

In addition to the papers named below, some of the publications listed under the heading "Cement" contain references to clays. Certain of the geologic folios also contain references to clays, fuller's earth, etc.

These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

ASHLEY, G. H. Notes on clays and shales in central Pennsylvania. In Bulletin No. 285, pp. 442–444. 1906.

BASTIN, E. S. Clays of the Penobscot Bay region, Maine. In Bulletin No. 285, pp. 428–431. 1906.

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

——— The clays of Arkansas. Bulletin No. 351. 1908.

BUTTS, C. Clays of the Birmingham district, Alabama. In Bulletin No. 315, pp. 291–295. 1907.

CRIDER, A. F. Clays of western Kentucky and Tennessee. In Bulletin No. 285, pp. 417–427. 1906.

DARTON, N. H. Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming. Professional Paper No. 65. (In press.)

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin No. 213, pp. 382–391. 1903. 25c.

——— Clays of Garland County, Ark. In Bulletin No. 285, pp. 407–411. 1906.

FENNEMAN, N. M. Clay resources of the St. Louis district, Missouri. In Bulletin No. 315, pp. 315–321. 1907.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin No. 260, pp. 559–563. 1905. 40c.

——— Clays in the Kootenai formation near Belt, Mont. In Bulletin No. 340, pp. 417–423. 1908.

FULLER, M. L. Clays of Cape Cod, Massachusetts. In Bulletin No. 285, pp. 432–441. 1906.

GARDNER, J. H. (See Shaler, M. K., and Gardner, J. H.)

HAWORTH, E. (See Schrader, F. C., and Haworth, E.)

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1891, pp. 474–528. 1892. 50c.

HILL, R. T. Clay materials of the United States. In Mineral Resources U. S. for 1892, pp. 712–738. 1893. 50c.

LANDES, H. The clay deposits of Washington. In Bulletin No. 260, pp. 550–558. 1905. 40c.

LINES, E. F. Clays and shales of the Clarion quadrangle, Clarion County, Pa. In Bulletin No. 315, pp. 335–343. 1907.

MARBUT, C. F. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

MARTIN, LAWRENCE. (See Phalen, W. C., and Martin, Lawrence.)

MIDDLETON, J. Clay-working industries. In Mineral Resources U. S. for 1907, pt. 2, pp. 495–556. 1908.[a]

PHALEN, W. C. Clay resources of northeastern Kentucky. In Bulletin No. 285, pp. 412–416. 1906.

——— Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia. In Bulletin No. 349, pp. 112–122. 1908.

PHALEN, W. C., and MARTIN, LAWRENCE. Clays and shales of southwestern Cambria County, Pa. In Bulletin No. 315, pp. 344–354. 1907.

PORTER, J. T. Properties and tests of fuller's earth. In Bulletin No. 315, pp. 268–290. 1907.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523–575. 1895. $1.20.

——— 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. 40c.

SCHRADER, F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin No. 260, pp. 546–549. 1905. 40c.

SHALER, M. K., and GARDNER, J. H. Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico. In Bulletin No. 315, pp. 296–302. 1907.

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.

SIEBENTHAL, C. E. Bentonite of the Laramie Basin, Wyoming. In Bulletin No. 285, pp. 445–447. 1906.

SIEBENTHAL, C. E. (See Darton, N. H., and Siebenthal, C. E.)

STOSE, G. W. White clays of South Mountain, Pennsylvania. In Bulletin No. 315, pp. 322–334. 1907.

VAN HORN, F. B. Fuller's earth. In Mineral Resources U. S. for 1907, pp. 731–734, pt. 2. 1908.

VAUGHAN, T. W. Fuller's earth of southwestern Georgia and Florida. In Mineral Resources U. S. for 1901, pp. 922–934. 1902.

——— Fuller's earth deposits of Florida and Georgia. In Bulletin No. 213, pp. 392–399. 1903. 25c.

VEATCH, O. Kaolins and fire clays of central Georgia. In Bulletin No. 315, pp. 303–314. 1907.

[a] Previous volumes of the Mineral Resources of United States contain chapters devoted to clay and the clay-working industries of the United States.

WILBER, F. A. Clays of the United States. In Mineral Resources U. S. for 1882, pp. 465–475. 1883. 50c.

——— Clays of the United States. In Mineral Resources U. S. for 1883–84, pp. 676–711. 1885. 60c.

WOODWORTH, J. B. (See Shaler, N. S., Woodworth, J. B., and Marbut, C. F.)

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin No. 225, pp. 463–480. 1904. 35c.

LIME AND MAGNESITE.

SURVEY PUBLICATIONS ON LIME AND MAGNESITE.

In addition to the papers listed below, which deal principally with lime, magnesite, etc., further references on limestones will be found in the lists given under the heads "Cement" and "Building stone." These publications, except the one to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BASTIN, E. S. The lime industry of Knox County, Me. In Bulletin No. 285, pp. 393–400. 1906. 60c.

BUTTS, C. Limestone and dolomite in the Birmingham district, Alabama. In Bulletin No. 315, pp. 247–255. 1907.

BUTTS, C., BURCHARD, E. F., and ECKEL, E. C. Iron ores, fuels, and fluxes, of the Birmingham district, Alabama. (In preparation.)

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. (In preparation.)

ECKEL, E. C. Lime and sand-lime brick. In Mineral Resources U. S. for 1907, pp. 545–551. pt. 2. 1908.

HESS, F. L. Some magnesite deposits of California. In Bulletin No. 285, pp. 385–392. 1906. 60c.

——— The magnesite deposits of California. Bulletin No. 355. 1908.

MACDONALD, D. F. (See Calkins, F. C., and MacDonald, D. F.)

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795–811. 1896.

STOSE, G. W. Pure limestone in Berkeley County, W. Va. In Bulletin No. 225, pp. 516–517. 1904. 35c.

YALE, C. G. Magnesite deposits in California. In Mineral Resources U. S. for 1903, pp. 1131–1135. 1904. 70c.

——— Magnesite. In Mineral Resources U. S. for 1906, pp. 1145–1147. 1907. 50c.

——— Magnesite. In Mineral Resources U. S. for 1907, pp. 737–740. pt. 2. 1908. $1.

GYPSUM AND PLASTERS.

SURVEY PUBLICATIONS ON GYPSUM AND PLASTERS.

The more important publications of the United States Geological Survey on gypsum and plasters are included in the following list. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin No. 223. 123 pp. 1904. 25c.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin No. 225, pp. 483–487. 1904. 35c.

BURCHARD, E. F. Gypsum and gypsum products. In Mineral Resources U. S. for 1906, pp. 1069–1078. 1907. 50c.

——— Gypsum. In Mineral Resources U. S. for 1907, pp. 643–650, pt. 2. 1908.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Salt and gypsum deposits of southwestern Virginia. In Bulletin No. 213, pp. 406–416. 1903. 25c.

——— Gypsum and gypsum products. In Mineral Resources U. S. for 1905, pp. 1105–1115. 1906. $1.

HESS, F. L. A reconnaissance of the gypsum deposits of California. (In preparation.)

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 506–601. 1888. 50c.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin No. 260, pp. 573–585. 1905. 40c.

SHALER, M. K. Gypsum in northwestern New Mexico. In Bulletin No. 315, pp. 260–265. 1907.

SIEBENTHAL, C. E. Gypsum of the Uncompahgre region, Colorado. In Bulletin No. 285, pp. 401–403. 1906. 60c.

——— Gypsum deposits of the Laramie district, Wyoming. In Bulletin No. 285, pp. 404–405. 1906. 60c.

——— (See also Darton, N. H., and Siebenthal, C. E.)

GLASS SAND, ETC.

SURVEY PUBLICATIONS ON GLASS SAND AND GLASS-MAKING MATERIALS.

The list below includes the important publications of the United States Geological Survey on glass sand and glass-making materials. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BURCHARD, E. F. Requirements of sand and limestone for glass making. In Bulletin No. 285, pp. 452–458. 1906.

——— Glass sand of the middle Mississippi basin. In Bulletin No. 285, pp. 459–472. 1906.

——— Glass-sand industry of Indiana, Kentucky, and Ohio. In Bulletin No. 315, pp. 361–376. 1907.

——— Notes on glass sands from various localities, mainly undeveloped. In Bulletin No. 315, pp. 377–382. 1907.

——— Glass sand, sand, and gravel. In Mineral Resources U. S. for 1906, pp. 993–1000. 1907. 50c.

——— Sand and gravel. In Mineral Resources U. S. for 1907, pt. 2, pp. 553–556. 1908.

CAMPBELL, M. R. Description of the Brownsville-Connellsville quadrangles, Pennsylvania. Geologic Atlas U. S., folio 94, p. 19. 1903.

COONS, A. T. Glass sand. In Mineral Resources U. S. for 1902, pp. 1007–1015. 1904.

STOSE, G. W. Glass-sand industry in eastern West Virginia. In Bulletin No. 285, pp. 473–475. 1906.

WEEKS, J. D. Glass materials. In Mineral Resources U. S. for 1883–1884, pp. 958–973. 1885. 60c.

——— Glass materials. In Mineral Resources U. S. for 1885, pp. 544–555. 1886. 40c.

ABRASIVES.

SURVEY PUBLICATIONS ON ABRASIVE MATERIALS, QUARTZ, FELDSPAR, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various abrasive materials. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The one marked "Exhausted" is not available for distribution, but may be seen at the larger libraries of the country.

ANDERSON, ROBERT. (See Arnold, Ralph, and Anderson, Robert.)

ARNOLD, RALPH, and ANDERSON, ROBERT. Diatomaceous deposits of northern Santa Barbara County, Cal. In Bulletin No. 315, pp. 438–447. 1907.

BASTIN, E. S. Feldspar and quartz deposits of Maine. In Bulletin No. 315, pp. 383–393. 1907.

——— Feldspar and quartz deposits of southeastern New York. In Bulletin No. 315, pp. 394–399. 1907.

——— Quartz (flint) and feldspar. In Mineral Resources U. S. for 1906, pp. 1253–1270. 1907. 50c.

——— Quartz and feldspar. In Mineral Resources U. S. for 1907, pt. 2, pp. 843–872. 1908.

CHATARD, T. M. Corundum and emery. In Mineral Resources U. S. for 1883–84, pp. 714–720. 1885. 60c.

ECKEL, E. C. The emery deposits of Westchester County, N. Y. In Mineral Industry, vol. 9, pp. 15–17. 1901.

FULLER, M. L. Crushed quartz and its source. In Stone, vol. 18, pp. 1–4. 1898.

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

HIDDEN, W. E. The discovery of emeralds and hiddenite in North Carolina. In Mineral Resources U. S. for 1882, pp. 500–503. 1883. 50c.

HOLMES, J. A. Corundum deposits of the southern Appalachian region. In Seventeenth Ann. Rept., pt. 3, pp. 935–943. 1896.

JENKS, C. N. The manufacture and use of corundum. In Seventeenth Ann. Rept., pt. 3, pp. 943–947. 1896.

MESLER, R. D. (See Siebenthal, C. E., and Mesler, R. D.)

PARKER, E. W. Abrasive materials. In Nineteenth Ann. Rept., pt. 6, pp. 515–533. 1898.

PHALEN, W. C. Abrasive materials. In Mineral Resources U. S. for 1907, pt. 2, pp. 607–626. 1908. $1.

PRATT, J. H. The occurrence and distribution of corundum in the United States, Bulletin No. 180. 98 pp. 1901. Exhausted.

——— Corundum and its occurrence and distribution in the United States. Bulletin No. 269. 175 pp. 1905. (Bulletin No. 269 is a later and revised edition of Bulletin No. 180.)

RABORG, W. A. Buhrstones. In Mineral Resources U. S. for 1886, pp. 581–582. 1887. 50c.

——— Grindstones. In Mineral Resources U. S. for 1886, pp. 582–585. 1887. 50c.

——— Corundum. In Mineral Resources U. S. for 1886, pp. 585–586. 1887. 50c.

READ, M. C. Berea grit. In Mineral Resources U. S. for 1882, pp. 478–479. 1883. 50c.

SIEBENTHAL, C. E., and MESLER, R. D. Tripoli deposits near Seneca, Mo. In Bulletin No. 340, pp. 429–437. 1908.

STERRETT, D. B. Abrasive materials. In Mineral Resources U. S. for 1906, pp. 1043–1054. 1907. 50c.

TURNER, G. M. Novaculite. In Mineral Resources U. S. for 1885, pp. 433–436. 1886. 40c.

——— Novaculites and other whetstones. In Mineral Resources U. S. for 1886, pp. 589–594. 1887. 50c.

WOOLSEY, L. H. Volcanic ash near Durango, Colo. In Bulletin No. 285, pp. 476–479. 1906.

MINERAL PAINT.

SURVEY PUBLICATIONS ON MINERAL PAINT.

The following publications, except the one to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BURCHARD, E. F. Southern red hematite as an ingredient of metallic paint. In Bulletin No. 315, pp. 430–434. 1907.

——— Mineral Paints. In Mineral Resources U. S. for 1907, pt. 2, pp. 697–709.

ECKEL, E. C. The mineral paint ores of Lehigh Gap, Pennsylvania. In Bulletin No. 315, pp. 435–437. 1907.

——— Metallic paints of the Lehigh Gap district, Pennsylvania. In Mineral Resources U. S. for 1906, pp. 1120–1122. 1907. 50c.

——— (See also Hayes, C. W., and Eckel, E. C.)

HAYES, C. W., and ECKEL, E. C. Occurrence and development of ocher deposits in the Cartersville district, Georgia. In Bulletin No. 213, pp. 427–432. 1903. 25c.

PHOSPHATES.

SURVEY PUBLICATIONS ON PHOSPHATES AND OTHER MINERAL FERTILIZERS.

The following papers relating to phosphates, gypsum (land plaster), and other mineral materials used as fertilizers have been published by the United States Geological Survey or by members of its staff. Further references will be found under the head of "Gypsum."

The United States publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

ADAMS, G. I., and others. Gypsum deposits in the United States. Bulletin No. 223. 127 pp. 1904. 25c.

DARTON, N. H. Notes on the geology of the Florida phosphates. In Am. Jour. Sci., 3d ser., vol. 41, pp. 102–105. 1891.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin No. 364. 1909.

ECKEL, E. C. Recently discovered extension of Tennessee white-phosphate field. In Mineral Resources U. S. for 1900, pp. 812–813. 1901. 70c.

——— Utilization of iron and steel slags. In Bulletin No. 213, pp. 221–231. 1903. 25c.

——— The white phosphates of Decatur County, Tenn. In Bulletin No. 213, pp. 424–425. 1903. 25c.

ELDRIDGE, G. H. A preliminary sketch of the phosphates of Florida. In Trans. Am. Inst. Min. Eng., vol. 21, pp. 196–231. 1893.

FERRIER, W. F. (See Weeks, F. B., and Ferrier, W. F.)

HAYES, C. W. The Tennessee phosphates. In Sixteenth Ann. Rept., pt. 4, pp. 610–630. 1895. $1.20.

——— The Tennessee phosphates. In Seventeenth Ann. Rept., pt. 2, pp. 1–38. 1896. $2.35.

HAYES, C. W. The white phosphates of Tennessee. In Trans. Am. Inst. Min. Eng., vol. 25, pp. 19–28. 1896.

——— A brief reconnaissance of the Tennessee phosphate field. In Twentieth Ann. Rept., pt. 6, pp. 633–638. 1899.

——— The geological relations of the Tennessee brown phosphates. In Science, vol. 12, p. 1005. 1900.

HAYES, C. W. Tennessee white phosphate. In Twenty-first Ann. Rept., pt. 3, pp. 473–485. 1901.

——— Origin and extent of the Tennessee white phosphates. In Bulletin No. 213, pp. 418–423. 1903. 25c.

HESS, F. L. A reconnaissance of the gypsum deposits of California. (In preparation.)

IHLSENG, M. C. A phosphate prospect in Pennsylvania. In Seventeenth Ann. Rept., pt. 3, pp. 955–957. 1896.

MEMMINGER, C. G. Commercial development of the Tennessee phosphates. In Sixteenth Ann. Rept., pt. 4, pp. 631–635. 1895. $1.20.

MOSES, O. A. The phosphate deposits of South Carolina. In Mineral Resources U. S. for 1882, pp. 504–521. 1883. 50c.

ORTON, E. Gypsum or land plaster in Ohio. In Mineral Resources U. S. for 1887, pp. 596–601. 1888. 50c.

PENROSE, R. A. F. Nature and origin of deposits of phosphate of lime. Bulletin No. 46. 143 pp. 1888. Exhausted.

PURDUE, A. H. Developed phosphate deposits of northern Arkansas. In Bulletin No. 315, pp. 463–473. 1907.

SIEBENTHAL, C. E. (See Darton, N. H., and Siebenthal, C. E.)

STOSE, G. W. Phosphorus ore at Mount Holly Springs, Pennsylvania. In Bulletin No. 315, pp. 474–483. 1907.

——— Phosphorus. In Mineral Resources U. S. for 1906, pp. 1084–1090. 1907. 50c.

STUBBS, W. C. Phosphates of Alabama. In Mineral Resources U. S. for 1883–84, pp. 794–803. 1885. 60c.

VAN HORN, F. B. Phosphate rock. In Mineral Resources U. S. for 1907, pt. 2, pp. 651–657. 1908.

WEEKS, F. B. Phosphate deposits in the western United States. In Bulletin No. 340, pp. 441–447. 1908.

WEEKS, F. B., and FERRIER, W. F. Phosphate deposits in western United States. In Bulletin No. 315, pp. 449–462. 1907.

WILBER, F. A. Greensand marls in the United States. In Mineral Resources U. S. for 1882, pp. 522–526. 1883. 50c.