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M. M. LEIGHTON, *Chief*
URBANA

REPORT OF INVESTIGATIONS—NO. 128

CLAY AND SHALE RESOURCES OF EXTREME SOUTHERN ILLINOIS

BY

J. E. LAMAR

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS

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Topographic Mapping in Cooperation with the United States Geological Survey.

This report is a contribution of the Division of Industrial Minerals.

December 15, 1947

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CLAYS AND SHALES OF EXTREME SOUTHERN ILLINOIS

BY

J. E. LAMAR

SUMMARY

EXTREME southern Illinois contains a wide variety of clays and shales including fuller's earth, kaolin, refractory clays, semi-refractory clays for stoneware, roofing tile, sewer pipe and brick, and non-refractory clays for pottery, terra cotta, ornamental tile, hollow tile, drain tile, brick and other structural products.

The clays and shales occur as parts of older geologic formations that range from Ordovician to Pennsylvanian in age, and as younger unconsolidated formations of Cretaceous, Eocene, Pliocene, and Pleistocene ages. The clays and shales of the older formations are found chiefly in Hardin, Pope, Johnson, Union, and Alexander counties, and the younger clays in Alexander, Union, Pulaski, and Massac counties. Best known of the southern Illinois clays are the fuller's earth of Pulaski County and the kaolin of Union County. The latter was widely used during the first World War for the manufacture of crucibles.

Deposits of the older shales and clays are relatively extensive and constant in character, and a number of them appear suitable for open-pit mining and an additional number for subsurface mining. Many of the deposits are available to railroad transportation; a few to water transportation.

The younger clays, in general, vary laterally in character and thickness. Their position is usually nearly horizontal except where they have slid and settled to conform to an uneven bedrock surface below and are therefore moderately or locally steeply inclined. This condition is common in the bluff regions or dissected uplands adjacent to Ohio, Mississippi, and Cache rivers. There are probably relatively extensive flat-lying deposits in some of the broader upland tracts which prospecting may show to be of commercial size. Some of these areas are accessible to rail or water transportation. In the much dissected country only the refractory clays and other clays of relatively high market value are apt to have commercial possibilities, because the nature of the deposits probably will involve relatively high-cost production operations.

CHAPTER 1—DEPOSITS, THEIR GEOLOGY AND EXPLORATION

INTRODUCTION

The region south of the Illinois coal fields, commonly known as extreme southern Illinois (fig. 1), contains a greater variety of clays than any other portion of the State of equal area but the commercial development of these resources is not commensurate with their diversity. This is due to a number of factors but may be attributed in part to the fact that the variety and quality of the clays are not more generally known. This report has been prepared, therefore, to make available information concerning these clays. It brings together important previously published descriptions of deposits and results of tests, particularly such data in publications now out of print, and adds much new data including especially the results of a study of clay deposits near enough to rail or water transportation to be of possible economic value in Union, Alexander, Pulaski, Massac, Pope, Johnson, and Hardin counties. Additional data are presented regarding materials which, though not now of evident commercial importance, may be of future significance. The report describes the principal types of clay found in southern Illinois, and it is believed that the general character of the clay of any undescribed deposit can be ascertained from the information presented concerning similar adjacent deposits.

The discussion of resources is presented by counties, and the resources are described in order of their age, beginning with the oldest—the bedrock formations. Generally it is not feasible to describe all outcrops in detail but for each group of clays or shales one or more typical or outstanding outcrops are described and identified by number, as "Outcrop 2," for reference. Other outcrops are described because they are the best available and because, though not necessarily of commercial significance in themselves, they suggest that clay deposits of possible commercial importance may occur in the vicinity. Some outcrops of clay, usually of Cretaceous age, which are now slumped and mostly obscured, are described as they ap-

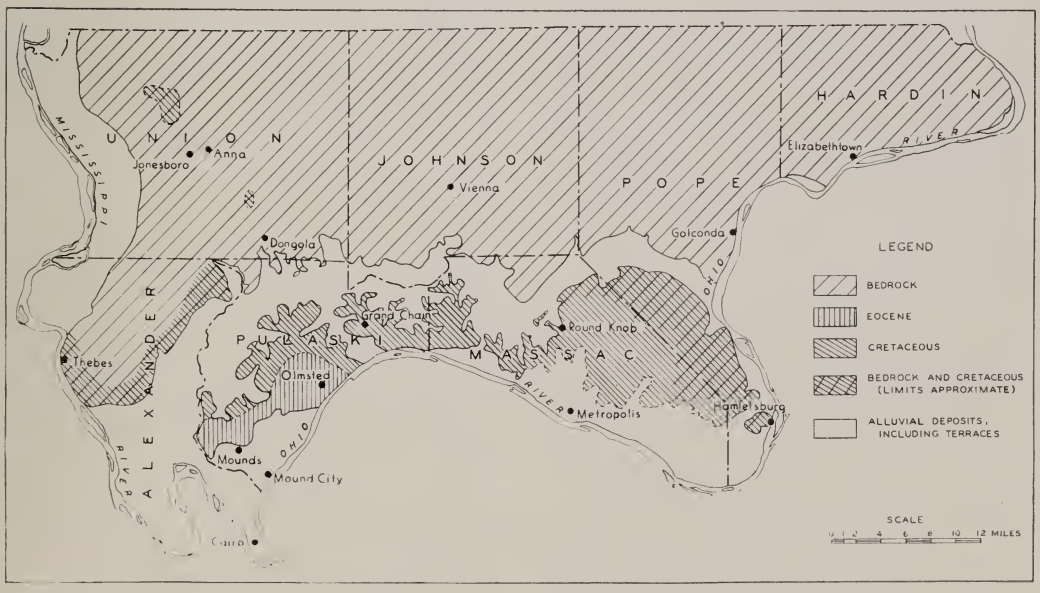

FIG. 1.—Generalized geologic map of extreme southern Illinois.

peared when fresh some years ago. A number of these deposits contain clay of possible commercial value, but others do not though they may appear to in the slumped outcrops. These last are described in order to present a true picture of their character and thus to prevent the drawing of incorrect inferences regarding clay possibilities.

The tests made on samples taken during this investigation are for the most part ceramic tests, intended to show their possibilities for making burned clay products, and chemical analyses. However, data are given on the possibilities of a number of samples as bonding clays for synthetic molding sands as well as on several typical highly colored clays as mineral pigments. Specific tests were not made to determine the suitability of the samples for making light weight burned clay aggregates or for various uses of clay in the unburned state, chiefly because of the considerable number of different tests involved. However, the information given by the ceramic tests, the clay mineral identifications, and the chemical analyses make possible a general evaluation of the clays and shales for many of those uses for which specific test data are not given.

Acknowledgments

The writer expresses his appreciation for the helpful assistance of the following people in locating, examining, and sampling certain deposits: the late J. C. Boyd of the Illinois Kaolin Company, Anna; A. M. Davis of the Illinois Minerals Company, Cairo; William Ferrill of Jonesboro; Henry Grothman of Round Knob; W. E. Kreitner of Cairo; and P. C. Shaver of Thebes. The able assistance of Carl E. Dutton in the field work is likewise gratefully acknowledged.

The clay and shale samples taken during the field study were tested by the Department of Ceramic Engineering of the University of Illinois, under the direction of the late C. W. Parmelee, Professor of Ceramic Engineering, *Emeritus*. Identification of clay minerals in samples was made by R. E. Grim, Petrographer, Illinois State Geological Survey.

AREAS OF CLAY PRODUCTION

The clay and shale deposits of southern Illinois, excepting the fuller's earth at Olmsted, are not now extensively worked, but a number of the deposits were at one time the source of considerable quantities of clay. These areas are briefly described below.

Kaolin Area

The Kaolin area centers about Kaolin station on the Gulf, Mobile, and Ohio Railroad near the center of the S. ½ sec. 35, T. 11 S., R. 2 W., Union County. This region reached its peak production during the time of the first World War when refractory clays were at a premium because imports of German clay were cut off. At that time eight mines having railroad facilities were operated, as well as a number of small pits some distance from such transportation. The clay was used largely in the manufacture of crucibles and glass pots. Activities in the Kaolin area gradually declined after the war and, in recent years production has been relatively small and intermittent. In 1946 W. P. Mautz operated a pit in the Kaolin area.

Choat Area

At Choat, in Massac County, the Paducah Pottery Company operated a small clay pit which has been a source of some of the raw material used in their pottery at Paducah.

Olive Branch Area

During the latter part of the spring of 1928, the Olive Branch Mineral Products Company began to mine a deposit of white clay and silica near Olive Branch. The clay and associated silica are separated hydraulically.

Round Knob Area

Three abandoned pits are evidence of former mining near Round Knob, Massac County. In 1905, clay was shipped by rail to Paducah, Kentucky, and hauled by wagon to Metropolis where it was used at two potteries.[1]

[1] Purdy, C. R., and F. W. DeWolf, Preliminary investigation of Illinois fireclays: Illinois Geol. Survey Bull. 4, p. 139, 1907.

Ullin Area

The Egypt Brick and Tile Company located at the east margin of the town of Ullin, Pulaski County, manufactured brick and tile until 1926 when the last production was reported. The clay, dug from the flood-plain of Cache River, burned a good quality ware said to be of fine red color. Operations were on a comparatively small scale and the output of the plant was sold locally.

Jonesboro Area

A quarry and a crushing plant are said to have been operated to produce roofing chips from the hard slaty Springville shale west of Jonesboro, Union County, in the NE. ¼ NE. ¼ sec. 23, T. 12 S., R. 2 W. The shale is reported to have had unsatisfactory weather resistance and quarrying was therefore discontinued.

Gale Area

The Illinois Minerals Company at one time mined a siliceous clay in a chert formation, probably the Bailey formation, about a third of a mile southeast of Gale, Alexander County.

Thebes Area

The Ozark Minerals Company of Elco produces a light gray clay from a deposit along the Missouri Pacific Railroad about 2½ miles south of Thebes, Alexander County.

Olmsted Area

At Olmsted in Pulaski County the mining and processing of fuller's earth was begun in 1920 by the Sinclair Refining Company, and later the Standard Oil Company of Indiana opened another deposit and plant. The Sinclair Company is now the only operator.

Other Areas

In the region covered by this report relatively small amounts of clay have been dug at numerous other places. Among them may be mentioned deposits at Yates Landing, Grand Chain Landing, and Pulaski, all in Pulaski County, which were likewise the sites of potteries that used the clays.[2] Apparently an appreciable amount of clay also was dug from the "clay diggings" near Raum in Pope County. This deposit was undeveloped in 1866[3] but appears to have been worked between that time and 1906.[4]

GENERAL GEOLOGY

The geology of extreme southern Illinois is varied and in some places complex. The large number of bedrock formations that outcrop in the area make it impracticable to include here a satisfactory geologic map showing their distribution. However, such maps and details of stratigraphy are given in a number of published reports.[5]

Figure 1 shows the general distribution of the Cretaceous-Tertiary formations which are important clay bearers in extreme southern Illinois. These data are not elsewhere adequately available.

The geologic column (table 1) gives the sequence of formations in southern Illinois, their names, and approximate thicknesses as known from outcrops or wells. The asterisk (*) indicates formations that are of particular interest in this investigation.

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[2] Purdy, C. R., and F. W. DeWolf, Preliminary investigation of Illinois fireclays: Illinois Geol. Survey Bull. 4, pp. 139, 149, and 153, 1907.

[3] Englemann, Henry, in Geol. Survey of Illinois, vol. I, p. 493, 1866.

[4] Purdy, C. R., and F. W. DeWolf, op. cit., p. 172.

[5] Weller, Stuart, with the collaboration of Charles Butts, L. W. Currier, R. D. Salisbury, and others, Geology of Hardin County and adjoining part of Pope County: Illinois Geol. Survey Bull. 41, 1920. (Out of print.)

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Weller, J. M., Geology and oil possibilities of extreme southern Illinois: Illinois Geol. Survey Rept. Inv. 71, 1940.

Weller, J. M., Devonian system in southern Illinois: Illinois Geol. Survey Bull. 68, pp. 89–102, 1944.

TABLE 1.—GENERALIZED SECTION OF FORMATIONS OCCURRING IN EXTREME SOUTHERN ILLINOIS†

	Approximate thickness *Feet*
Cenozoic	
Recent system	
*Gravel, sand, silt, and clay in the flood-plains of present streams, particularly Mississippi, Ohio, and Cache rivers	0–100
Pleistocene system	
*Loess: brown, noncalcareous; found in uplands	0–35
*Loess: gray, found on the margins of the highlands bordering the alluvial flats south of Gale and in the vicinity of Cache	0–30
*Valley-fill; clay, sand, silt and gravel in terraces along streams and beneath their flood-plains	0–150
Pliocene system	
Clay: red and brown, containing sand, gravel or angular sandstone fragments; best developed in Massac County	0–6
"Lafayette" formation	
Chert gravel; brown; locally underlain by coarse red sand	0–40
Eocene system	
*Wilcox group	
Clay and sand formations interbedded; clays dominantly white, gray or pinkish. Exposed in Pulaski County	0–25±
Paleocene system	
Midway group	
*Porters Creek formation	
Clay dominantly buff-gray, gray-black or blue-gray, locally sandy in the basal portion; upper part of the formation is the source of the fuller's earth at Olmsted; outcrops in Pulaski County	125
Mesozoic	
Cretaceous system	
Gulf series	
*McNairy formation	
Sand and clay formations interbedded; clays gray, white, pink, locally greenish; locally highly silty; thin lignitic clay or lignite layers in places. The clays worked at Kaolin, Union Co. are probably part of this formation. Exposed in Union, Alexander, Pulaski, Massac, and Pope counties	350±
Paleozoic	
Pennsylvanian system	
*Tradewater and Caseyville groups	
Thick sandstones; a few coal beds; clays and shales. Exposed in Union, Johnson, Pope, and Hardin counties	600±
Mississippian system	
*Chester series	
Limestones, alternating with sandstone or shale formations. Exposed in Union, Johnson, Pope, Hardin, and Massac counties	1000±
Iowa series	
Meremec and Osage groups	
Principally limestone, some of it cherty	900–1050
Kinderhook group	
*Springville formation	
Shale: blue-gray or greenish, locally siliceous and resembling slate; outcrops in Union and Alexander counties	0–60
Devonian system	
Upper Devonian series	
Chautauquan group	
*Mountain Glen formation	
Shale: black, laminated. Exposed in Union, Alexander, and Hardin counties	0–50
Senecan group	
*Alto formation	
Shale and limestone; shale is greenish-gray, buff, or gray, usually in relatively thick beds. Exposed in Union County	100±
Middle Devonian series	
Erian group	
*Lingle limestone and shale	100±
Shale: gray, buff, or mottled, thick-bedded. Exposed in Union County	

Table 1.—Generalized Section of Formations Occurring in Extreme Southern Illinois—(Contd.)

	Approximate thickness *Feet*
Ulsterian group	
Limestone, sandstone and chert	300–450
Lower Devonian series	
Oriskanian group	
Backbone limestone formation	150±
*Grassy Knob chert	
Mostly chert but includes locally clay interbedded with tripoli and chert. Exposed in Alexander and Union counties	185±
Helderbergian group	
*Bailey limestone and chert	
Siliceous limestone containing numerous nodules and layers of chert. When leached of carbonate gives rise locally to irregular bodies of white clay. Exposed in Union and Alexander counties	200–350
Silurian system	
Niagaran series	
*Bainbridge limestone and shale	40±
Alexandrian series	
*Sexton Creek limestone and shale	
Limestone: granular, interbedded with greenish or red shale. Exposed in Alexander and Union counties	10–50
Edgewood formation	10±
Girardeau limestone	40±
*Orchard Creek formation	
Shale: calcareous, blue-gray; locally containing thin limestone beds. Exposed in Alexander County	20–25
Ordovician system	
Sandstone and limestone	175–200

† Data on Pennsylvanian and older strata principally from Weller, J. M., Geology and oil possibilities of extreme southern Illinois: Illinois Geol. Survey Rept. Inv. 71, 1940.
Weller, J. M., Devonian system in southern Illinois; Illinois Geol. Survey Bull. 68, 1944, pp. 89–102.
* Clay or shale from this formation described in this report.

SAMPLING

The samples for which tests or analyses are given in this report include some that were taken during earlier investigations as well as those taken during the current investigation. The procedure by which the earlier samples were obtained is not known, but they are believed to be reasonably representative of the exposures available and therefore worth including, especially as some of the deposits they represent are now obscured.

The samples taken during the present investigation represent the average character of the clay deposits as accurately as possible, although sampling procedure varied according to the extent and kind of exposure. Usually, weathered or contaminated clay was first removed from a strip vertical to the deposit and about two feet wide. From all parts of this cleaned area, roughly equal amounts of clay were taken to make up a sample of 35 pounds or more.

COMPARABILITY OF TEST DATA

This report contains the results of ceramic tests from Illinois Geological Survey Bulletins 4[6] and 38D[7], dated 1907 and 1921 respectively, as well as a large amount of new test data. The results of ceramic tests and chemical analyses taken from Bulletin 4 all have the letter "D" prefixed to the identifying sample number, as D-44; ceramic tests from Bulletin 38D are prefixed by the letters "PS", as PS-62. In general the new data and those taken from Bulletin 38D result from approximately the same methods of testing, described on pages 19 to 30 in that Bulletin, and are therefore in general comparable. The ceramic tests reported from Bulletin 4 were made by somewhat different methods and are probably not closely comparable with the later data.

[6] Purdy, R. C., and F. W. DeWolf, Preliminary investigation of Illinois fireclays, in Illinois Geol. Survey, Bull. 4, "Yearbook for 1906," pp. 131 to 175, 1907.
[7] Parmelee, C. W., and C. R. Schroyer, Further investigation of Illinois fireclays: in Illinois Geol. Survey. Bull. 38D, 1921.

Details regarding the methods of testing used are described on pages 135 to 137 of Bulletin 4. However, it is worthy of note here that plasticity, as reported in Bulletin 4, was determined by comparing the plasticity of the samples with the following arbitrary standards.

A—Tennessee ball clay No. 3.
B—4 parts of Tennessee ball clay and 1 part of flint.
C—2 parts of Tennessee ball clay and 3 parts of flint.
D—1 part of Tennessee ball clay and 4 parts of flint.

The mechanical analyses of samples, as reported in Bulletin 4, include data on "Moisture" and "Volatile." As these items are not now commonly included in mechanical analyses, the data in Bulletin 4 have been recalculated to exclude these determinations.

OCCURRENCE AND EXPLORATION

The clays and shales associated with the consolidated bedrock formations of extreme southern Illinois are essentially flat-lying or have only small or moderate dip. These formations may thicken and thin or vary in character from place to place, but in general the ordinary drilling procedures used in exploring such deposits as coal or limestone will bring out the variations in the clay and shale deposits.

Residual clays, resulting from the weathering of limestone, usually rest on an uneven limestone floor, have a tendency to slump down slopes, and are often thicker on the upper slopes of ridges than on the crests. Deposits of these clays therefore require careful exploration by drilling or test-pitting.

Loess deposits are apt to be fairly uniform in their major characteristics over a reasonable area and frequently from top to bottom, but they should be drilled or test-pitted to determine uniformity. The same applies to a lesser extent to clays and clayey silts in the valley-flats of streams or terraces along streams, but not necessarily to materials in present flood-plains.

The Cretaceous-Eocene clays, probably with the exception of the Porters Creek formation, occur in such a manner as to require detailed prospecting by drilling or test-pitting, chiefly because the clays and some of the sands are plastic when wet, so that they are unstable on slopes. Thus if normally flat-lying Cretaceous-Eocene sediments are cut into by valleys, they often slump and slide. Such action is not always restricted to areas near the outcrop but is known to occur as much as 750 feet from the outcrop.[8]

Another significant feature of many Cretaceous-Eocene deposits is that they rest on an irregular bedrock surface. This appears to have been the cause of considerable slumping and sliding of some deposits and results in "pockety" clay deposits.

Still another feature of the Cretaceous-Eocene clays, except the Porters Creek formation, is that some deposits show relatively abrupt changes in thickness and character that are related to conditions of original deposition rather than to slumping from causes mentioned above.

The crests of hills and ridges are therefore most likely to contain undisturbed deposits of Cretaceous-Eocene clays, and data obtained from surface exploration of deposits on hill slopes may be misleading, especially as to the thickness of the deposits. Examples of conditions described are shown in figure 2. *A* shows how the outcrop thickness of a flat-lying deposit may be misleading. Its true thickness is revealed by drilling. *B* illustrates the need for drilling to discover depositional or erosional thinning of clays, whereas *C* pictures another effect of slumping which exaggerates the apparent outcrop thickness of a clay bed and gives a false conception of the vertical position of the clay body. Note also the irregular thickness of the sandy clay bed and the abnormal thickness developed by slumping on the slope of the hill.

[8] Lamar, J. E., and A. H. Sutton, op. cit., pp. 681, 682.

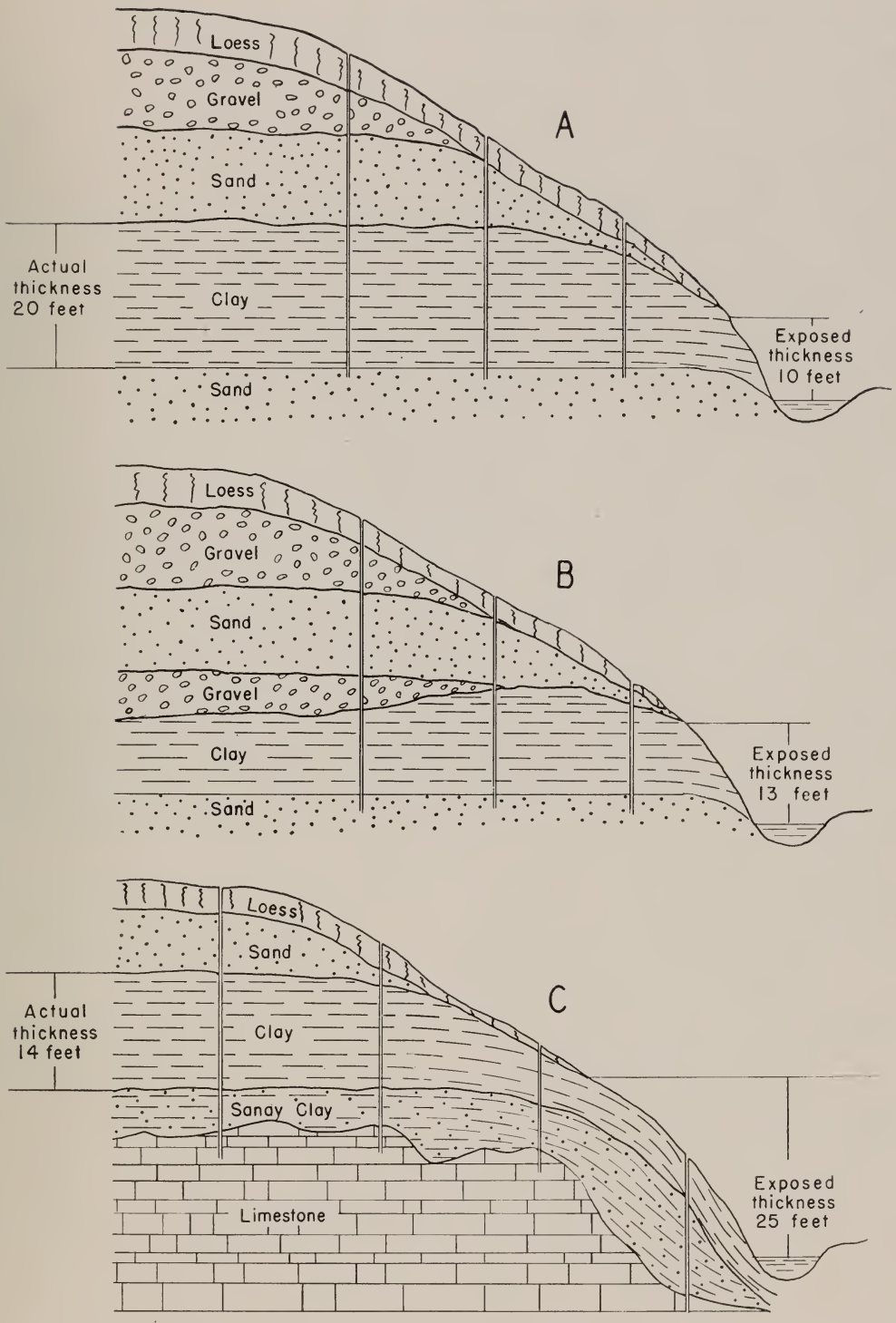

FIG. 2.—Possible erratic relations between apparent and actual thickness of clay strata.

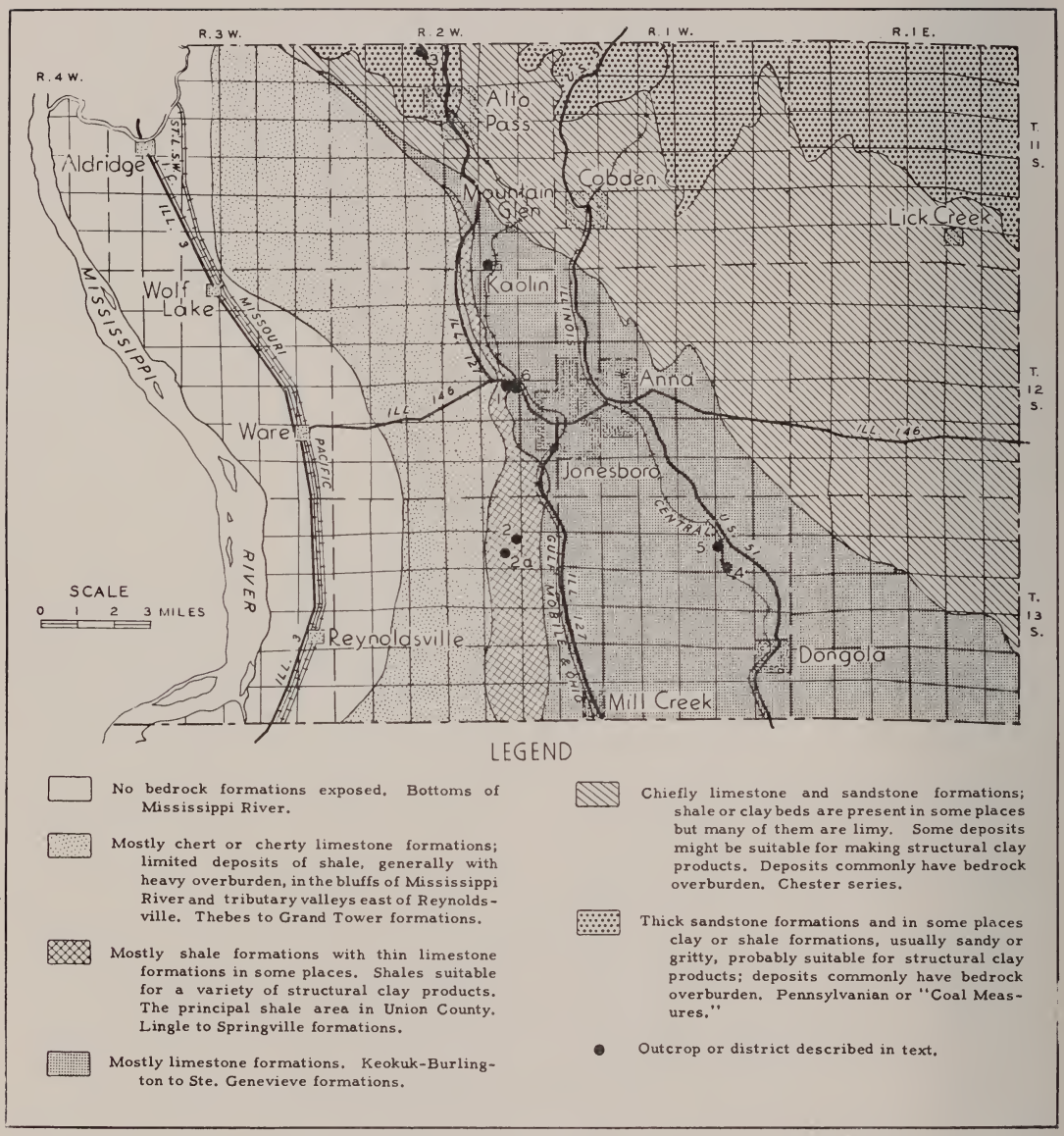

FIG. 3.—Character of bedrock formations in Union County and their clay and shale resources.

CHAPTER 2--UNION COUNTY RESOURCES

The clay and shale resources of Union County consist of bedrock deposits, deposits probably of Cretaceous age, residual clays, alluvial clays, and loess.

BEDROCK CLAYS AND SHALES

The general distribution of the bedrock clays and shales of Union County and their character as ceramic materials is indicated in figure 3. The most promising area is the narrow north-south band lying west of Jonesboro and Mill Creek. Here the Springville formation (about 60 feet thick) and the Mountain Glen shale formation (about 50 feet thick) afford material that is probably suitable for making a variety of structural clay products.

Lingle Shale

The shale of the Lingle formation, which also includes limestone, is not well exposed near a railroad in Union County. At more distant points, however, typical outcrops occur in the south bank of Darty Creek in the SE. ¼ sec. 10, T. 12 S., R. 2 W., along Lingle Creek in the southwest part of sec. 26, and along Meisenheimer Creek in the west part of sec. 35, T. 13 S., R. 2 W.[1] The shale is gray, gritty, and locally calcareous. The use of the shale in the ceramic field would probably be limited to structural clay products.

Mountain Glen Shale

The Mountain Glen shale is a thin-bedded hard brittle brownish-black or black shale. The best outcrops occur near the State Pond in the SE. ¼ SW. ¼ sec. 14, T. 12 S., R. 2 W., and in the W. ½ SW. ¼ sec. 11, of the same township. The shale is normally not plastic but structural clay products may possibly be made from it.

The average potash (K_2O) content of nine samples of Mountain Glen shale was 5.48 percent as compared with 2.90 percent for 8 samples of other shale formations from the northern half of Illinois.[2] The possibility of using the Mountain Glen shale in cement making and recovering the potash as a by-product has been suggested.[2] Also preliminary data point out that the shale is worth further investigation as a fertilizer because of its potash content.[3] Another possible use of the shale, if finely ground, might be as a black mineral filler or pigment. Two chemical analyses of Union County Mountain Glen shale are given in table 2, samples 1 and 2.

Springville Shale

The Springville shale formation is mainly a greenish or brownish, medium to thick-bedded shale. The upper part of the formation is commonly more siliceous than the lower part and in some places is hard enough to resemble slate. Locally the shale is white or cream, mottled with pink, red, and purple blotches and is commonly known as "calico shale." Good outcrops occur on Harrison Creek in the center W. ½ SE. ¼ sec. 1, T. 13 S., R. 2 W., and center E. ½ NE. ¼ sec. 11, and along Lingle Creek in sec. 26 of the same township. Another good exposure is found along the Gulf, Mobile and Ohio Railroad at the center sec. 36, T. 12 S., R. 2 W. The silicified phase may be seen in an old quarry along the concrete road in the NW. ¼ NE. ¼ NE. ¼ sec. 23, T. 12 S., R. 2 W. This deposit is described in more detail as Outcrop 1 below. The outcrop in sec. 11 is described as Outcrop 2.

Two ceramic tests of Springville shale are given under the discussion of Outcrop 2. They indicate that the samples may be suitable for the manufacture of building brick and possibly for quarry or floor tile, roofing tile, hollow tile and drain tile. Table 2, p. 18, gives three chemical analyses of Springville shale, samples LM-14, NF-413, and W-286. The last of these samples came from a 40-foot exposure in the NE.

[1] Weller, J. M., and George E. Ekblaw, Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes quadrangles: Illinois Geol. Survey Rept. Inv, 70. pp. 16, 17, 1940.

[2] Schroyer, C. R., Notes on potash possibilities in Illinois: Illinois Geol. Survey Bull. 38, p. 437, 1922.

[3] Parr, S. W., M. M. Austin, Frank Krey, and Robert Stewart, Potash shales of Illinois: Univ. of Ill. Agric. Expt. Station Bull. 232, March, 1921.

TABLE 2.—CHEMICAL ANALY-

Sample No.	County	Location near	Formation	Thickness sampled ft.
1 [b]	Union		Mt. Glen shale	—
2 [b]	Union		Mt. Glen shale	—
LM–14 [a]	Union	Mill Creek	Springville shale	10
NF–413 [a]	Union	Mill Creek	Springville shale	7
W–286 [c]	Union	Springville	Springville (?) shale	40
L–11 [c]	Union	Cobden	Chester shale	10
L–16 [d]	Union	Anna	Renault shale	16
AK [a]	Union	Kaolin	Cretaceous (?) kaolin	—
R–83 [c]	Union	Kaolin	Cretaceous (?) kaolin	—
L–10 [c]	Union	Anna	Loess	—
DS–4 [a]	Alexander	Gale	Loess	48
D–44 [f]	Pulaski	Unity	Devonian clay	10
D–45 [g]	Pulaski	Pulaski	Cretaceous clay	9
D–46 [g]	Pulaski	Pulaski	Cretaceous clay	5
B–4 [a]	Pulaski	Grand Chain	Cretaceous clay	13
D–36 [h]	Pulaski	Dam 53	Cretaceous clay	—
D–33 [h]	Pulaski	Yates Landing	Cretaceous clay	8
La–3 [a]	Pulaski	Olmsted	Porters Creek clay	15
FE–116 [a]	Pulaski	Olmsted	Porters Creek clay	20
D–28 [j]	Massac	Round Knob	Cretaceous clay	6
D–29 [j]	Massac	Round Knob	Cretaceous clay	—
D–30 [j]	Massac	Round Knob	Cretaceous clay	6
D–31 [j]	Massac	Round Knob	Cretaceous clay	7½
D–32 [k]	Massac		Cretaceous clay	4
D–50 [l]	Massac	Unionville	Cretaceous clay	2
Bu–21 [c]	Pope	Golconda	Chester shale	5½
Bu–22 [c]	Pope	Golconda	Chester shale	5½
Bu–23 [c]	Pope	Golconda	Chester shale	6½
D–34 [m]	Pope	Rosebud	Cretaceous clay	3
D–35 [m]	Pope	Rosebud	Cretaceous clay	2
D–56 [n]	Pope	Raum		—
B–21 [a]	Hardin	Eichorn	Residual clay	7

* Described as "moisture" and "volatile" respectively in source of analyses.

[a] Analysis by Geochemical Section, Illinois State Geological Survey.

[b] Schroyer, C. R., Notes on potash possibilities in Illinois: Illinois Geol. Survey Bull. 38, p. 437, 1922.

[c] Bleininger, A. V., Lines, E. F., and Layman, F. E., Portland cement resources of Illinois: Illinois Geol. Survey Bull. 17, 1912, pp. 104, 111 and 113.

[d] Lamar, J. F., and Willman, H. B., Fryling, C. F., and Voskuil, W. H., Rock wool from Illinois mineral resources: Illinois Geol. Survey Bull. 61, 1934, p. 150.

[e] Piersol, R. J., Lamar, J. E., and Voskuil, W. H., Anna "kaolin" as a new decolorizing agent for vegetable oils: Illinois Geol. Survey, Rept. Inv. 27, 1933, p. 25.

SES OF CLAYS AND SHALES

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	CO_2	H_2O-	Loss on ignition	Remarks
53.8	.....	17.7	5.8	1.8	0.7	0.5	5.0	.....	.....	11.9	
55.0	.....	16.3	6.0	1.5	0.3	0.4	4.9	.....	.....	13.0	
78.63	0.60	11.36	2.33	0.79	0.10	0.11	2.68	0.04	1.24	3.38	
77.88	0.66	12.85	1.61	0.97	0.33	0.17	2.60	.....	0.78	3.44	"Calico shale"
71.24	.....	13.74	.....	1.50	5.32	.....	.....	.....	.....	7.66	
64.78	.....	18.17	6.74	1.69	1.43	.....	.....	.....	.....	5.62	
46.54	.....	17.85	0.43	2.01	14.05	.....	.....	.....	.....	.....	
51.10	0.95	34.01	1.41	0.37	0.15	0.36	0.31	.....	2.14	11.95	From "Boyd" pit
48.52	1.21	30.94	1.60	0.85	1.03	0.01	0.29	.....	0.74	14.21	Washed kaolin
73.10	.....	13.45	5.33	2.18	2.12	.....	.....	.....	.....	2.86	FeO–0.40; P_2O_5–0.91
63.96	.....	13.76	3.27	5.11	5.17	.....	.....	5.52	.....	8.82	
69.92	0.98	20.19	1.21	.....	.....	.....	.....	.....	1.11*	6.35*	
62.76	0.97	22.36	3.07	.....	.....	.....	.....	.....	2.99*	6.12*	
57.14	1.08	25.52	2.82	.....	.....	.....	.....	.....	3.48*	8.12*	
59.60	0.72	26.48	2.39	0.77	0.44	0.37	1.67	.....	2.74	8.03	
68.26	1.14	20.87	1.70	.....	.....	.....	.....	.....	1.90*	5.56*	
67.54	0.78	21.54	1.70	.....	.....	.....	.....	.....	2.48*	6.29*	
69.07	0.84	11.87	4.36	1.79	0.85	0.00	1.40	0.03	.....	10.21	Lower part of formation
61.06	0.21	15.99	4.50	2.00	0.86	0.07	1.43	.....	5.88	13.36	Commercial fuller's earth: FeO–0.12
66.04	1.60	22.00	1.60	.....	.....	.....	.....	.....	1.64*	6.81*	
71.58	1.40	18.31	1.51	.....	.....	.....	.....	.....	1.41*	5.27*	
60.50	1.40	22.52	3.84	.....	.....	.....	.....	.....	3.44*	7.52*	
69.46	1.64	18.82	1.32	.....	.....	.....	.....	.....	1.13*	5.31*	
64.88	1.26	21.54	1.86	.....	.....	.....	.....	.....	2.58*	6.83*	
63.32	0.48	19.25	4.09	.....	.....	.....	.....	.....	3.55*	6.02*	
60.75	.....	20.49	7.30	1.73	0.52	.....	.....	.....	.....	6.05	
59.97	.....	21.00	7.15	1.58	0.60	.....	.....	.....	.....	5.54	
59.90	.....	20.27	6.80	1.66	1.14	.....	.....	.....	.....	6.70	
63.20	1.04	22.60	2.50	.....	.....	.....	.....	.....	3.36*	7.04*	
61.20	1.36	24.11	1.89	.....	.....	.....	.....	.....	3.88*	7.20*	
58.06	0.14	26.57	1.23	.....	.....	.....	.....	.....	4.62*	9.84*	Halloysite clay
56.96	0.37	23.47	8.84	0.82	0.53	0.30	1.56	.....	3.58	7.92	

[f] Purdy, R. C., and DeWolf, F. W., Preliminary investigation of Illinois fire clays: Illinois Geol. Survey Bull. 4, Yearbook for 1906, 1907, p. 156.
[g] Idem. p. 157.
[h] Idem. p. 153.
[i] Idem. pp. 150, 151.
[j] Idem. p. 149.
[k] Idem. p. 152.
[l] Idem. p. 159.
[m] Idem. p. 155.
[n] Idem. p. 173.

¼ SE. ¼ sec. 1, T. 13 S., R. 2 W., and is probably Springville shale. The clay mineral in the Springville shale is illite and the chemical analyses suggest that with it there is a large amount of free quartz.

No use is being made of the Springville shale at present.

Outcrop 1

In an abandoned quarry in the SW. corner, NW. ¼ NE. ¼ NE. ¼ sec. 23, T. 12 S., R. 2 W., along a concrete road, there is exposed 42 feet of hard, brittle, siliceous shale, belonging to the Springville formation. The lower part of the exposure is slightly calcareous. The upper 28 feet of shale is buff or gray, and the shale occurs in relatively thick beds when fresh, but weathers into thin slabby, irregular fragments. The lower 14 feet of shale is blue-gray or greenish-gray and well-bedded. It weathers into thin flakes.

The overburden on the shale ranges from a few feet to about 100 feet at the top of the ridge. It is believed, however, that a relatively large amount of shale under less than 20 feet of cover can be obtained by working along the edge of the hill.

The quarry in which this exposure occurs is reported to have been worked at one time as a source of natural roofing granules. The operation is said to have been abandoned because the granules had unsatisfactory weather resistance.

Both types of shales exposed were sampled but neither had sufficient plasticity by itself

Sample L-12.—Springville Shale

Kind of material ..... shale

Drying conduct ..... good

Volume drying shrinkage ..... *percent* 12.73

Linear drying shrinkage ..... *percent* 4.44

Water of plasticity ..... *percent* 31.70

Bonding strength—Modulus of rupture ..... *lbs. per sq. in.* 103.8

Bulk specific gravity 1.66

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Fracture
02	18.95	6.76	18.11	Bright red	Granular
3½	12.14	4.22	.....	Bright red	Granular
5	26.82	9.89	0.0	Reddish-brown	Granular
6	29.41	10.96	1.31	Dark red	Granular
8	28.06	10.40	2.62	Dark red	Granular

Fusion test: Shale not refractory.

Oxidizing conduct: Poor.

Summary: Drying shrinkage is medium low; bonding strength medium low; vitrification complete at cone 5; shrinkage at cone 5 medium.

Suggested uses: Building brick, possibly quarry tile, roofing tile, hollow tile, and drain tile.

to make clay products. The chief use of the shales in this field appears to be as an admixture with highly plastic clays to decrease their plasticity. The samples were nonrefractory.

Outcrop 2

About 50 feet of Springville shale outcrops in the bluff on the south side of Harrison Creek at the center E. ½ NE. ¼ sec. 11, T. 13 S., R. 2 W. The bluff extends for about half a mile in the northeast quarter of sec. 11 and into the NW. ¼ NW. ¼ sec 12, and outcrops of shale occur at intervals either in the bed of Harrison Creek or in tributary valleys.

The shale occurs in beds from 1 to 2 inches thick and is mostly buff in color, although it is locally white, brown, or pink. Where the shale has been subject to frequent wetting it has weathered to a plastic clay. Locally the shale contains inconspicuous gritty layers and small masses of quartz. The upper 30 feet of the shale is somewhat harder and browner than the lower 20 feet. Two samples, for which results of ceramic tests follow, were taken from this outcrop. Sample L-12 was taken from the basal 15 feet of the upper 30 feet of shale; the upper 15 feet were inaccessible for sampling. Sample L-13 came from the lower 20 feet of shale.

SAMPLE L-13.—SPRINGVILLE SHALE

Kind of material ..... shale

Drying conduct ..... good

Cracks; rough texture

Volume drying shrinkage ..... *percent* 6.95

Linear drying shrinkage ..... *percent* 2.38

Water of plasticity ..... *percent* 23.40

Bonding strength—Modulus of rupture ..... *lbs. per sq. in.* 158.3

Bulk specific gravity 1.71

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Fracture
02	5.87	2.00	26.80	Light red	Hackly
2	7.75	2.65	25.42	Light red	Hackly
3	11.09	3.84	18.28	Brownish-red, black spots	Hackly
6	12.04	4.18	17.31	Brownish-red, black spots	Hackly
8	11.62	4.04	19.19	Pinkish (reduced), buff and black spots	Hackly
9½	12.25	4.26	16.81	Buff, black spots	Hackly
11	13.71	4.80	13.59	Grayish-buff, black spots	Hackly

Fusion test: Fusion point, pyrometric cone equivalent 13.

Oxidizing conduct: Medium.

Summary: Drying shrinkage low; bonding strength medium low; vitrification incomplete at cone 11; shrinkage at cone 11 medium low. Nonrefractory shale.

Suggested uses: Building brick, possibly roofing tile, quarry tile, and drain tile.

Outcrop 2a

In secs. 11 and 26, T. 13 S., R. 2 W., and intervening localities, a gray or white, silty clay or clayey silt, in some deposits mottled with yellow or pink, is exposed and probably results from the weathering of the Springville shale. Several outcrops showing such material occur along the road and along Lingle Creek in the NW. ¼ NE. ¼ sec. 26 and the SE. ¼ SW. ¼ sec. 23 adjacent. The maximum observed thickness was 7 feet but the clay may be thicker than this. A sample, L-301, was taken from 5 feet of the clay exposed in a gully south of a house in the E. ½ NE. ¼ SW. ¼ sec. 11. Overburden was loess about 15 feet thick. Results of ceramic tests on sample L-301 follow.

Chester Series

The Chester series (table 1) consists principally of limestones and sandstones but locally contains relatively thin shale formations. These are usually calcareous when unweathered, and in general their ceramic possibilities are believed to be restricted to the making of common structural clay products such as brick and tile. Two chemical analyses are given in table 2, p. 18, samples L-11 and L-16.

Pennsylvanian Clays and Shales

The Pennsylvanian rocks of Union County are mostly sandstone but locally relatively thin shale beds are present. One typical outcrop of this sort is found along Cave Creek in the SE. ¼ NE.¼ NW. ¼

Sample L-301.—Springville Shale

Kind of material: clayey silt

Reaction for carbonates: none. For pyrites: none.

Color: dirty white with limonite color spots.

Hardness: soft.

Working property: medium.

Air shrinkage: linear 3.7%

Burning test:

Cone	Color	Hardness	Burning shrinkage *lin. percent*	Total shrinkage *lin. percent*	Remarks
010	Cream to lt. buff	Does not attain steel hardness in this range.	0.9	2.8	
07	White		0	3.7	
01	Lt. buff		0	3.7	
3	Lt. buff		1.8	5.5	Bars are still quite porous at cone 3. Tested with tongue.

Fusion (Deformation) test: P.C.E. cone 28—white.

Drying shrinkage: Low medium.

Burning shrinkage: Low (plastic basis).

Color range: O.K.

Plasticity: Medium.

Vitrification: Still porous at cone 3.

Suggested uses: Floor and wall tile; face, glazed and enamel brick; terra cotta; refractory bricks, blocks, shapes; glass house refractories; saggars; glass pots; crucibles.

sec. 4, T. 11 S., R. 2 W., where the following strata are exposed.

Outcrop 3

		Thickness Feet
4.	Sandstone	3
3.	Sandstone and shale, interbedded	12
2.	Shale, dark gray, nodular, thin partings of carbonaceous matter	4½
1.	Sandstone and shale, interbedded. Covered, base of outcrop	6

Preliminary ceramic tests on sample 6, taken from bed 2, showed it to be of ordinary quality probably suited for making common brick and tile. The shale would have to be mined underground because of heavy overburden. The deposit appears to have scant commercial possibilities.

CRETACEOUS (?) CLAYS

Kaolin District

In the vicinity of the village of Kaolin, or Kaolin Station as it is also known, about 4½ miles northwest of Anna, there are deposits of kaolin. The term "Anna kaolin" is sometimes applied to these deposits. During World War I these deposits were the source of large tonnages of crucible and glass pot clay. However, since that time production has been intermittent and relatively small.

Currently, only the latest pit is available for study as against 10 or more pits and mines at the time of World War I. Information regarding the nature of the deposits is therefore of necessity drawn primarily from earlier reports[4] covering conditions at the heyday of development.

OCCURRENCE

The largest clay deposits at Kaolin are thought to occur in depressions in the limestone bedrock of the area and usually at or near the base of the ridges, and as accumulations on the flanks of the limestone ridges. A few deposits are known on the crests of the ridges but none have been proved extensive.

[4] St. Clair, S., Clay deposits near Mountain Glen, Union County, Illinois: Illinois Geol. Survey Bull. 36, pp. 71 to 85, 1920.
Parmelee, C. W., and C. R. Schroyer, Further Investigations of Illinois fireclays: Illinois Geol. Survey Bull. 38D, pp. 42 to 63, 1921.

The individual deposits of clay in the Kaolin area thus far found have been of relatively limited extent but some have been quite thick. The greatest thickness reported was in the Goodman shaft which penetrated 87 feet of clay resting on orange sand and overlain by 13 feet of sand, gravel, and silt.[5] Other deposits were less thick but reports of 30 to 50 feet of clay are relatively common.

Orange, yellow, or red sand commonly underlies the clay deposits and locally occurs with the clay. The sand is often water bearing. The structure of the clay strata is roughly horizontal in some deposits and in others the beds are notably inclined or distorted. The area known to contain clay deposits of possible commercial importance is shown in figure 4.

Most of the clay deposits have been found along or near the bottom of the east slope of Iron Mountain, a ridge extending north-south through the E. ½ sec. 34, T. 11 S., R. 2 W., and the E. ½ sec. 3, T. 12 S., R. 2 W., or on the slopes of ridges east of Iron Mountain. However, a shaft is reported to have been sunk in the NE. ¼ SW. ¼ NE. ¼ sec. 3, T. 12 S., R. 2 W., on the west side of Iron Mountain and to have encountered the following:

		Thickness Feet
4.	Clay, white	18
3.	Clay, red	8
2.	Clay, yellow	8
1.	Sand, yellow	

A small sample of the white clay was subjected to preliminary ceramic tests and appears to be similar to the kaolin found elsewhere east of Iron Mountain.

Overburden on the clay deposits usually consists of silt and more or less sand and gravel and varies greatly in thickness. It is probably greatest on the crests of the ridges.

ORIGIN

No entirely satisfactory theory of origin for the Anna kaolin can be postulated because of lack of information regarding the detailed nature of the deposits. The clays generally have been considered to be de-

[5] Parmelee, C. W., and C. K. Schroyer, op. cit.

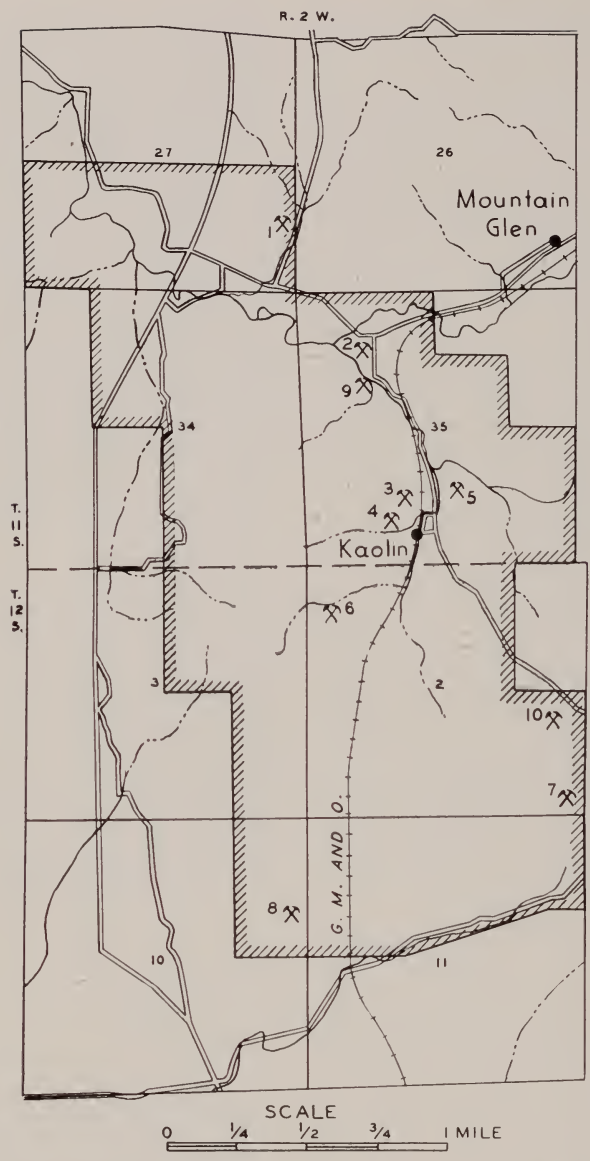

FIG. 4.—Map of the Kaolin area showing mines active during World War I and more recently. The area known to include deposits of clay of proved or possible commercial value is indicated by shading.[a]

Names of owners or operators of the pits or mines shown on the map are:

1. Frederick E. Bausch (Mine No. 3)
2. French Clay Blending Co.
3. Frederick E. Bausch (Mine No. 2)
4. Illinois Kaolin Co. (3 pits)
5. Frederick E. Bausch (Mine No. 1)
6. Dr. Goodman
7. Elmer Gant
8. Maddox and Nixon
9. W. P. Mautz
10. Saddler pit

Another pit, operated by T. P. Sifford on the Mary Walker farm in the SW. ¼ sec. 1, T. 12 S., R. 2 W., is not shown on the map.

[a] Modified from Figure 51, Bull. 38D, Illinois Geol. Survey.

posits made in an arm of the Cretaceous sea which extended into the Kaolin area. The dating of the clay as Cretaceous in age is largely inferential. Strangely enough, however, no other Cretaceous clays in southern Illinois are like the Anna kaolin in mineral composition. Therefore, it appears that some unknown special set of conditions probably affected the Anna clays. The presence of kaolin clay and sand in places on or near the tops of ridges in the Kaolin area suggests that the Cretaceous sea inundated the ridges. In the lower parts of the valleys of the region the clay deposits now found may represent Cretaceous deposits which were protected from later erosion by their presence in bedrock depressions, probably limestone sinks, which extend below the level to which the streams have cut. The deposits on the sides of the bedrock ridges may well be an accumulation caused by slumping and sliding of clay from the ridge tops. The distortion of some deposits, including those in sink-holes, suggests instability of the deposits at some time in their history.

MINING

Clay has been mined in the Kaolin area by open pits, by underground shafts and tunnels, and from cribs sunk into the deposits.

PROSPECTING

Because of the variation in the kaolin deposits, prospecting requires closely spaced test-drilling or test-pitting. The presence in some places of a few feet of chert gravel in the overburden on the clay sometimes makes test-drilling difficult. Prospecting should also take account of the possibility that old workings may be encountered. Little of the prospecting thus far done has been on the tops of the ridges, and the possibility of deposits there has not been evaluated. Conceivably on the ridges well layered clay deposits may occur which, though probably thinner than the clays on the ridge sides near the valley floors, may be more uniform and capable of being stripped on a considerable scale.

CHARACTER OF CLAYS

Two or more types of clay were found in most of the mines at Kaolin. Commonly a pink or pink and white mottled clay was encountered overlying a blue-gray or white clay, although in the shaft at the Sifford pit (fig. 4) the reverse is said to have been the case. In the F. E. Bausch mine all the clay was white or blue-gray. Lignitic clays or lignite were encountered locally.

Bonding tests.[6]—Sample B-54, a white kaolin from the Kaolin area, was tested to determine the possibilities of the clay in that area as a bonding clay for synthetic molding sands. Results of tests follow in which 8 percent of clay was used.

Water *percent*	Green compressive strength *lb. per sq. in.*	Dry compressive strength *lb. per sq. in.*
4.0	2.2	—
4.0	2.0	—
3.3	4.2	—
3.2	4.2	35.1
2.8	6.4	26.7
1.8	10.3	13.4
1.4	8.3	9.5

Ceramic tests.—A great many ceramic tests have been made on samples of clay from the Kaolin area.[7,8] Tests[8] on samples PS-16, PS-23, PS-30, and PS-121 give an idea of the ceramic character of the clay.

Chemical analyses.—A chemical analysis of the gray, crucible type clay of the district, sample AK, is given in table 2, p. 18. Another analysis, R-83, is of kaolin purified by sedimentation.

Mineralogical character.—The kaolin varies greatly in the amount of sand and grit it contains, some clay being highly sandy. Most of the clay sold, however, has been low in these materials. Tests on 10 samples[9] show a content of material retained on a 200-mesh sieve ranging from 0.33 percent to 11.0 percent. Four samples had less than 1 percent on the sieve and four ranged between 1 and 3 percent.

The clay mineral in the kaolin is of the kaolinite type.

[6] Grogan, R. M., and J. E. Lamar, Illinois surface clays as bonding clays for molding sands: Illinois Geol. Survey, Rept. Inv. 104, p. 24, 1945.
[7] St. Clair, S., op. cit.
[8] Parmelee, C. W., and C. R. Schroyer, op. cit.
[9] Parmelee, C. W., and C. R. Schroyer, op. cit.

Sample No. PS-16.*—Cretaceous? Clay
(Maddox and Nixon mine: NE. ¼ sec. 10, T. 12 S., R. 2 W.)

This is a soft nearly white clay. Its working property is good. Its conduct when flowing through a die is satisfactory.

Water of plasticity	*percent*	28.3
Shrinkage water	*percent*	10.8
Pore water	*percent*	17.5
Modulus of rupture	*lbs. per sq. in.*	64.1
Slaking test, average	*min.*	10.5

Screen test:

Mesh	Residue *percent*	Character of residue
60	0.05	White mica and white sand
80	0.22	White mica and white sand
120	5.3	White sand
200	5.4	White sand

Drying shrinkage, linear; dry length	*percent*	4.3
Volume	*percent*	17.8

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Total shrinkage *percent*
02	35.7	Light cream	2.1	6.4
1	35.2	Light cream	2.1	6.4
3	32.2	Light cream	3.3	7.6 Conchoidal fracture
5	20.4	Light cream	7.4	11.7
7	19.6	Light cream	8.0	12.3
9	17.8	Light cream	9.2	13.5
13	13.0	Dark gray	9.7	14.0

Fusion test: It fused at cones 30/31.

SUMMARY

The strength of this clay is low. The percentage of screen residues is considerable. Its drying shrinkage is low. The total shrinkage at cone 9 is medium high. It is not completely vitrified even at cone 13. This is a refractory clay and it will be found useful in the manufacture of refractories.

* All tests having the prefix PS to the sample number are from Parmelee, C. W., and Schroyer, C. R., Further investigations of Illinois fireclays: Illinois Geol. Survey Bull. 38D, 1921.

USES

Aside from the ceramic and bonding clay possibilities of the Anna kaolin, previously mentioned, a number of other possible uses have been suggested. If a uniform white, grit-free grade of clay could be produced, it might find use as a paper filler. Off color grades might find other filler uses, as for rubber. Laboratory tests indicate that the kaolin has decolorizing properties and that if properly prepared it may be used to bleach both edible and mineral oils.[10]

[10] Piersol, R. J., J. E. Lamar, and W. H. Voskuil, Anna "kaolin" as a new decolorizing agent for edible oils: Illinois Geol. Survey Rept. Inv. 27, 1933.

SAMPLE NO. PS-23.—CRETACEOUS? CLAY
(Elmer Gant mine: SE. ¼ SE. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a white soft clay which has some veins of red through it. Its working properties in the plastic condition are good. It flows fairly well through a die.

Water of plasticity	*percent*	35.8
Shrinkage water	*percent*	19.2
Pore water	*percent*	16.6
Modulus of rupture	*lbs. per sq. in.*	311.2
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	302.3
Slaking test, average	*min.*	23

Screen test:

Mesh	Residue *percent*	Character of residue
20	Trace	.....
40	Trace	.....
60	Trace	.....
120	0.2	White sand
200	0.43	White sand

Drying shrinkage:	*Percent*
Linear; dry length	7.7
Linear; wet length	7.1
Volume	32.5

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
2	12.1	Cream white	10.0	
3	4.8	Cream white	9.0	
6	2.6	Cream; bluestoned	9.5	Hackly vitreous fracture
9	2.4	Cream; bluestoned	10.0	Vitreous fracture
12	2.9	Bluestoned	10.0	Vitreous fracture
13	1.1	Light tan exterior; bluestoned	.....	Vitreous fracture
15	2.0	Tan exterior; bluestoned	10.0	Fine closed cracks on the surface

Fusion test: It deformed at cone 32.

SUMMARY

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of screen residue is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is complete at cone 13. It is a refractory clay. It is suggested that it will be found of use in the manufacture of refractories requiring a densely burned body at a low temperature, such as crucibles.

SAMPLE NO. PS-30.—CRETACEOUS? CLAY
(Goodman pit: NW. ¼ sec. 2, T. 12 S., R. 2 W.)

This is a soft clay of a cream color, shading into reddish. Its working properties in the plastic condition are good. Its flows satisfactorily through a die when it has a stiff consistency.

Water of plasticity	*percent*	44.2
Shrinkage water	*percent*	21.4
Pore water	*percent*	22.8
Modulus of rupture	*lbs. per sq. in.*	345
With 50% standard sand—Modulus of rupture	*lbs. per sq. in.*	229.4
Slaking test	*min.*	13

Screen test:

Mesh	Residue *percent*	Character of residue
120	1.46	Cream-colored sand
150	0.39	Cream-colored sand
200	0.24	Very fine sand

Drying shrinkage:

	Percent
Linear: wet length	7.5
Linear: dry length	8.25
Volume	34.6

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
2	25.7	Cream	12.3	
5	1.3	Gray	13.7	
9	3.7		13.0	Hackly vitreous fracture
12	3.2	Tan exterior; bluestoned interior	13.2	
13	0.1		12.4	
15	5.3	Buff; bluestoned	11.4	Hackly vitreous fracture. Surface covered with mesh due to cracks.

Soluble salts: Piece burned at cone 2 after soaking in water shows greenish-yellow surface coating. Possibly vanadium salts.

Fusion test: It fused at cone 32.

SUMMARY

The strength of the unburned clay is medium. Its bonding strength is medium. The percentage of residues is slight. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and overburning is slight if any at cone 15.

Suggested uses: Refractories, particularly crucibles and glass pots, etc.; architectural terra cotta, sanitary ware, stoneware.

SAMPLE NO. PS-121.—CRETACEOUS? CLAY
(Frederick E. Bausch mines: near Mountain Glen)

This is a soft white clay. When tempered with water, it becomes very plastic and inclined to be sticky. It flows very poorly through the die.

Water of plasticity ..... *percent* 37.1

Shrinkage water ..... *percent* 20.9

Pore water ..... *percent* 16.2

Modulus of rupture ..... *lbs. per sq. in.* 191

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 123.3

Slaking test, average ..... *min.* 22

Screen test:

Mesh	Residue *percent*	Character of residue
60	Trace	Sand
80	Trace	.....
120	.09	Fine white sand
200	.24	White sand and mica

Drying shrinkage:

	Percent
Linear: wet length	7.4
Linear: dry length	8.2
Volume	33.5

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
2	18.3	Cream white	8.3	Hackly fracture
5½	13.0	Cream white	8.8	
9	1.68	Gray; bluestoned	9.6	
12	1.40	Gray; bluestoned	10.3	Hackly vitreous fracture
13½	2.0	Gray; bluestoned	9.8	
15	2.5	Gray exterior; bluestoned	9.8	

Fusion test: It deforms at cone 30.

SUMMARY

The clay has a medium low strength and medium low bonding strength. The amount of screen residues is negligible. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9 and the clay is not overburned at cone 15. The clay is refractory.

This is the type of clay which is useful in the manufacture of dense burning refractories.

Balcom District

Outcrop 4

South of the village of Balcom, in the SE. ¼ SW. ¼ sec. 11, T. 13 S.' R. 1 W., in a cut along the Illinois Central Railroad there are exposed, together with other materials, clays probably of Cretaceous age. The outcrops are very much slumped but evidently include a stratum of red and brown clay, chert, gravel, and sand. In the SW. ¼ SE. ¼ SW. ¼ sec. 11, an outcrop showed 4 feet of plastic sandy red clay mottled with white, overlain by about 2 feet of white and yellow angular chert gravel, and capped with 15 feet of clayey silt. A partial chemical analysis of a sample of this clay follows:

	Percen
SiO_2	77.06
Fe_2O_3	3.08
Al_2O_3	12.98

Outcrop 5

Farther north, a little north of the center of the W. ½ NW. ¼ sec. 11, in the same township, in a cut on the east side of the Illinois Central Railroad, a badly slumped outcrop showed approximately the following sequence of beds.

Strata Exposed at Outcrop 5

		Thickness Feet
7.	Silt, clayey, brown	5±
6.	Rubble, chert, angular fragments up to 12 inches in diameter	1–12
5.	Gravel, gray and black, rounded, chert	0–½
4.	Clay, red, very sticky, sandy	5±
3.	Clay, yellow, green, red and white mixed, bedding badly distorted; contains angular chert fragments	4+
2.	Sand, red and orange; contains angular chert fragments	5–8±
1.	Sand, yellow, fine-grained; contains angular chert fragments	4+
	Covered, base of outcrop	

The clays in these outcrops in themselves are probably not of commercial importance but suggest the possibility that the hills in the vicinity may be underlain by Cretaceous sediments including clay. Prospecting is necessary to determine the extent and character of the deposits.

Other Districts

Cretaceous sediments occur in the vicinity of Elco, a short distance south of the south line of Union County, and may extend northward into the region around Mill Creek, especially west of that place. However, no deposits of Cretaceous clays were observed in this area.

In the uplands northeast of Wolf Lake no Cretaceous clay deposits were observed, but there is some evidence suggesting that Cretaceous sediments may be present in that area.

RESIDUAL CLAYS

In those parts of Union County which are underlain by thick limestone formations, especially those of the Meramec and Osage groups, there occur in some places red or maroon colored clays which are believed to be a residuum resulting from the solution of the carbonates from the limestone. The best exposure of residual clay noted is described below.

Outcrop 6

Just north of the center of the E. ½ NE. ¼ sec. 23, T. 12 S., R. 2 W.

Along the south side of the concrete road, in the side of a hill, excavations for the road exposed the following sequence of materials. The exposure was about 300 feet long.

Strata Exposed West of Jonesboro

		Thickness Feet
4.	Silt, brown, clayey	3
3.	Gravel, angular, cherty	1±
2.	Clay, red, cherty, (possibly 25 percent chert, ranging from granules to 6-inch angular fragments)	8–12
1.	Limestone, dark gray, dense	30±

The red clay comprising bed 2 is residuum from the weathering of the limestone which was once continuous with the formation beneath it. The chert in the clay indicates that it was derived from a cherty

limestone. The limestone surface on which the clay rests is very irregular and has a relief of as much as 20 feet.

The hill in which this deposit occurs rises to the south and the silt over-burden probably becomes thicker. The size and extent of the deposit is problematical, as are its uses. Conceivably after removal of the chert the clay might have use as a red mineral pigment; probably it could be used for common structural clay products.

ALLUVIAL CLAYS

The flood-plains of the larger streams in Union County, especially Mississippi River, and the terraces locally adjoining these flood-plains, are believed to be underlain by silty clays or clayey silts in some places. Little is known about these materials but probably some of the more clayey deposits can be used for making brick and possibly tile, providing they are noncalcareous or only slightly calcareous.

LOESS

The uplands of Union County are mantled by a covering of brown clayey silt known as loess which reaches a thickness of 40 feet or more in and near the Mississippi River bluffs but is 15 to 25 feet thick over most of the rest of the uplands of the county. In general the loess is noncalcareous except the deeper parts of the river bluff deposits. Extensive deposits of loess are available, especially on the broader upland tracts. Loess has been used in other parts of Illinois for making structural clay products, and many of the Union County deposits can probably be similarly used. Results of ceramic tests on loess samples from Alexander and Pulaski Counties are given under those counties. A chemical analysis of sample L-10, probably loess, from the overburden on the limestone in an old quarry believed to be at or near the site of the present Anna Quarries, Inc., at the east edge of Anna, is given in table 2, p 18.

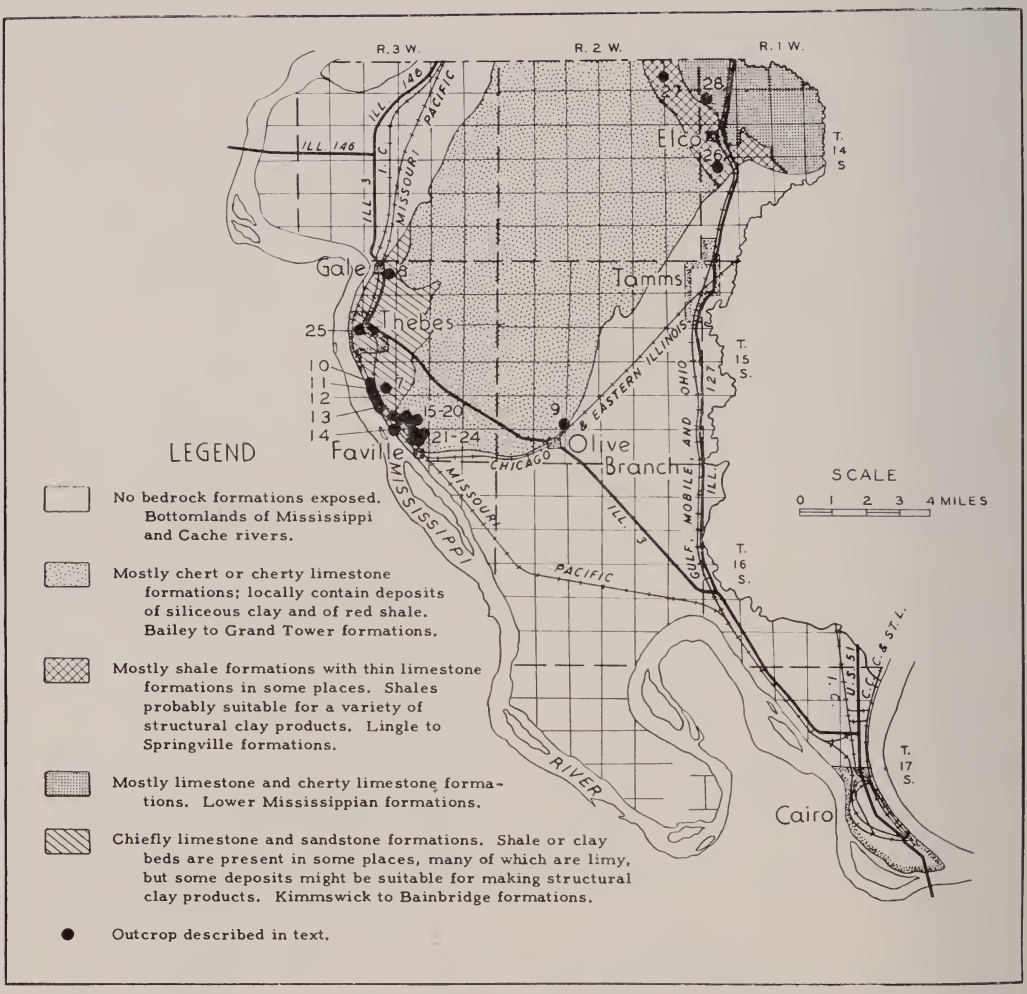

FIG. 5.—Character of bedrock formations in Alexander County and their clay and shale resources.

CHAPTER 3—ALEXANDER COUNTY RESOURCES

The clay and shale resources of Alexander County include bedrock deposits, deposits of Cretaceous age, alluvial clays, and loess.

BEDROCK CLAYS AND SHALES

The bedrock clay and shale resources are parts of the Orchard Creek and Bainbridge formations of Silurian age, the Bailey, Grassy Knob, Lingle, and Mountain Glen formations of Devonian age, and the Springville shale of Mississippian age (fig. 5).

Orchard Creek Formation

This formation has a maximum observed thickness of 22 feet and consists of greenish-gray to drab silty shale with interbedded limestone strata in the middle and upper portions.[1]

Gray shale with interbedded limestone layers totalling 8 feet thick were exposed at the mouth of Orchard Creek, near the wagon road in the SE. ¼ SW. ¼ NW. ¼ sec. 21, T. 15 S., R. 3 W.; 9 feet of it was exposed in an old quarry ¼ mile southeast of Gale in the N. ½ sec. 4 of the same township,[2] and about 15 feet in a cut along State Route 3 in the SW. ¼ NE. ¼ sec. 4. Because of its thinness and the fact that all known deposits have relatively heavy overburden, the formation appears to have scant commercial possibilities. The limestone in the formation practically eliminates it from the structural clay products field.

Bainbridge-Bailey Shale

The upper part of the Bainbridge formation consists of red, greenish, and drab shale, and similar red shale occurs in the basal part of the Bailey formation.[3] Some deposits are calcareous but others contain little calcareous material. The line of separation between the two formations is not well marked. The shaly strata are limited above by the cherty Bailey limestone and below by earthy limestone with interbedded shale in the Bainbridge formation. No outcrops are known that afford an opportunity to determine the thickness of the Bainbridge-Bailey shale but it may be on the order of 40 feet thick.

Some of the better outcrops within 1½ miles of a railroad occur along the south bank of Horse Creek in the W. ½ SW. ¼ sec. 23, T. 14 S., R. 3 W., along Orchard Creek at the center of the E. ½ SW. ¼ SE. ¼ sec. 21, along the same creek near the center of the north line sec. 27, and in the upper part of a small hollow in the SW. ¼ NE. ¼ SE. ¼ sec. 28, all in T. 15 S., R. 3 W.[4]

Other good outcrops of the shale occur along the lower part of Aetna Hollow, see "Section beside ammonia house" and "Section near nitroglycerin wheeling walk" under discussion of Cretaceous clays in Alexander County (p. 41).

Most deposits of Bainbridge-Bailey shale are overlain by brown clayey silt (loess) ranging up to about 25 feet thick. In addition many deposits have an overburden of Bailey limestone or chert.

In general the best chances for finding the Bainbridge-Bailey shale without bedrock overburden are in the general vicinity of the NE. corner sec. 4, T. 15 S., R. 3 W. and in the S ½ sec. 10 and the central part of sec. 15 in the same township.

Careful prospecting of deposits of the Bainbridge-Bailey shale is desirable before large scale use is attempted, to determine overburden conditions and shale thickness, as well as variations in the character of the shale, especially as to its carbonate content and the presence of limestone layers.

Results of ceramic tests on sample L-62 indicate that it is probably suitable for making a variety of clay products. Possibly some of the reddest shale might find use as a red pigment or mineral filler. The clay mineral in the shale is believed to be illite.

[1] Weller, J. M., and George E. Ekblaw, Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes quadrangles: Illinois Geol. Survey Rept. Inv. 70, p. 9, 1940.

[2] Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri, Illinois Geol. Survey Bull. 23, p. 79, 1917.

[3] Weller, J. M., op. cit., pp. 10 and 11.

[4] Weller, J. M., op. cit., pp. 10 and 11.

Outcrop 7

Plastic clay of the Bainbridge-Bailey formation, 20 feet thick, for the most part red but including irregular masses of green clay, is exposed in the bank of Orchard Creek, or Rock Springs Creek as it is also known, at the center of the E. ½ SW. ¼ SE. ¼ sec. 21, T. 15 S., R. 3 W. (fig. 5). The shale is noncalcareous but may be limy where unweathered. Sample L-62 was taken from the deposit. Results of ceramic tests follow.

Bailey Formation

In Alexander County the lower part of the Bailey formation where weathered contains white clay in some places. Only one such deposit of appreciable size was noted but there probably are others.

Outcrop 8

The International Silica Company operated a small underground mine about 15 years ago in a soft clayey bed believed to be a part of the Bailey formation. The mine was located in the south bluff of a small creek a short distance southwest of Gale in the NE. ¼ sec. 4, T. 15 S., R. 3 W. The clay was white, very plastic when wet, and contained irregular fragments of white chert. The deposit was 5 to 8 feet thick and was worked by means of rooms and pillars.

The extent of the clay bed is not known because the outcrops in the vicinity are covered with slumped material, nor has there been previous development of a similar deposit in Illinois which might give a clue to the size of such deposits.

The results of a ceramic test of sample L-201 from the mine follow.

Sample No. L-62.—Bainbridge-Bailey Shale

Kind of material ..... clay

Drying conduct ..... good

Volume drying shrinkage ..... *percent* 24.8

Linear drying shrinkage ..... *percent* 9.0

Water of plasticity ..... *percent* 31.7

Bonding strength—Modulus of rupture—without sand ..... *lbs. per sq. in.* 446.8

Bulk specific gravity 1.86

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
04	18.79	6.70	11.08	Red	Vitreous
02	24.74	9.04	1.83	Reddish-brown	Vitreous
5	19.00		.65	(Bloated)	Vitreous
6		Over fired			Vitreous

Fusion test: Clay not refractory.

Oxidizing conduct: Poor.

Summary: Drying shrinkage high, bonding strength medium high, vitrification complete at cone 5, overburned at cone 6, shrinkage at cone 02 medium.

Suggested uses: Building brick, possibly quarry tile, roofing tile, hollow tile and sewer pipe.

SAMPLE NO. L-201.—BAILEY CLAY

Kind of material ..... siliceous clay

Drying conduct:

Volume drying shrinkage ..... *percent* 10.4

Linear drying shrinkage ..... *percent* 3.5

Water of plasticity ..... *percent* 31.5

Transverse strength—Modulus of rupture—without sand ..... *lbs. per sq. in.* 61.7

Bulk specific gravity 1.538

Character of residue ..... chert pebbles

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Remarks
06	.07	.02	39.5	White	
04	1.5	.5	40.4	White	
02	1.9	.6	39.4	White	
1	4.9	1.7	38.2	White	
2	1.8	.6	39.6	White	
4	7.5	2.6	35.7	White	
6½	9.0	3.1	31.8	White	
8	6.1	2.1	36.2	White	

Fusion test: P.C.E. 28–29

Summary: This is an open-burning clay, white at all temperatures; drying and burning shrinkages are low; strength in the raw condition is low.

Suggested uses: Refractory wares, white wares, such as pottery, tile, etc.

GRASSY KNOB FORMATION

In places the Grassy Knob formation, which is usually mostly chert, consists of interbedded strata of clay, tripoli, and chert. At no place has the formation been observed to be sufficiently clayey to be worked for the clay alone, although such deposits may exist, as the deposit near Unity in Pulaski County (p. 51).

Outcrop 9

The Olive Branch Minerals Company has operated an underground mine by the room and pillar method in a deposit of interbedded tripoli (silica), clay and chert in the bluff about three quarters of a mile northeast of the village of Olive Branch. By suitable processing of their raw material, including hydraulic classification, the company produced tripoli (silica) and clay as separate products.

LINGLE, MOUNTAIN GLEN, AND SPRINGVILLE SHALES

The situation regarding the Lingle shale in Alexander County is similar to that in Union County, and no good outcrops are known near railroads. The Mountain Glen and Springville formations underlie the SW. ¼ sec. 1 and extend in a northwest-southeast band about half a mile wide through sec. 12, both in T. 14 S., R. 2 W. The Mountain Glen and Springville shales underlie the lower slopes of the hills near the Gulf, Mobile and Ohio Railroad in the S. ½ sec. 7, in sec. 18, and in the N. 2/3 of sec. 19, T. 14 S., R. 1 W.[5] One of the

[5] Weller, J. M., Cir. 70, Plate 1.

FIG. 6.—Topographic map of Mississippi River bluff, Miami Hollow, and Aetna Hollow districts showing locations of outcrops.

better outcrops of Mountain Glen shale occurs in the bluff along the road in the NW. ¼ SE. ¼ sec. 18.

The Springville shale is also exposed in places in the slopes of the hills in secs. 16 and 17, T. 14 S., R. 1 W., and in the center of sec. 21 in the same township.

No samples were taken from the above formations in Alexander County but they probably have about the same characteristics as in Union County.

CRETACEOUS CLAYS

Deposits of Cretaceous clays probably occur at many places in Alexander County but are best known in that part of the county lying west of the roughly straight line made by State Route 150 between Thebes and Olive Branch (fig. 5). Other deposits are known in the vicinity of Elco.

The Cretaceous deposits consist principally of clays and fine- to medium-grained sands, with thin beds of chert gravel in places. The total thickness of the deposits is estimated to be about 90 feet. The Ozark Minerals Company produces clay from a deposit in the bluff of Mississippi River between Thebes and Fayville, and in the same general area a small tonnage of ocher was once produced.

For convenience the deposits of Cretaceous clays are described by districts as follows (figs. 5 and 6): The Mississippi bluff district between Rock Springs Hollow and Fayville, the Aetna Hollow district, the Miami Hollow district, the Thebes district, and the Elco district.

Character of Outcrops

In general there appears to have been considerable slumping of the Cretaceous deposits, probably because they are unstable when wet, rest on an uneven bedrock surface in many places, and occur mainly on the crests and slopes of hills and ridges. The best outcrops were found in railroad cuts between Thebes and Fayville. Formerly there were good exposures in Miami and Aetna Hollows which were the site of an explosives plant during World War I. The plant is now dismantled. The exposures which resulted from excavations in connection with this plant are now largely obscured but data obtained when they were still reasonably fresh are given. In the Elco district the principal outcrops were found at the heads of ravines or along creeks, but in general they afford only limited data concerning the extent and character of the clay deposits.

Character of Deposits

The Cretaceous clays are generally light gray to gray but locally beds of white, greenish-gray, or dark lignitic clay are present. They are believed to be water-laid. The clay mineral in some samples is illite, in others a mixture of kaolinite and illite, and in a few clays it is kaolinite.

The discontinuity of outcrops of the Cretaceous clays does not permit determination of their extent, but it appears that some of them may thicken or thin rapidly in relatively short distances.

The size of deposits is problematical. Probably there are deposits of considerable size but the outcrops available do not demonstrate this. It is suggested that prospecting of upland flats or of ridges might locate mostly undisturbed and sizable deposits.

Overburden

Most of the deposits have an overburden of clayey silt plus gravel and sand of the Lafayette formation. Potentially these may reach a thickness of 75 feet or more. There are probably deposits with less overburden than this, but the overburden situation for a fairly large deposit can be evaluated only by test drilling.

Uses

The results of ceramic tests indicate that the Cretaceous clays in Alexander County are probably suitable for the manufacture of a considerable variety of burned clay products. Most of the clays are nonrefractory but the fusion point of many of them is not greatly below that of refractory clays. A number of the clays are light burning. In the nonceramic field the clays may find use as fillers for those products in which

a white filler is not required, and they may also merit investigations as bonding clays for synthetic molding sand and other nonceramic uses.

Mississippi River Bluff District (rock springs hollow to fayville)

Outcrops of Cretaceous clays occur at intervals in the bluff of Mississippi River for about a mile south of Rock Springs Hollow, chiefly in cuts along the Missouri Pacific Railroad right-of-way (fig. 6). These cuts show a greenish-gray clay and other Cretaceous sediments, but further south the cuts along the railroad reveal principally conglomerates, gravels, and red sands believed to be Lafayette formation although Cretaceous beds are also present as at Outcrop 14. The outcrops of Cretaceous clay are described below as Outcrops 10, 11, 12, 13 and 14 (fig. 6). Details of the outcrops are given and their significance is discussed collectively.

Outcrop 10

NW. corner NW. ¼ SW. ¼ sec. 21, T. 15 S., R. 3 W.; cut along M. P. R. R., 400 feet south of trestle at Rock Springs Hollow

		Thickness Feet
6.	Silt, brown, clayey	10+
5.	Gravel, chert	½
4.	Sand, iron-stained	2½
3.	Gravel, angular, chert	3
2.	Clay, gray-green, locally contains thin sand layers (Sample L-210)	17
1.	Chert, porous, streaked with iron	6+
	Covered	

Outcrop 11

SE. ¼ NW. ¼ SW. ¼ sec., 21 T. 15 S., R. 3 W.; cut along M. P. R. R. 1000 feet south of trestle over Rock Springs Hollow

		Thickness Feet
5.	Silt, brown, clayey (loess)	15+
4.	Sand, red	0–2
3.	Gravel, rounded black chert and iron-stained quartz pebbles	½–⅔
2.	Conglomerate, of angular chert fragments, and "fibrous chert"; overlain by angular white chert conglomerate which varies from 0 to 2 feet thick	4±
1.	Clay, greenish-gray	12+
	Covered	

Outcrop 12

Center E. ½ SW. ¼ SW. ¼ sec. 21, T. 15 S., R. 3 W.; cut along M. P. R. R. 2300 feet south of trestle over Rock Springs Hollow

		Thickness Feet
6.	Silt, brown, clayey (loess)	20+
5.	Gravel, chert, unsorted, in a variety of colors; quartz sand	1
4.	"Chert, fibrous"	1½
3.	Clay, mottled yellow and white	2½
2.	Clay, white with gray layers. Locally contains thin siliceous beds (Sample L-59)	9
1.	Clay, greenish-white	3+
	Covered	

Outcrop 13

NE. ¼ NW. ¼ sec. 28, T. 15 S., R. 3 W., cut along M. P. R. R.

		Thickness Feet
9.	Silt, brown, clayey (loess)	2+
8.	Gravel, brown and white chert	2½
7.	Sandstone, iron-stained	½–2
6.	Sand, red	15
5.	Gravel, chert, cemented by iron oxide	½
4.	Clay, gray	½–1⅙
3.	Chert, porous, contorted, high in iron oxide	4–12
2.	Covered	2
1.	Limestone, dense, very fine-grained, with thin shaly layers (Girardeau formation)	6+
	Covered	

Outcrop 14

NW. ¼ NW. ¼ sec. 34, T. 15 S., R. 3 W., along M. P. R. R. north of Miami Hollow

		Thickness Feet
7.	Silt, brown, clayey (loess)	7
6.	Clay, gray	4
5.	Gravel, brown and white chert, rounded	¼
4.	Sand, yellow and clay, gray, interbedded	5
3.	Gravel, black and white chert, rounded	⅙
2.	Sand, yellow and white mottled	2½
1.	Clay, yellow, sandy	5
	Covered	

It is believed that the data for Outcrops 10–12 suggest the presence of a clay stratum 10 to 20 feet thick which is probably continuous in the hills between Outcrops 10 and 12 and thereabouts. In Outcrops 10 and 11 the clay bed has a characteristic greenish-gray color, in Outcrop 12 the clay is lighter colored and includes white and gray clay, beds 1, 2, and 3. Bed 4, Outcrop 13, is probably equivalent to a part of the clay at Outcrop 12. It rests on the same stratum of porous chert as does the green clay in Outcrop 10. The thinness of bed 4 may be due to slumping of the red sand from above or to a concomitant thicken-

ing of the red sand and thinning of the clay. Such data as are available suggest the latter may be at least partly responsible for the thinness of the outcrop.

The data on Outcrop 14 are included to show the nature of the beds exposed in the southern part of the district but show no certain correlation with the other outcrops.

Another outcrop, which is believed to be badly slumped, occurs in the river bluff along the gravel road about 1¼ miles south of Rock Springs Hollow in the SW. ¼ NW. ¼ SW. ¼ sec. 28, T. 15 S., R. 3 W. This outcrop is mentioned chiefly to give information bearing on its true character which is apt to become less evident as time goes on. The best exposure seen here over a period of years consisted of about 10 feet of white clay containing bands of black chert pebbles, overlain by about 3 feet of yellow sand and black chert gravel. The clay rests on about 10 feet of unstratified angular chert gravel which lies on limestone bedrock.

The extent of the thick clay stratum in Outcrops 10–12 is problematical. The clay in the Thebes district (p. 47) may be its equivalent. Test-drilling will be necessary to evaluate the extent and commercial possibilities of the clay stratum.

Results of ceramic tests on sample L-210 from the clay in Outcrop 10 and L-59 from Outcrop 12 follow:

Sample No. L-210.—Cretaceous Clay

Kind of material ..... clay

Drying conduct ..... safe

Volume drying ..... *percent* 24.4

Linear drying shrinkage ..... *percent* 8.9

Water of plasticity ..... *percent* 31.7

Transverse strength—Modulus of rupture—without sand ..... *lbs. per sq. in.* 536

Bulk specific gravity 1.859

Percent residue on 100-mesh sieve ..... none

Burning Test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness
06	17.6	6.26	12.6	Yellow	
04	23.9	8.69	5.1	Yellow	Steel hard
02	22.8	8.25	5.1	Brown olive	Steel hard
1	23.6	8.56	.3	Yellow	
2	24.4	8.90	2.2	Olive	
4	11.3	3.91	3.6	Olive	Harder than steel
6½	5.9	1.99	.2	Olive	Harder than steel
8			.3	Olive	Harder than steel

Summary: This material has a medium high dry strength, a safe drying conduct and medium shrinkage. It burns to a dense body at a low temperature and has a wide burning range. Its burning shrinkage is medium. Soluble salts are present in the burned ware. It is well vitrified at cone 6.

Suggested uses: Face brick, architectural terra cotta, stoneware, flue linings, roof tile.

Sample No. L-59.—Cretaceous Clay

Kind of material ..... clay

Drying conduct: Has tendency to crack while drying, slight warping.

Volume drying shrinkage ..... *percent* 12.37

Linear drying shrinkage ..... *percent* 4.31

Water of plasticity ..... *percent* 30.8

Transverse strength—Modulus of rupture—without sand ..... *lbs. per sq. in.* 133.00

Bulk specific gravity 1.64

Screen test:

Mesh	Percent residue retained
28	2.2
48	0.4
65	2.1
100	2.5
200	1.4

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Fracture
02	12.00	4.17	27.31	Cream	Smooth
2	20.52	7.37	18.01	Cream	Smooth
5	25.10	9.18	11.00	Light buff, iron spots	Smooth
7	30.18	11.28	.81	Dark gray	Smooth
10	28.81	10.71	0	Bluestoned	Smooth
11	28.26	10.44	.27	Gray	Smooth
13	16.50	5.69	4.25	Dark gray bluestoned	Smooth

Fusion test: Fusion Point P.C.E. 15.

Oxidizing conduct: Good.

Summary: Drying shrinkage medium, drying conduct fair, transverse strength medium low, vitrification complete at cone 7, overburned at cone 13, shrinkage at cone 11 is medium. It is nonrefractory.

Suggested uses: Building brick, stove linings, possibly flue linings.

Aetna and Miami Hollow Districts

Aetna and Miami hollows have in the past contained some of the best outcrops of Cretaceous sediments in Alexander County although most of them are now considerably obscured. The outcrops are described as they appeared in 1930 and are identified both by locations on a map (fig. 6) and with reference to former structures of the explosives plant which once was located in the hollows.

It was not possible to correlate the deposits in the hollows with those in the cuts along the Missouri Pacific Railroad. The only distinctive bed appearing in common is the porous chert stratum in Outcrop 15, but it is not certain how this outcrop correlates with the other outcrops in the hollows. Probably the Cretaceous strata in the railroad cuts are younger than the beds in the hollows and therefore would overlie them under suitable conditions. Following is a

tentative generalized section of the Cretaceous beds in the hollows.

TENTATIVE GENERALIZED SECTION SHOWING POSSIBLE SUCCESSION OF CRETACEOUS BEDS IN AETNA AND MIAMI HOLLOWS

		Thickness Feet
5.	Sand and clay; layers of white or yellow sand interbedded with layers of dark gray or black clay. The sand is very micaceous and is commonly separated from the clay by a thin parting of mica flakes. The clay and sand layers vary from ½ to 1 inch in thickness	30±
4.	Sand; very fine-grained, clayey, micaceous, white, locally containing thin layers of white clay	35±
3.	Clay; gray to dark gray, well bedded, locally very sandy	7±
2.	Sand; medium-grained, yellow, locally contains thin gravel and clay strata	10±
1.	Clay; dark gray to light gray, usually fine-grained, plastic. Locally this clay contains fragmentary plant remains	6±
	Covered or bedrock	

The best exposure noted of bed 5 was near the upper end of Miami Hollow in the SE. corner NW. ¼ NE. ¼ sec. 34, a short distance below an abandoned gravel pit. Bed 4 was well exposed in the cut-off between Miami and Aetna Hollows in the NE. ¼ NW. ¼ sec. 34. Beds 1, 2, and 3 were exposed on the north side of Aetna Hollow near the old nitroglycerine wheeling walk in the center of the SW. ¼ SW. ¼ sec. 27, Outcrop 17.

AETNA HOLLOW DISTRICT

Outcrops were more or less common along the entire length of Aetna Hollow. Thebes sandstone crops out in the lower portion; a few hundred feet further up the valley, shale is exposed for a short distance. At Outcrop 15 (fig. 6), the following strata were exposed.

Outcrop 15

STRATA EXPOSED BESIDE THE AMMONIA HOUSE

		Thickness Feet
11.	Silt, brown, clayey (loess)	10
10.	Conglomerate, gray and white chert	2
9.	Sand, gravel, and clay, interbedded	2–4
8.	Chert, porous	⅔–2½
7.	Sand, coarse, yellow	3
6.	Conglomerate	1
5.	Chert and clay; angular fragments of chert in a clayey matrix partly composed of rotted chert	22
4.	Shale, dark gray, gritty	7
3.	Shale, like above but containing ferruginous pebbles	5
2.	Shale, dark gray, gritty, with nodules of limestone	7
1.	Shale, greenish-gray, thin-bedded, gritty	16
	Covered, creek level	

Beds 1 to 5 in the above section are believed to be bedrock formations. Beds 6 to 10 are probably Cretaceous.

Outcrop 16

The exact location of Outcrop 16 is not known but it is believed to be a little further up Aetna Hollow than Outcrop 14. The following strata are said to have been exposed in excavations made for the foundations of the first separator house.[6]

STRATA EXPOSED AT OUTCROP 16

		Thickness Feet
3.	Silt, brown, clayey (loess); soil at top	20
2.	Gravel	1–2
1.	Clay, laminated, light drab to gray, interstratified with distinct beds of mica and fine sand; small crystals of gypsum. Sample PS-41	9
	Covered	

Sample PS-41 was taken from the upper 5 feet of Bed 1 which is believed to be of Cretaceous age.

Outcrop 17

Further up the Hollow, at the intersection of the nitroglycerine wheeling walk and the northeast wall of the valley, is Outcrop 17, where the following strata were exposed.

STRATA EXPOSED AT OUTCROP 17

		Thickness Feet
7.	Silt, clayey, brown (loess)	10
6.	Gravel, lens	2½
5.	Clay, gray, gritty, well-bedded, locally contains gypsum crystals, lower 2 feet sandy. Sample L-301	7
4.	Sand, white, medium-grained	1
3.	Sand, medium- to coarse-grained, yellow, locally contains ocherous bands, consolidated to sandstone in places in upper part, gravel in basal portion	7

[6] Parmelee, C. W., and C. R. Schroyer, Further investigations of Illinois fireclays, Illinois Geol. Survey Bull. 38D, pp. 74, 75, 1921.

2.	Clay, gray, locally pink along bedding planes, small gypsum crystals present in places. Sample L-302	6
1.	Shale, greenish-gray, grades into overlying clay without sharp line of separation	16
	Covered, about 15 feet to creek level	

Bed 1 is a part of the bedrock; beds 2 to 5 are probably Cretaceous. Sample L-301 was taken from the lower six feet of clay of bed 5. The upper foot was not included because it was abnormally discolored. Sample L-302 was taken from the lower 3 feet of Bed 2. The upper 3 feet was not included because it was abnormally iron stained.

Outcrop 18

In a tributary valley to Aetna Hollow, behind the nitroglycerine storage, the following section was exposed.

Strata Exposed at Outcrop 18

		Thickness Feet
9.	Silt, clayey, brown (loess)	10
8.	Clay, sandy, sticky, yellow	2
7.	Sand, fine-grained, locally pebbly	2½
6.	Clay, gray, plastic	4½
5.	Clay, sand and gravel, interbedded	1½
4.	Sand, medium-grained, partly cemented to sandstone	3½
3.	Gravel and sand	½
2.	Sandstone	½–1½
	Covered	3
1.	Clay, light gray, mottled with yellow, plastic	4
	Covered	

Beds 1 to 7 are regarded as Cretaceous and possibly bed 8.

Miscellaneous Outcrops

Above Outcrop 18 in the main valley, lesser outcrops were visible at intervals. About 200 feet upstream from Outcrop 16, sandy clay was exposed in the south valley wall and 250 feet farther, gray clay with a thin sand lens appeared. About 150 feet above this point, and also on the south side of the valley, 15 feet of medium- to coarse-grained sand was visible. Just west of the cut-off to Miami Hollow at the center of the north line of sec. 34, 6 feet of gray and yellow clay, interbedded with sand and underlain by 2 feet of coarse-grained yellow sand, could be seen. Continuing up Aetna Hollow, a few feet of green clay was exposed on the north side of the valley about 400 feet above the cut-off.

Outcrop 19

In the south valley wall southeast of the paraffin melt house the following beds were exposed.

Strata Exposed at Outcrop 19

		Thickness Feet
4.	Gravel, sand and clay interbedded	3
3.	Sand, fine-grained, light yellow and brown	5
	Covered	9
2.	Clay, gray, plastic	1
1.	Gravel and coarse sand	3
	Covered	

Outcrop 20

The last outcrop of importance noted lay well toward the head of Aetna Hollow and showed the following:

Strata Exposed at Outcrop 20

		Thickness Feet
5.	Silt, brown, clayey (loess)	15
4.	Clay, very sticky, sandy and pebbly	5
3.	Conglomerate, cemented by iron oxide	½
2.	Sand, yellow, interbedded with thin clay beds	4½
1.	Sand and clay interbedded	15
	Covered	

Miscellaneous Outcrops

According to Parmelee and Schroyer,[7] "in the hollow behind the old powder plant, clay is exposed at several places. The section varies from place to place, but the following is representative." No further location is given but the hollow referred to is probably Aetna Hollow, judging from the description given for sample PS-42 taken by them from this place.

Section behind Old Powder Plant

		Thickness Feet
7.	Soil	1½
6.	Loess	10
5.	Clay and sand, ash-colored	4
4.	Sand, buff, loosely cemented	5½
3.	Conglomerate layers, cemented by iron; pebbles up to 3 inches	1½
2.	Clay, lignitic	3
1.	Clay, sandy, micaceous; very pure in places. Sample PS-42	4

[7] Parmelee, C. W., and C. R. Schroyer, op. cit. p. 75.

RESULTS OF CERAMIC TESTS

Results of ceramic tests on four samples of Cretaceous clays, PS-41, L-301, L-302, and PS-42, follow.

Miami Hollow District

Outcrop 21

In the lower part of Miami Hollow (fig. 6), there are few good outcrops. One of the best is as follows:

Strata Exposed at Outcrop 21

		Thickness Feet
5.	Silt, brown, clayey (loess)	4
4.	Gravel, chert	0–2
3.	Clay, gray. Sample L-44	15
2.	Sand, clayey, especially in basal portion, various colors	6
1.	Sand, various colors. Covered	9

Beds 1 to 3 are believed to be Cretaceous. The strata dip about 30° northeast and the bedding is distorted. The deposits apparently have slid into the valley from the adjoining valley wall. The contact of the clay (bed 3) with the overlying gravel is irregular. Sample L-44 was taken from the clay and is regarded as suggestive of the nature of this clay where found in place.

Outcrop 22

Outcrop 22 occurred along the north side of Miami Hollow and is described below:

Strata Exposed at Outcrop 22

		Thickness Feet
11.	Silt, brown, clayey (loess)	2
10.	Gravel, rounded, brown and white, with sand	2
9.	Sand, micaceous, with thin clay laminae	7
8.	Clay, with thin sand layers	8
7.	Conglomerate, rounded, gray, white and pink chert pebbles	1
6.	Sand, buff and gray	4

Sample No. PS-41.—Cretaceous Clay

This is a micaceous clay of a gray color streaked with brown. It is moderately hard. When plastic, it is rather sticky.

Water of plasticity	*percent*	32.3
Shrinkage water	*percent*	21.9
Pore water	*percent*	10.4
Slaking test, average	*min.*	8
Drying shrinkage, linear	*percent*	8.6

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Total shrinkage *percent*	Remarks
02	18.9	Cream	3.9	12.5	Shrinkage determined on very small piece
13	8.4	Gray	3.9	12.5	Vitreous; conchoidal fracture; not overburned; shrinkage determined on very small piece

Fusion test: ⅓ deformed at cone 25. The cone appears to have developed a decided vesicular structure.

SUMMARY

A very plastic and rather sticky clay, which has a medium drying shrinkage. It has a medium porosity at cone 02 and is still quite porous at cone 13 with a medium high shrinkage. Its fusion point is about cone 25, which places it among the nonrefractory clays.

The incomplete tests indicate a clay which may be suited for stoneware, sanitary ware, or similar wares.

5.	Conglomerate, black, gray and red, rounded chert pebbles, cemented by iron oxide	1
4.	Clay, dark gray	4
3.	Sand, clayey	6
2.	Conglomerate, chert pebbles, cemented by iron oxide	1
1.	Clay, gray	3
	Covered, creek level	

Beds 1 to 9 are believed to be of Cretaceous age.

Outcrop 23

One of the best outcrops of Cretaceous sediments noted in Miami Hollow was observed in the north valley wall near the carpenter shop, where the following section was measured.

STRATA EXPOSED AT OUTCROP 23

		Thickness Feet
9.	Clay, with interbedded sand layers	6
8.	Sand, yellow, medium- to coarse-grained	5
7.	Sand, very clayey, dark gray, carbonaceous	4
6.	Sand, yellow, medium-grained	6
5.	Conglomerate, chert pebbles, cemented by iron oxide	⅔
4.	Sand, medium-grained, yellow	½
3.	Clay, black, plastic	1/12
2.	Clay, white, plastic, non-gritty. Sample L-303	4
1.	Clay, dark gray, carbonaceous, very gritty	2½
	Covered; 10 feet to water in creek. The talus in the covered interval suggests that it is underlain by a bedrock chert formation.	

Miscellaneous Outcrops

From Outcrop 23 for a distance of about 800 feet up Miami Hollow very fine-grained white or light yellow sand is exposed at intervals. Roughly 200 feet further upstream the stream has intrenched itself in a deposit of alternating thin layers of micaceous sand and plastic dark gray clay. About 35 feet of such sediments were ex-

SAMPLE NO. PS-42.—CRETACEOUS CLAY

The clay is a uniform light gray in color. It is rather hard. When tempered with water it has a fair degree of plasticity and flows through a die satisfactorily.

Water of plasticity	*percent*	29.1
Shrinkage water	*percent*	15.4
Pore water	*percent*	13.6
Modulus of rupture	*lbs. per sq. in.*	283.1
Slaking test, average	*min.*	10
Drying shrinkage, linear		7.5

Burning test:

Cone	Porosity *percent*	Color	Total shrinkage *percent*	Remarks
02	12.8	Cream	13.7	Hackly fracture, vitreous
5	1.3	Gray	16.0	
9	0.0	Gray	17.5	
13	0.0	—	17.5	

Fusion test: Cone down at cone 25. No vesicular structure seems to have been developed in the cone.

SUMMARY

The clay has a medium strength. Its linear shrinkage is medium. The total shrinkage at cone 9 is high. Practically complete vitrification is reached at cone 5 and there are no signs of overburning at cone 13. It is a nonrefractory clay.

Suggested uses: Stoneware, architectural terra cotta, sanitary ware, and facebrick.

SAMPLE NO. L-301.—CRETACEOUS CLAY

Kind of material ..... No. 2 fire clay
Reaction for carbonates ..... Trace For pyrites ..... none
Hardness ..... medium
Working property ..... A little too sticky to work well
Conduct when flowing through a die ..... too sticky
Water of plasticity ..... *percent* 31.1 Shrinkage water ..... *percent* 11.1
Pore water ..... *percent* 20.0

Transverse strength of unburned clay:
With 50% standard sand
Number of briquettes tested 12
Modulus of rupture ..... *lbs. per sq. in.* 330
Without sand
Number of briquettes tested 14
Modulus of rupture ..... *lbs. per sq. in.* 543

Fineness: (Bureau of Standards Standard Sieves)

Screen	Percent residue	Character of residue
10 mesh	none	
20 mesh	none	
48 mesh	0.1	Sandy
100 mesh	0.7	Sandy, micaceous
200 mesh	1.9	Micaceous
Through 200 mesh	97.3	

Drying:
Air shrinkage: Linear ..... *percent* 6.3 Volume ..... *percent* 20.1
Drying conduct: Warps badly in drying. Scums a little.

Burning test:

Cone	Porosity *percent*	Color	Hardness not	Shrinkage	
				Lin.	Vol.
01	17.8	Cream	Steel hard	5.0	14.1
2	16.7	Cream	Steel hard	5.3	15.2
4	15.1	Cream	Steel hard	5.9	16.6
6	14.5	Cream	Steel hard	6.8	19.0
8	14.0	Grayish	Steel hard	7.2	20.0
10	10.9	Gray	Steel hard	7.4	20.7
12	4.0	Gray	Steel hard	7.9	21.8
14	8.4	Gray	Steel hard	4.7	13.3

Oxidation conduct: Readily oxidized.
Soluble sulfates: Present.
Fusion (deformation) test: Pyrometric Cone Equivalent, Cone 28.
Warpage: Some warping in firing.

USES SUGGESTED

The clay has only fair working properties, being a little too sticky to work well and cracking and warping in drying. This difficulty could be overcome by mixing the clay with a more sandy clay or with sand or grog.

The firing properties are good, the clay becoming dense and hard at cone 2 and not overfiring until above cone 12. The best firing range is cones 2-6, inclusive. There is a color change between cones 6 and 8.

The clay could be used in the manufacture of low grade refractories, face brick, flue linings, sewer pipe terra cotta, conduit and stoneware. The addition of a non-plastic would probably be desirable in all cases.

SAMPLE NO. L-302.—CRETACEOUS CLAY

Kind of material.....Sub-fire clay
Reaction for carbonates.....trace For pyrites.....none
Working property.....a little too sticky to work well
Conduct when flowing through a die.....too sticky
Water of plasticity.....*percent* 36.3 Shrinkage water.....*percent* 11.5
Pore water.....*percent* 24.8

Transverse strength of unburned clay:
With 50 percent Standard Sand
Number of briquettes tested..... 14
Modulus of rupture.....*lbs. per sq. in.* 112
Without sand
Number of briquetts tested..... 14
Modulus of rupture.....*lbs. per sq. in.* 294

Fineness: (Bureau of Standards Standard Sieves)

Screen	Percent residue	Character of residue
10 mesh	0.2	Limonite like material
20 mesh	0.1	Limonite like material
48 mesh	0.1	Limonite like material
100 mesh	0.3	Clayey
200 mesh	0.9	Clayey
Through 200	98.4	

Drying:
Air shrinkage: Linear—6.1 percent. Volume—19.4 percent.
Drying conduct: Warps and cracks in drying.

Burning test:

Cone	Porosity *percent*	Color	Hardness	Burning Shrinkage		Remarks
				Lin.	Vol.	
05	9.4	Tan	Steel hard	10.0	27.0	
03	1.6	Tan	Steel hard	11.2	29.9	
01	1.0	Tan	Steel hard	10.5	30.0	
2	0.7	Darker tan	Steel hard	11.2	29.9	
4	0.7	Darker tan	Steel hard	10.3	27.7	Surface vitrified and "self-glazed"
6	0.6	Grayish tan	Steel hard	6.9	19.2	
8	0.5	Grayish tan	Steel hard	1.1	3.3	
10	Stuck in kiln					

Oxidation conduct: Easily oxidized. Soluble sulfates: present.
Fusion (deformation) test: Pyrometric Cone Equivalent, Cone 14–15.
Warpage: Some.

USES SUGGESTED

The clay has only fair working properties, being a little too sticky to work well and cracking and warping in drying. This difficulty could be overcome by mixing the clay with a more sandy clay or with sand or grog.

The clay is not refractory, overfiring around cone 4.

The chief value of the clay would probably be in the manufacture of buff face brick, but it could probably also be used for flue linings, conduit, etc. Best firing temperature is below cone 01.

posed. These were the youngest Cretaceous sediments exposed in the Hollow, the next exposure being Lafayette gravel in the old gravel pit at the head of the hollow, said to have been operated at one time by the Chicago and Eastern Illinois Railroad.

Outcrop 24

In the W. ½ NE. ¼ NW. ¼ sec. 34 is an artificially made cut that connects Aetna and Miami hollows and that is known locally as the cut-off. Here 35 feet of fine to very fine-grained sand was exposed containing a relatively large amount of white mica, and locally thin bands of clay. Beneath the sand it is reported that 4½ feet of clay was encountered when the cut-off was dug.

RESULTS OF CERAMIC TESTS

Results of ceramic tests on sample L-44 from Outcrop 21 and L-303 from Outcrop 23 follow.

Thebes District

Outcrop 25

The only outcrops of Cretaceous clays noted in the Thebes district near railroads occur along both branches of the Y formed by the railroad tracks about a third of a mile east of the bridge across Mississippi River at Thebes in the NE. ¼ NE. ¼ sec. 17, T. 15 S., R. 3 W. In the northernmost branch of the Y, 1½ to 2½ feet of yellow-brown plastic clay were exposed, overlain by 10 feet of brown clayey silt (loess) which increases in thickness back from the outcrop.

In the southernmost branch the maximum exposure was as follows:

Strata Exposed at Outcrop 25

		Thickness Feet
4.	Silt, clayey, brown (loess)	25±
3.	Gravel, angular white and buff chert and rounded gray chert	1¼

Sample No. L-44.—Cretaceous Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	24.12
Linear drying shrinkage	*percent*	8.79
Water of plasticity	*percent*	32.2
Bonding strength—Modulus of rupture—without sand	*lbs. per sq. in.*	176.5
Bulk specific gravity		1.82

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
04	17.06	6.05	13.50	Salmon	Smooth
02	15.69	5.53	1.03	Dark tan (Bloated)	Smooth
2	25.11	9.19	0	Light brown	Smooth
5	26.15	9.61	0	Grayish brown	Smooth
6	—	Bloated			

Fusion test: Clay not refractory.

Oxidizing conduct: Poor.

Summary: Drying shrinkage medium, bonding strength medium low, vitrification complete at cone 02, overburned at cone 6, shrinkage at cone 02 is medium low.

Suggested uses: Building brick, possibly quarry tile, hollow tile, flower pots, roofing tile.

SAMPLE NO. L-303.—CRETACEOUS CLAY

Kind of material..... No. 3 fire clay

Reaction for carbonates..... trace For pyrites..... none

Hardness..... medium

Working property..... a little too sticky to work well

Conduct when flowing through a die..... too sticky

Water of plasticity..... *percent* 31.5 Shrinkage water..... *percent* 14.4

Pore water..... *percent* 17.1

Transverse Strength Tests of Unburned Clay:

With 50% Standard Sand

Number of briquettes tested..... 14

Modulus of rupture..... *lbs. per sq. in.* 112

Without sand

Number of briquettes tested..... 14

Modulus of rupture..... *lbs. per sq. in.* 290

Fineness: 99.9% passes 200 mesh Bureau of Standards sieve.

Drying: Air shrinkage: 9.6 *percent* Linear 25.5 *percent* Volume

Drying conduct: Warps and cracks in drying.

Burning test:

Cone	Porosity *percent*	Color	Hardness	Burning Shrinkage	
				Lin.	Vol.
03	18.9	Buff	Steel hard	5.9	16.8
01	16.4	Buff	Steel hard	6.6	18.5
2	12.1	Buff	Steel hard	7.7	21.3
4	8.7	Buff	Steel hard	8.7	24.0
6	0.7	Grayish buff	Steel hard	9.1	24.9
8	0.9	Grayish buff	Steel hard	9.8	26.7
10	0.9	Gray		10.3	27.7
12	13.0	Gray	Steel hard	4.5	12.9

Oxidation conduct: Easily oxidized.

Soluble sulfates: Present.

Fusion (deformation) test: Pyrometric Cone Equivalent, Cone 23.

Warpage: Not very much.

USES SUGGESTED

This clay is somewhat too sticky to work well. It warps in drying and also tends to crack, which accounts for the low strength.

The firing properties are good; the clay becomes dense and hard at a low temperature and does not overfire, until above cone 10. There is a color change between cones 4 and 6.

Mixed with a less plastic clay or a non-plastic the clay should be valuable in the manufacture of light colored face brick, terra cotta, flue linings, conduit, sewer pipe and stoneware.

2.	Clay, plastic, mottled brown and white; locally highly ferruginous in basal portion	3–5
1.	Clay, plastic, slightly gritty; color varies from slightly streaked with yellow to red throughout in short distances	9
	Covered	

The strata exposed appear to be arched, possibly as a result of slumping of the marginal portions of the deposit. The clay beds may be less iron-stained back from the outcrop.

Elco District

As previously noted the exposures of clay in the vicinity of Elco are not numerous nor do they afford a gauge of the possible clay resources. Below are described two exposures observed in this district.

Outcrop 26

At the center W. ½ NE. ¼ NW. ¼ sec. 19, T. 14 S., R. 1 W., a test-pit was dug about 3 feet into a bed of blue-gray clay, probably of Cretaceous age, which crops out on a hillside in several places in this vicinity. The outcrops are poor and little data are available regarding the extent and character of the deposit. Overburden is probably heavy over any considerable area.

Outcrop 27

At the center of the SE. ¼ NE. ¼ sec. 2, T. 14 S., R. 2 W., a yellow clay, probably underlain by a pink clay, was exposed along a small creek near the base of a hill. The material in the slope above the clay is clayey silt and angular chert fragments. It is not known whether the clay is in place or has slumped from higher up on the hill, though the latter is possible. The extent of the deposit is problematical.

ALLUVIAL CLAYS

The valley flats of Mississippi and Cache rivers are in places underlain by clayey silt or silty clay which likewise extends up some of the other larger valleys. No extensive study was made of these materials and in only a few places, as along drainage ditches, can more than a foot or so of the materials be seen. The greatest thickness noted in the Cache and Mississippi flats was about 5 feet. The silt was not calcareous but the deeper parts of the deposit may be. Probably the more clayey alluvial silts could be used for making common structural clay products, as they were at one time at Ullin in Pulaski County (p. 11).

A deposit of a different sort was noted on the north side of Rock Springs Hollow just east of the railroad trestle in the SW. corner SE. ¼ NW. ¼ sec. 21, T. 15 S., R. 3 W., where about 20 feet of calcareous clayey silt and silty clay containing irregular masses of impure calcium carbonate was exposed. This was the only deposit of this sort seen in the area studied. It is probably not an important ceramic material.

LOESS

The loess of Alexander County is a clayey silt which mantles the uplands where it was deposited by winds that picked it up from the valley flats of Mississippi and Cache rivers. Commonly the loess is brown, but near Mississippi River the lower part of some deposits is gray, as in a road-cut about three quarters of a mile south of Gale in the center of the S. ½ sec. 4, T. 15 S., R. 3 W., where 15 feet of gray loess overlain by 25 feet of brown loess was exposed. A chemical analysis of sample DS-4 which came from this exposure is given in table 2, p. 18. The maximum observed thickness of loess was 40 feet at the site mentioned. Probably the loess is about 50 feet thick near the river flats and is thinner inland from these flats. It is apt to contain more sand and silt and less clay in those places on the uplands where it is thick than where it is thin. The loess observed in Alexander County was generally not calcareous or only mildly so. None of the characteristic calcareous concretions found in the loess in more northerly counties were observed.

Because it is widespread and relatively thick the loess of Alexander County will afford a ready source of clay which tests suggest can be used to make building brick and possibly several kinds of tile.

Outcrop 28

A gully in a loess hill in the NW. ¼ SW. ¼ NW. ¼ sec. 7, T. 14 S., R. 1 W., north of Elco, gave opportunity to obtain a good sample of the loess inland from the bluffs that border the valley flat of Cache River. Sample L-27 was obtained here from 20 feet of brown loess which was overlain by about a foot of soil and underlain by chert gravel mixed with loess-like material. Results of a ceramic test on this sample follow.

Sample No. L-27.—Loess

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	14.33
Linear drying shrinkage	*percent*	5.02
Water of plasticity	*percent*	24.78
Bonding strength—Modulus of rupture—without sand	*lbs. per sq. in.*	440.1
Bulk specific gravity		1.77

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
04	3.05	1.03	31.92	Light red	Granular
2	21.88	7.90	12.32	Dark red	Granular
3	21.61	7.80	11.54	Dark red	Granular
5	6.20	1.83			
8	4.78	1.41	2.10	Purple red	

Fusion test: Clay not refractory.

Oxidizing conduct: Poor.

Summary: Drying shrinkage, medium; bonding strength, medium high; vitrification nearly complete at cone 8, indications of overburning at cone 5; shrinkage at cone 8 is low.

Suggested uses: Building brick, possibly floor tile, roofing tile, drain tile, flower pots.

CHAPTER 4—PULASKI COUNTY RESOURCES

The clay resources of Pulaski County are, in order of age: bedrock deposits, Cretaceous and Eocene deposits, alluvial clays, and loess. The latter two materials may be in part contemporaneous.

BEDROCK CLAYS

Outcrop 29

One outcrop of bedrock clay was noted near transportation in Pulaski County. This occurs in the SE. ¼ NE. ¼ SW. ¼ sec. 31, T. 15 S., R. 1 W., about 1¼ miles northeast of Unity where the following materials are reported to have been encountered in a boring and were partly exposed in a test-pit dug in the valley flat on the east side of Cache River.

STRATA REPORTED AT OUTCROP 29

		Thickness Feet
4.	Earth and firm silica, probably rotted chert	1½
3.	Clay, soft, white	3
2.	Silica, firm, probably rotted chert	½
1.	Clay, soft, white	3
	Covered	

The beds described, with the exception of the earth, are thought to be a highly weathered part of the Bailey or Grassy Knob formations. Sample L-121 was taken from clay dug from beds 1 and 3.

Another exposure of about 4 feet of similar clay containing chert occurs near the test-pit in the bank of Cache River. It is reported that test borings have shown that the clay underlies about 50 acres of the river flat in this area. In parts of the area the overburden is thin, in others there is probably as much as 10 feet of stream silt resting on the clay deposit. The hills east of the stream flat are made up of loess, sand, and gravel.

According to DeWolf[1] a bore hole on the flood-plain of Cache River on the John Mansperger farm, in sec. 31, penetrated 10 feet of clay at a depth of 8 feet. The clay is said to have rested on silica. Six feet of the latter material was reported exposed along Cache River. This is probably the same clay stratum as that previously mentioned. Sample D-44 was obtained from material said to have been taken from the boring.

[1] Purdy, R. C., and F. W. DeWolf, op. cit., p. 156.

Uses

The results of ceramic tests on samples L-121 and D-44 follow and indicate the ceramic possibilities of the white clay. In addition the clay, because of its white color, might find uses as a mineral filler. A chemical analysis of sample D-44 is given in table 2, p. 18.

SAMPLE NO. D-44*—BAILEY OR GRASSY KNOB CLAY

MECHANICAL ANALYSIS

Screen	Percent retained
20 mesh	0.89
50 mesh	0.24
100 mesh	0.42
150 mesh	1.80
200 mesh	1.14
Passing 200 mesh	95.45
	99.94

PYROMETRIC TEST

This clay did not begin to bend over until cone 27 was reached, but was fused down at cone 30. In the preliminary test it vitrified at cone 20.

SUMMARY

This is a comparatively fine-grained clay, relatively high in silica and with a fair amount of plasticity.

Its pyrometric value is equal to or better than that of many clays used for fire brick purposes.

* All samples having the prefix "D" are from Purdy, R. C., and DeWolf, F. W., Preliminary investigation of Illinois fireclays, Illinois Geol. Survey, Bull. 4, Yearbook for 1906, pp. 148-159, 172-175, 1907.

CRETACEOUS AND EOCENE CLAYS

The clays of Cretaceous and Eocene age in Pulaski County crop out chiefly in the southern and eastern parts of the County (fig. 7). Because some deposits contain clays of both ages, resources of these clays are described as a unit. The Eocene clays exposed belong to two formations, the

Sample No. L-121.—Bailey or Grassy Knob Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	12.34
Linear drying shrinkage	*percent*	4.30
Water of plasticity	*percent*	35.70
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	118.37
Bulk specific gravity		1.47

Screen test:

Mesh	Percent residue retained
28	26.0
48	5.9
65	0.5
100	0.6
200	1.8

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Fracture
05	4.07	1.38	39.17	White (reddish spots)	Granular fracture
02	10.94	3.79	35.71	White (reddish spots)	Granular fracture
2	12.40	4.32	34.86	White (reddish spots)	Granular fracture
5	14.73	5.17	31.55	White (reddish spots)	Granular fracture
6	19.60	7.01	31.87	White (reddish spots)	Granular fracture
7^1_2	21.76	7.86	22.93	White (red and black spots)	Granular fracture
11	21.66	7.82	24.48	White (black spots)	Granular fracture
13	44.91	....	16.92	Bluestoned	

Fusion test: P.C.E. 30-31.

Summary: Drying shrinkage medium low, bonding strength medium low, oxidizing conduct good, vitrification not complete at cone 13. It is a refractory clay.

Suggested uses: Refractories such as fire brick block or slabs, building brick, possibly flue linings.

Porters Creek formation and the overlying Wilcox sediments. Only a few outcrops which could be certainly identified as Wilcox were noted.

The Cretaceous clays occur in association with sand and thin gravel strata and are not greatly different from those described in adjacent counties. Principal areas of outcrop are near Pulaski, Grand Chain, and in and adjacent to the bluff of Ohio River near the east line of the county.

The Porters Creek formation crops out in Illinois only in Pulaski County and is one of the most easily recognizable clay formations of extreme southern Illinois. It consists of a gray or dark gray to almost black clay, which breaks with conchoidal fracture, and although it develops a slippery surface when wet it does not readily become plastic and consequently stands in relatively steep faces. The clay normally contains considerable fine sand and disseminated fine

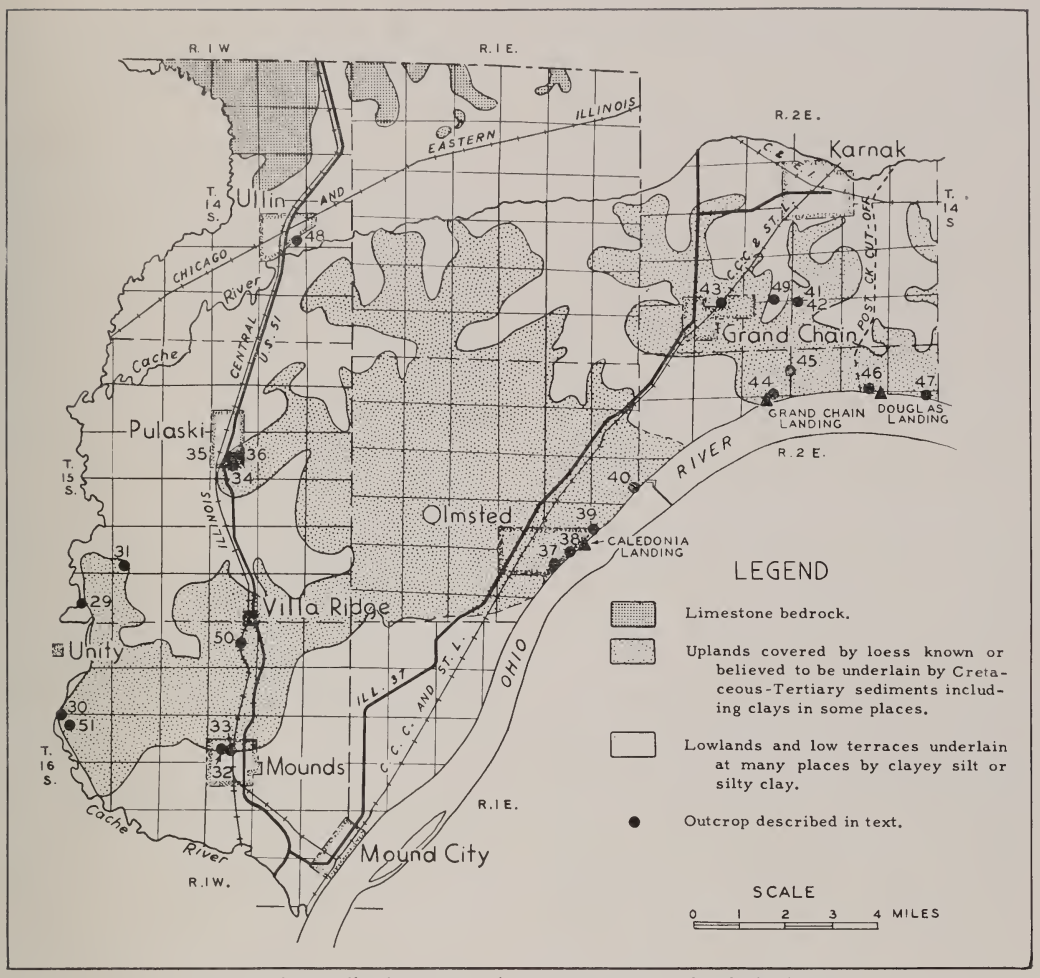

FIG. 7.—Generalized map showing clay resources of Pulaski County.
(Erratum: Location 49 should be 2 miles east of that shown.)

flakes of white mica. When the clay is exposed to the weather for a long time, the dark color disappears and a grayish tan exterior mottled with yellow streaks is developed. The upper part of the Porters Creek formation is the source of the fuller's earth produced at Olmsted.[2]

The best exposures of the formation occur in the pits of the fuller's earth plant at Olmsted. Only about 15 to 40 feet normally outcrops, but from borings and wells the thickness of the formation is known to be as much as 80 feet near Olmsted, 100 feet at Mounds City, 65 feet at Mounds, and 120 feet at Cairo.

[2] Lamar, J. E., Preliminary report on the fuller's earth of Pulaski County, Ill. Geol. Survey Rept. Inv. 18, 1926.

Aside from the outcrops in the pits at Olmsted and vicinity and a reported outcrop on the golf course at Villa Ridge, four other outcrops of Porters Creek clay were observed as follows:

A series of outcrops of 5 to 15 feet of clay along the east bank of Cache River and tributary valleys in and near the SW. ¼ sec. 7, T. 16 S., R. 1 W.

About 2 feet of clay in the bottom of a gravel pit just west of Mounds near the center NE. ¼ SW. ¼ sec. 15, T. 16 S., R. 1 W.

Five feet of clay in the hills east of Villa Ridge in the SE. ¼ sec. 36, T. 15 S., R. 1 W.

Four feet of clay in the floor of a gravel pit about a mile northeast of Olmsted in the SW. ¼ NE. ¼ sec. 23, T. 15 S., R. 1 E.

Other reported outcrops[3] of clay, probably a part of the Porters Creek formation, are:

In the east bank of Cache River near the north line of sec. 19, T. 16 S., R. 1 W.

In or near the NE. ¼ SE. ¼ SE. ¼ sec. 19, T. 16 S., R. 1 W., at the lower end of a "branch."

Along Hodges Bayou in the SW. ¼ sec. 28, the NE. ¼ sec. 29, and possibly in sec. 17, all in T. 15 S., R. 1 E.

Along a creek in the SE. ¼ sec. 18, T. 15 S., R. 1 E.

A line encircling the outcrops mentioned above may well roughly delimit the approximate northward extension of the Porters Creek formation in Illinois, although a well in the SE. ¼ SW. ¼ sec. 9, T. 15 S., R. 1 E., encountered clay which may possibly be Porters Creek between depths of 102 and 154 feet. If the clay is correctly identified, the delimiting line would be extended somewhat to the north.

Character of Outcrops

The outcrops of Cretaceous and Eocene clays in Pulaski County are generally of limited extent and occur principally in railroad-cuts, road-cuts, and stream banks or bluffs. The extent of the deposits cannot be told without test-drilling. In some places they appear to be reasonably horizontal, but slumping has affected many outcrops. The possibility of finding deposits of reasonable lateral extent seems promising in some areas.

Overburden

Overburden on the clay deposits consists of brown clayey silt (loess) which probably reaches a maximum of about 30 feet thick but is generally believed to be less. Lafayette gravel and sand also overlie some deposits as well as sands of the Wilcox formation or of Cretaceous age.

Mineral Composition

The Cretaceous and Wilcox clays are composed of kaolinite and illite with the former predominant. A few clays may be very largely kaolinite. The clay mineral in the Porters Creek formations is primarily montmorillonite of the nonswelling type.[4]

Uses

Ceramic tests show that some of the Cretaceous clays are refractory and suitable for refractory ware and that others, although not refractory, have reasonably high fusion points. Many of the clays are light burning. Uses suggested include face brick, terra cotta, stoneware, certain types of crucibles, quarry tile, flue tile, roof tile, stove linings, and sanitary ware. Other possible uses for some clays are for filler and as a bond for synthetic molding sands and possibly for other nonceramic purposes.

The Porters Creek formation is currently of greatest importance as a source of fuller's earth. According to a ceramic test of the clay (p. 59) its value in the clay products field is limited. Some deposits may have possibilities as a source of bonding clay for synthetic molding sands as indicated by the following tests.[5]

Bonding Clay Tests

Percent clay in strength test mixture	8
Maximum green compression strength, lb. per sq. in.	18.0
Percent water at maximum strength	3.12
Percent A.F.A. clay grade	66.1
Percent clay mineral in total sample	70.

Cache River District

The Cache River district is arbitrarily defined to include two outcrops of clay in the vicinity of Cache River in the southwest part of Pulaski County.

Outcrop 30

In the W. ½ SW. ¼ sec. 7, T. 16 S., R. 1 W., and continuing south into the adjacent NE. corner of sec. 13 and the NW. part of sec. 18, clay of the Porters Creek formation crops out in the riverward slope of a terrace along Cache River for a distance of half a mile or more and locally appears in valleys that cut back into the up-

[3] Englemann, Henry, in Geological Survey of Illinois, vol. I, pp. 419, 422, 1866.

[4] Grim, Ralph E., Petrography of the fuller's earth deposits, Olmsted, Illinois: Illinois Geol. Survey, Rept. Inv. 26, 1933.

[5] Grim, R. E., and R. A. Rowland, The relation between the physical and mineralogical characteristics of bonding clays: Illinois Geol. Survey, Rept. Inv. 69, p. 26, 1940. Sample 2, Eocene clay, Pulaski County.

lands to the east. The maximum exposure noted was 10 feet. In recent years an area of about an acre of the clay was stripped of its cover which was used for fill in connection with a highway bridge across Cache River nearby. The upper part of the exposed clay is yellow or buff, below this it is gray with locally an almost black layer as much as about 5 feet thick. The overburden on the terrace is silt, probably 3 to 5 feet thick. In the bluffs east of the terrace, sands, locally containing lenses of white clay, chert gravel with associated sand, red clay, and brown clayey silt, crop out to a thickness of 40 feet or more.

The thickness of the Porters Creek formation here is unknown although it may reach 100 feet. About 30 feet of the formation is reported to have been penetrated in a test-boring north of the wagon road, but this is probably not its full thickness.

Results of tests on outcrop samples of the buff and gray clay in this deposit[6] suggest that it may have possibilities as fuller's earth; however, testing of more samples taken from test-pits or borings in the fresh clay is necessary to determine the value of the clay for this purpose.

Outcrop 31

The bluffs on the south side of Boar Creek show poor outcrops of white sand and locally clay at places in the S. ½ SW. ¼ sec. 29, T. 15 S., R. 1 W. In the NE. ¼ SW. ¼ SW. ¼ of this section, the following beds were exposed near the road.

Strata Exposed at Outcrop 31

		Thickness Feet
4.	Silt, brown, clayey	10+
3.	Clay, pink	3
2.	Clay, gritty, grades into clay above	1½
1.	Sand, white	2
	Covered	

The extent of the clay of beds 2 and 3 was not evident. Prospecting might reveal a more extensive deposit of clay in this vicinity and possibly further west.

[6] Piersol, R. J., J. E. Lamar, and W. H. Voskuil, Anna "kaolin" as a new decolorizing agent for edible oils, Illinois Geol. Survey, Rept. Inv. 27, p. 22, 1933.

Mounds District

This district includes two outcrops close together at the northwestern outskirts of Mounds. Clays of both the Porters Creek and Wilcox formations are exposed.

Outcrop 32

In the SW. ¼ NE. ¼ SW. ¼ sec. 15, T. 16 S., R. 1 W., a series of gravel pits in a southward facing ridge exposed the following:

Strata Exposed at Outcrop 32

		Thickness Feet
5.	Silt, brown and gray, clayey	5–30
4.	Gravel, chert, brown, with interbedded sand lenses containing thin clay bands	5–15
3.	Clay, buff and pink, silty, lenticular	3–5
2.	Clay, very dark gray	3
1.	Clay, buff gray	3
	Covered	

Beds 1 and 2 are Porters Creek formation; bed 3 is probably Wilcox formation.

Results of ceramic tests on sample L-89 taken from bed 3 follow. Tests on samples of the Porters Creek strata suggest that some of the clay may have possibilities as fuller's earth; however, testing of more samples to better represent the clay throughout the deposit is necessary to determine this. The Porters Creek formation is believed to be at least 65 feet thick and possibly more at this place.

Outcrop 33

A road-cut a short distance west of the west end of the road bridge over the Illinois Central Railroad north of Mounds in the SE. ¼ NE. ¼ SW. ¼ sec. 15, T. 16 N., R. 1 W., showed the following:

Strata Exposed at Outcrop 33

		Thickness Feet
6.	Silt, brown, clayey (loess)	3–8
5.	Gravel, brown, chert	1½–4
4.	Sand, clayey, red and yellow	4
3.	Sand, fine-grained and clay, interbedded	2½
2.	Clay, silty, light gray, locally yellow along joints, in places contains masses of black organic material	4
	Covered	3±
1.	Silt, gray, clayey, less iron-stained than bed above but contains more organic material	4
	Covered	

Sample No. L-89.—Wilcox Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	20.90
Linear drying shrinkage	*percent*	7.52
Water of plasticity	*percent*	25.4
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	393.6
Bulk specific gravity		1.96

Screen test:

Mesh	Percent residue retained
28	0.2
48	1.4
65	1.8
100	8.0
200	55.9

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
05	.21	.071	27.21	Light salmon	Granular fracture
02	2.64	.889	25.40	Light salmon	Granular fracture
2	3.65	1.234	24.44	Light salmon	Granular fracture
5	2.53	.95	21.76	Light salmon	Granular fracture
8	4.75	1.61	22.80	Very light salmon, iron spots	Granular fracture
11	6.54	2.23	20.70	Light salmon, iron spots	Granular fracture

Fusion test: P.C.E. 20–26.

Summary: Drying shrinkage medium, bonding strength medium, oxidizing conduct good, vitrification incomplete at cone 11, shrinkage at cone 11 is low. It is a nonrefractory clay.

Suggested uses: Building brick, stove linings, possibly flue linings.

Outcrop 33 lies at a higher elevation than Outcrop 32. Comparing the strata exposed below the gravel in both outcrops, it is probable that the beds in Outcrop 33 are above those in Outcrop 32. Beds 1 to 3 in Outcrop 33 and possibly bed 4 are regarded as of Wilcox age.

Pulaski District

The Pulaski district covers an area east of the town of Pulaski in the central part of sec. 15, T. 15 S., R. 1 W. where a group of hills showed a number of outcrops of gray clay, probably of Cretaceous age. The same group of hills continues eastward into sec. 14 and may also contain clays.

Outcrop 34

About 1905, when exposures of the strata comprising the hills were probably superior to those of more recent years, the following section was measured and sampled on the J. L. Aldred farm.[7] The lowest beds ex-

[7] Purdy, R. C., and F. W. DeWolf, Preliminary investigations of Illinois fireclays, Illinois Geological Survey Bull. 4, p. 157, 1906.

posed are in the basal part of the hill east of town.

STRATA EXPOSED AT OUTCROP 34

		Thickness Feet
9.	Loess	15
8.	Sand, clayey, red-brown, containing gravels	9
7.	Clay, drab, gray and brown, with some ferruginous streaks	10
6.	Sand, fine and white	1
5.	Clay, bituminous[a]	1
4.	Clay, drab, micaceous, interbedded with a little white sand	5
3.	Sand and clay, predominantly sand	6
2.	Clay, drab, fat	6½
1.	Sand, fine, white, micaceous	1½

[a] It is believed that the word bituminous as used here means carbonaceous. J.E.L.

Sample D-45 was taken from the lower 5 feet of bed 7 and all of bed 4; sample D-46, from the upper 5 feet of bed 7.

Outcrop 35

More recently the following strata were exposed on the J. M. Sheets farm at the south edge of Pulaski in the NE. ¼ SW. ¼ sec. 15.

GENERALIZED SECTION OF STRATA EXPOSED AT OUTCROP 35

		Thickness Feet
6.	Silt, brown, clayey (loess)	1–20
5.	Gravel, brown and white, chert	1–7
	Covered	15–20
4.	Clay, gray with yellow spots, exposed in test-pit	6
3.	Conglomerate, brown chert, cemented by iron oxide	½
2.	Sand, medium-grained, mostly yellow	6
1.	Sand, fine-grained, clayey, micaceous	5
	Covered	

Sample L-211 was taken from the clay of bed 4.

Outcrop 36

In gullies just south of the Christian Church in Pulaski in the SE. ¼ SE. ¼ NW. ¼ sec. 15, the following strata were exposed.

STRATA EXPOSED AT OUTCROP 36

		Thickness Feet
	Covered	
4.	Clay, gray	3
3.	Clay, black, high in carbonaceous material	⅔
2.	Clay, dark gray, plant stem fragments, carbonaceous	1⅙
	Covered	5±
1.	Sand, fine-grained, white, micaceous. Covered	3½

From the data available it appears that the hills east of Pulaski contain several clay strata interlayered with beds of sand. Samples of the clays are not refractory; some of them are light burning. Whether or not they can be profitably developed commercially would have to be determined by test-borings or pitting and testing of samples.

Results of ceramic tests for sample L-211 obtained during the current investigation and samples D-45 and D-46 obtained much earlier follow. Chemical analyses of samples D-45 and D-46 are given in table 2, p. 18.

SAMPLE NO. D-45.—CRETACEOUS CLAY
J. L. Aldred farm, Pulaski

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	1.43
60 mesh	0.93
100 mesh	0.46
150 mesh	1.96
200 mesh	1.45
Passing 200 mesh	94.00
	100.23

PYROMETRIC TESTS

The final test on this clay was unsatisfactory; reducing conditions prevailed, and the distribution of heat was unequal. Under these conditions cone 22 was fused no more than cone 25. The clay was bending and badly bloated. In the preliminary burn it was thoroughly vitrified at cone 18 and would have gone down at cone 20.

BURNING TEST

Briquets made from this clay were so fine grained and plastic that they were dried with difficulty. Burning in the kiln produced incipient vitrification.

SUMMARY

The clay is high in free iron but contains only a little over 1½ percent of other fluxes. It is as plastic as the ball clay used as a standard in these tests. Although a good test was not obtained on the clay, it may be safely assumed that it does not have a refractory value sufficient to recommend it for first class fire clay. It would seem, however, to be a paving brick possibility.

OLMSTED DISTRICT

The Olmsted district embraces a number of outcrops of clay occurring in the vicinity

Sample No. L-211.—Cretaceous Clay

Kind of material		clay
Drying conduct		safe
Volume drying shrinkage	*percent*	35.4
Linear drying shrinkage	*percent*	13.5
Water of plasticity	*percent*	40.7
Transverse strength—Modulus of rupture	*lbs. per sq. in.*	962
Bulk specific gravity		1.901
Percent residue on 100-mesh sieve		none

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Hardness
06	12.9	4.49	19.43	Cream	Steel hard
04	18.4	6.55	14.14	Cream	Steel hard
02	17.6	6.26	14.33	Cream	Steel hard
1	21.9	7.88	4.37	Gray	Steel hard
2	19.8	7.10	8.48	Gray	Steel hard
4	23.9	8.69	1.71	Gray	Steel hard
6½	23.4	8.50	1.98	Gray	Steel hard
8	24.5	8.95	1.63	Gray	Steel hard

Fusion test: P.C.E. cone 20-23, bloated a little.

Summary: This is a clay which gives a plastic body of good working properties. Its drying conduct is safe and its shrinkage is medium high. Its dry strength is high. It burns to a light color and is well vitrified at a low temperature (cone 4). Its burning shrinkage is medium. It is not a refractory clay.

Suggested uses: Face brick, architectural terra cotta, stoneware; certain types of crucibles, etc., for which dense burning strong clays are needed; quarry tile, flue linings, roof tile.

of the Mississippi River bluffs at Olmsted and northeast to Lock and Dam 53.

Outcrop 37

In the W. ½ NW. ¼ sec. 26, T. 15 S., R. 1 E., is located the fuller's plant and pit of the Sinclair Refining Company. Formerly the Standard Oil Company of Indiana also operated a plant and pit in the NE. ¼ SE. ¼ sec. 27 and adjacent part of sec. 26. The fuller's earth is obtained from the upper buff-gray portion of the Porters Creek formation. The total thickness of the formation is about 80 feet in this area; the upper part used for fuller's earth ranges up to about 40 feet thick.[8] Overburden consists at some places of as much as 5 feet of clay, sometimes called "kaolin" locally, overlain by 3 to 5 feet of clayey brown chert gravel and 10 to 25 feet of brown clayey silt (loess).

The extent of the Porters Creek formation in this area is not well known, but the formation is present about a mile northeast of Olmsted in the NE. ¼ SW. ¼ NE. ¼ sec. 23, T. 15 S., R. 1 E., where 4 feet was exposed in the floor of a gravel pit. The Olmsted city well in the SE. corner SW. ¼ sec. 22, passed through clay, probably Porters Creek, between depths of 23 and 92 feet; and a well in the SE. ¼ SW. ¼ sec. 9, T. 15 S., R. 1 E., penetrated a clay between depths of 102 and 154 feet which may also be Porters Creek. It is believed that the top of the formation is uneven.

[8] For a more detailed discussion see Lamar, J. E., Preliminary report of the fuller's earth deposits of Pulaski County, Illinois Geological Survey, Rept. Inv. 15, 1928.

The darker lower part of the formation is available in considerable quantities below the floors of the fuller's earth pits and probably at other places. A chemical analysis of a sample La-3, representing 15 feet of the lower part of the Porters Creek formation at Olmsted, and of Sample FE-116 from 20 feet of the upper fuller's earth portion are given in table 2, p. 18.

The clay mineral in the fuller's earth is montmorillonite. The average of six analyses[9] of the clay mineral separated from samples taken from the fuller's earth pits follows:

Analysis of Montmorillonite

	Percent		Percent
SiO_2	58.49	Na_2O	0.14
Al_2O_3	14.68	K_2O	1.15
Fe_2O_3	3.71	H_2O-	5.49
FeO	0.56	H_2O+	12.46
MgO	1.85	TiO_2	0.39
CaO	0.75	P_2O_5	0.36
			100.03

Results of ceramic tests on samples L-305 and PS-17 follow. Sample L-305 was obtained from 20 feet of the lower part of the Porters Creek formation exposed beneath

[9] Grim, Ralph E., Petrography of the fuller's earth deposits, Olmsted, Illinois: Illinois Geol. Survey, Rept. Inv. 26, p. 347, 1933.

Sample No. D-46.—Cretaceous Clay
J. L. Aldred farm, Pulaski

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	.68
60 mesh	.54
100 mesh	.34
150 mesh	.74
200 mesh	1.02
Passing 200 mesh	96.58
	99.90

PYROMETRIC TESTS

This clay started to bend at cone 24. At cone 29 it was not down but thoroughly fused and blistered. In the preliminary burn it gave evidence of incipient fusion at cone 18.

SUMMARY

This clay is high in free iron but contains only a a little over 1½ percent of other fluxes. It is as plastic as the ball clay used as a standard in these tests. The clay falls below the refractoriness of the better fire bricks but may be of value for stoneware, terra cotta, and No. 2 fire brick.

Sample No. L-305.—Porters Creek Clay

The material is light gray in color, has moderate plasticity when first wet but becomes quite plastic on soaking, and requires 82.9% water to develop its normal medium working consistency. A medium bonding strength is indicated by a value of 275 pounds per square inch for the modulus of rupture.

It dries somewhat slowly under ordinary atmospheric conditions without difficulty and has a shrinkage of 12.9%.

When slaked and washed on a 40 mesh sieve, 71.5% residue remains which consists of unslaked original material which, however, is quite soft and friable.

Treatment with cold and hot hydrochloric acid causes no evolution of gas, indicating the absence of carbonates.

When burned, the clay oxidizes readily and has vitrification characteristics indicated in the accompanying table.

Cone	Porosity *percent*	Color	Hardness	Linear Shrinkage	
				Burning	Total
07	50.7	Salmon		3.6	16.6
02	47.6	Bright pink to yellow buff		6.1	19.1
2	46.3	Bright pink to yellow buff		7.1	20.1
4	43.3	Bright pink to yellow buff		8.7	21.7
6	44.8	Yellow buff		8.5	21.5
9	2.4	Mahogany	Steel hard	20.1	33.1
12	5.7	Mahogany to completely fused	Steel hard	19.3	32.3
14	....	Completely fused	Steel hard		

This is a very porous material at temperatures as high as cone 6. It then vitrifies rapidly to a porosity of 2.4% at cone 9 and is overburned at that temperature, as is shown by the shrinkages. The total shrinkages are very high. The color is a bright pink between cones 02 and 4, and yellow buff to mahogany at higher cones.

Suggested uses: Because of the peculiar working properties and high shrinkages of this material, its suitability for ordinary clay products is doubtful. Possibly it may serve for the manufacture of light weight products, common brick.

Sample No. PS-17.—Porters Creek Clay

This is a clay of rather hard and shaly character which seems to contain a considerable quantity of mica. The clay is of a brownish color marked with yellow specks. It has rather a poor degree of plasticity and does not flow satisfactorily through a die.

Water of plasticity ..... *percent* 80.9

Shrinkage water ..... *percent* 28.1

Pore water ..... *percent* 52.8

Modulus of rupture ..... *lbs. per sq. in.* 180.9

Slaking test, average ..... *min.* 4

Screen test:

Mesh	Residue *percent*	Character of residue
10	0.25	Particles of clay
14	2.2	Particles of clay
20	8.8	Particles of clay
35	19.5	Sand and clay
48	6.3	Clay and flakes of mica
65	4.3	Clay and flakes of mica
100	5.0	Clay and flakes of mica
150	4.0	Clay and flakes of mica
200	4.1	Clay and flakes of mica

Drying shrinkage, linear ..... *percent* 5.0

Volume ..... *percent* 25

Burning test:

Cone	Porosity *percent*	Color	Remarks
02	38.6	Light brown	Poorly oxidized
1	38.2	Light brown	
3	38.8	Light brown	
5	38.6	Darker brown	
7	34.6	Darker brown	
9	34.0	Black	Appears to show vitrification
13	14.8	Black	Overburned

Fusion test: It melts to a glass below cone 26.

SUMMARY

The strength of the clay is medium low. The percentage of screen residue is high. Its drying shrinkage is medium low. It appears to be overburned at cone 13 even though its porosity is still quite high. The exceptionally high contents of water of plasticity and pore water indicates a very high colloidal content. Because of this the clay gives erratic results in the strength tests.

the fuller's earth in and near the pit at Olmsted. Sample PS-17 was obtained from a 25-foot exposure of clay of the Porters Creek formation along the Ohio River bank south of Caledonia (probably Caledonia Landing) approximately in the NW. corner of the NE. ¼ sec. 26, and is probably from a weathered outcrop of the lower part of the formation. The clay could possibly be used for making structural clay products. The unburned clay is light in weight when dry as compared to other clays, and the

burned clay has a high porosity up to about cone 9. The possibility that these properties could be utilized in making light weight burned clay aggregates or structural products may bear investigation.

Some of the clay of the Porters Creek formation has been found to have possibilities as a bonding clay for synthetic molding sands.[10]

Outcrop 38

In the river bluffs and tributary valleys in the vicinity of Caledonia Landing, which is along the Ohio River at the center N. line, NW. ¼ NW. ¼ NE. ¼ sec. 26, T. 15 S., R. 1 E., there were numerous small outcrops of sands and silts, mostly Cretaceous in age, especially in the lower part of the valley in the SW. ¼ SW. ¼ SE. ¼ sec. 23. A generalized section of these beds follows.

Generalized Section of Strata Exposed at Outcrop 38

		Thickness Feet
5.	Sand, yellow, medium-grained, micaceous, glauconitic, contains molds of invertebrate fossils	6
4.	Sand, yellow, cemented by iron oxide	2
3.	Silt, gray, clayey, micaceous, lower 6 feet contains interbedded thin bands of yellow clay	11±
2.	Sand, yellow, medium-grained, micaceous, with thin yellow clay bands	8±
1.	Silt, white, micaceous	4
	Covered	

Bed 5 is probably overlain by the Porters Creek formation, although the latter was not observed. Of the strata described above, only beds 1 and 3 have possible significance in the field of clays. No samples were tested, but tests of a sample of silt from Massac County of similar appearance to bed 3 indicated it had possibilities for the manufacture of face brick, stoneware, terra cotta, and flue linings.

The silts in the vicinity of Caledonia Landing would be difficult to obtain in large quantities because of heavy overburden and unfavorable underground mining conditions, but considerable amounts may possibly be obtained by working beneath the flats of some of the small valleys cutting through the silts.

[10] Grim, Ralph E., and Richards A. Rowland, The relationship between the physical and mineralogical characteristics of bonding clays: Illinois Geol. Survey, Rept. Inv. 69, p. 26, 1940 (sample 2).

Outcrop 39

The following strata cropped out in the bluff of Ohio River in the NE. ¼ NW. ¼ NW. ¼ SW. ¼ sec. 24, T. 15 S., R. 1 E., about 1¼ miles northeast of Olmsted.

Strata Exposed at Outcrop 39

		Thickness Feet
6.	Silt, brown, clayey (loess)	15+
5.	Clay, hard, gray (Porters Creek)	6+
4.	Sand, fine-grained, micaceous, partly covered	10+
3.	Silt, clayey, carbonaceous	3±
2.	Lignite, impure, clayey and sandy	1¾
1.	Clay, dark gray, with small lenses of silt	3
	Covered	

Sample L-306 was taken from bed 1. Results of tests follow.

Outcrop 40

Outcrop 40 covers exposures in the bluff of Ohio River near Dam 53 and in adjacent areas. Below is a generalized section of the strata exposed in this area.

Generalized Section of Strata Exposed at Outcrop 40

		Thickness Feet
6.	Silt, brown, clayey (loess)	25±
5.	Sand, medium-grained, micaceous, locally cross-bedded, red at top grading to yellow at base with interspersed layers of white sand, iron-cemented zone at base	25
4.	Sand, medium-grained, white, bedding indistinct	12
3.	Silt, white, micaceous, with irregular iron-stained bands and numerous turnip-shaped concretions from 1 to 12 inches in diameter having a shell of iron-cemented silt	18
2.	Silt, cemented by iron oxide to make a shelly, slabby bed	2½
1.	Clay, gray-black, plastic, in layers about ⅛ inch thick separated by thin partings of mica, locally contains pyrite nodules	12
	Covered	

Sample L-67 was taken from bed 1 which was well exposed at the center of the east line, SE. ¼ NE. ¼ SE. ¼ sec. 13, T. 15 S., R. 1 E. The strata exposed are of Cretaceous age.

Sample No. L-306.—Cretaceous Clay

Color ..... dark gray

Plasticity ..... short; loamy in character

Water content required ..... *percent* 39.8

Molding properties ..... difficult to work

Drying shrinkage: Linear—10.1 *percent;* Volume —28.6 *percent*

Modulus of rupture of dry body:

No. tests 9

Arithmetic mean 504

Pyrometric cone equivalent 18–19

Firing Tests:

Cone fired	Color	Hardness	Porosity	Linear shrinkage	Volume shrinkage
010	Pink		41.2	0	0
08	Pink		41.5	0.9	3.2
06	Pink		41.0	0.9	2.6
04	Buff—pink stains		39.8	0.9	4.6
02	Buff—pink stains		40.1	1.8	6.3
1	Buff—pink stains		38.0	2.8	7.4
3	Buff—pink stains		34.8	4.0	11.7
5	Gray buff—brownish red stains	Steel hard	31.7	4.9	13.3
7	Gray—brownish red stains	Steel hard	29.8	5.8	16.6
9	Dark gray	Steel hard	21.0	6.7	24.1

Due to its lack of plasticity the clay is difficult to work and lacks in bonding strength. Its softening temperature is too low to give it value as a refractory. The burned body is too porous and does not vitrify sufficiently to permit its use for structural clay products. The clay contains soluble iron salts which are deposited on the surface to produce red to brown discolorations. This is a serious disadvantage in its commercial use.

A somewhat similar deposit of gray thin-bedded micaceous clay is reported[11] in the river bluffs on the Barber farm in the SE. ¼ sec. 13, T. 15 S., R. 1 E. Fourteen feet of clay was exposed, and the deposit is said to extend 20 feet below the base of the outcrop to the low-water level of Ohio River before the erection of Dam 53. A small outcrop of plastic clay occurred a short distance downstream at water level. Sample PS-37a was taken from the 14 feet of gray clay.

Another description,[12] possibly of the same bed of micaceous clay, mentions an exposure of clay near Lockharts Landing in sec. 18, T. 15 S., R. 2 E., which reached from near water level of the Ohio River up the sloping beach for about 25 feet to a 30-foot cliff of sand and gravel. The clay is described as "mostly micaceous and sandy, varying in color from dark blue-gray or brown at the base to light gray or white at the top." Sample D-36 was taken from this outcrop.

Results of ceramic tests on the three samples follow. None of the clays are refractory but the tests suggest that they may be suitable for a variety of nonrefractory products. Results of a chemical analysis of sample D-36 are given in table 2, p. 18. The overburden on all the deposits is heavy, amounting possibly to a maximum of 75 to 100 feet, thus handicapping their commercial development.

[11] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 68.
[12] Purdy, R. C., and F. W. DeWolf, op. cit., p. 153.

Grand Chain District

The Grand Chain district includes clay deposits lying east and northeast of the town of Grand Chain. The range of roughly north-south hills about two miles east of Grand Chain appear particularly promising because of the possibility of the presence of a relatively thick clay stratum with a reasonably thin overburden.

Outcrop 41

At the center south line SW. ¼ SW. ¼ sec. 27, T. 14 S., R. 2 E., the following strata were noted.

Strata Exposed at Outcrop 41

		Thickness Feet
6.	Silt, brown, clayey (loess)	8
5.	Gravel, chert, partly cemented by iron oxide	2
4.	Clay, gray and brown, mottled	3
3.	Clay, gray, plastic, lower 2 feet brownish	10
2.	Clay, brown, and silt brown, interbedded	3
1.	Iron crust	

Strata 4, 5, and 6 crop out in the sides and bottom of the ditch along an east-west road about two miles east of Grand Chain. Strata 1, 2, and 3 were explored by means of a soil auger. Because stratum 4 is closely

Sample No. L-67.—Cretaceous Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	19.27
Linear drying shrinkage	*percent*	6.88
Water of plasticity	*percent*	30.29
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	323.2
Bulk specific gravity		1.76

Screen test:

Mesh	Percent residue retained
28	0.5
48	32.8
65	5.1
100	7.0
200	28.8

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
2	6.09	2.07	29.33	Light buff	Granular
5	8.44	2.90	24.06	Light buff	Granular
7	20.17	7.34	15.42	Buff	Granular
10	23.76	8.65	.89	Gray	Granular
11	24.47	8.93	3.15	Gray	Granular

Fusion test: Clay not refractory.

Summary: Drying shrinkage medium, bonding strength medium, oxidizing conduct medium, vitrification complete at cone 10, overburned at cone 11, burning shrinkage at cone 10 medium. It is not refractory.

Suggested uses: Building brick, possibly roofing tile, quarry tile, drain tile, and hollow tile.

Sample No. PS-37a.—Cretaceous Clay

This is a light gray soft clay which contains many mica particles. The plastic mass is readily molded into shape and it flows well through a die.

Water of plasticity ..... *percent* 27.9

Shrinkage water ..... *percent* 14.9

Pore water ..... *percent* 13.0

Modulus of rupture ..... *lbs. per sq. in.* 240.7

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 238.7

Slaking test, average ..... *min.* 15

Drying shrinkage:

Linear; wet length ..... *percent* 3.2

Linear; dry length ..... *percent* 3.4

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*
2	28.80	Cream	2.6
5	27.00	Cream	2.2
9	3.7	Light gray	6.1
12	7.2	Light gray	5.0
13½	13.0		2.4

Fusion test: Complete fusion at cone 25.

SUMMARY

This clay has medium strength. Its drying shrinkage is medium low. It develops a high degree of vitrification between cones 5 and 9 with a medium burning shrinkage. It overburns at cone 12 and is non-refractory since it fuses at cone 25.

The clay ought to find use for manufacture of stoneware, architectural terra cotta, sanitary ware and similar wares.

similar to stratum 3 except in color, it was mixed with the latter in the proportion of 3 parts to 10 parts to form sample B-4.

The clay is of Cretaceous age and crops out on the west slope of an irregular ridge which trends approximately north-south. The deposit probably caps most of the ridge, and other deposits like it may cap similar hills and ridges in the vicinity. The loess and gravel overburden is probably thickest on the crest of the ridge and thinner on its flanks. It is believed, however, that a considerable quantity of clay may be available in the vicinity of the outcrop with an average of 10 to 15 feet of overburden.

Sample B-4 consists principally of kaolinite with lesser amounts of illite and probably some halloysite. Results of a chemical analysis of the sample are given in table 2, p. 18. Other tests[13] given below indicate that the clay has possibilities as a bonding clay for synthetic molding sands.

Bonding Clay Tests on Sample B-4

8 percent Clay with Ottawa Bonding Sand

Water *percent*	Green compressive strength *lb. per sq. in.*	Dry compressive strength *lb. per sq. in.*
3.9	3.6	93.7
3.4	4.9	61.9
2.5	7.7	36.4
1.7	10.9	21.6
1.4	9.4	12.7

[13] Grogan, R. M., and J. E. Lamar, Illinois surface clays as bonding clays for molding sands: Illinois Geol. Survey, Rept. Inv. 104, pp. 24 and 37, 1945.

SAMPLE NO. D-36.—CRETACEOUS CLAY

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.28
60 mesh	0.24
100 mesh	0.36
150 mesh	0.73
200 mesh	0.47
Passing 200 mesh	97.90
	99.98

PYROMETRIC TESTS

In both the preliminary and the final test this clay was touching the plaque and badly blistered at cone 21.

BURNING TESTS

When moulded into briquettes by the plastic "stiff mud" process and burned at 1120 degrees centigrade in an open kiln, this clay was hard, nearly vitrified, and had a good buff color.

SUMMARY

This clay is high in silica and yet fine-grained. Its refractory value is low. In fusibility the clay is well within the nonrefractory class. It is possibly of value for the manufacture of stoneware, terra cotta, building and paving brick, and No. 2 fire brick.

Outcrop 42

A deposit of clay is reported[14] to occur in and beneath a road gutter two miles east of Grand Chain, but a precise location is not given. Possibly this deposit is the same as Outcrop 41 described above; it probably occurs in the same general area. The following strata were noted.

STRATA EXPOSED AT OUTCROP 42

		Thickness Feet
4.	Loess	16–32
3.	Gravel and red clay	4½
2.	Clay, red	1±
1.	Clay, white to gray, plastic	21⅓

Bed 1 was penetrated by boring. Sample PS-44 is "from the lower portion of the deposit"; sample PS-45 "represents the upper portion." Because the ceramic test of sample PS-45 describes the clay as having a red color, it seems probable that the sample either was taken from bed 2 or includes clay from that stratum.

Results of ceramic tests follow.

[14] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 68.

Outcrop 43

About three quarters of a mile northeast of Grand Chain at the center of the north line sec. 32, T. 14 S., R. 2 E., the C. C. C. and St. L. R. R. cuts through a ridge where the following sediments were exposed.

STRATA EXPOSED AT OUTCROP 43

		Thickness Feet
6.	Silt, brown, clayey (loess)	3–20
5.	Gravel, brown, chert	3–7
4.	Sand, red, poorly exposed	6–8
3.	Clay, yellow, hard, lower 2 inches brown	⅔
2.	Clay, gray and pink, plastic, poorly exposed	3±
1.	Sand, red Covered	½

The deposit shows signs of marked slumping. No sample of the clay was taken because a representative sample could not be obtained. The clay, however, appears to be similar in general characteristics to the clays at Outcrop 41 except in color. The outcrop occurs in the crest of a series of hills. Prospecting may reveal additional deposits of the clay of bed 2 in these hills as well as deposits of other clays.

GRAND CHAIN LANDING DISTRICT

The Grand Chain Landing District covers a number of Cretaceous clay deposits in or near the Ohio River bluff and lying between Grand Chain Landing in the NW. ¼ NE. ¼ sec. 9, T. 15 S., R. 2 E., and the east line of Pulaski County. Years ago the area appears to have been one of considerable clay producing activity. The deposits lately visible have heavy overburden, but clay is reported to occur in some places with only 15 feet of overburden. This, coupled with the fact that locally the thickness of the clay approaches 20 feet, suggests that systematic prospecting of some of the upland areas in the vicinity might reveal economically workable deposits. The deposits are 2½ miles or more by road from a railroad but are near water transportation.

Outcrop 44

Along the valley paralleling the road to Grand Chain Landing and extending up

SAMPLE NO. PS-44.—CRETACEOUS CLAY

This is a soft clay of a gray color. It develops a fair degree of plasticity.

Water of plasticity ..... *percent* 33.8

Shrinkage water ..... *percent* 21.4

Pore water ..... *percent* 12.4

Modulus of rupture ..... *lbs. per sq. in.* 465.6

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 325.6

Slaking test ..... *min.* 32

Screen test:

Mesh	Residue *percent*	Character of residue
20	Trace	
40	Trace	Mica
60	Trace	
80	Trace	
120	1.32	Mica and sand
150	5.47	Mica and sand
200	4.80	Mica and sand

Drying shrinkage:

Linear; wet length ..... *percent* 6.8

Linear; dry length ..... *percent* 7.0

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*
08	31.0	Light gray	1.45
06	27.6	Light gray	2.24
04	23.2	Cream	3.81
02	22.2	Cream	3.6
1	17.2	Cream	4.1
3	17.4	Cream	4.6
5	11.5	Grayish	4.9
7	12.3	Grayish	5.1
9	10.4	Grayish	5.3
11	10.9	Grayish	5.0

Fusion test: It deforms at cone 29.

SUMMARY

This clay has a medium high bonding strength. The drying shrinkage is medium. It does not reach a low porosity within the temperature range employed—up to cone 11. The shrinkage at cone 9 is medium. It is a refractory clay, but not of high grade. In addition to its use in refractories, it is of the type used for stoneware, architectural terra cotta, and sanitary ware.

SAMPLE NO. PS-45.—CRETACEOUS CLAY

It is a clay of medium hardness and a red color. It develops a good plasticity when worked with the addition of a sufficient amount of water. When the plastic clay is squeezed through a die it flows fairly well.

Water of plasticity ..... *percent* 29.2

Shrinkage water ..... *percent* 15.8

Pore water ..... *percent* 13.4

Modulus of rupture ..... *lbs. per sq. in.* 526.6

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 299.5

Slaking test ..... *hours* 2½

Screen test:

Mesh	Residue *percent*	Character of residue
20	1.0	Brown sandstone
40	Trace	Mica and white sand
60	Trace	Mica and white sand
80	Trace	Mica and white sand
120	30.2	Brown and white sand
150	9.4	Brown and white sand
200	2.0	Brown and white sand

Drying shrinkage: linear ..... *percent* 6.8

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*
08	36.8	Reddish brown	0.6
06	35.0	Reddish brown	1.1
04	34.9	Reddish brown	2.0
02	35.0	Reddish brown	2.2
1	33.8	Reddish brown	2.5
3	33.5	Reddish brown	2.4
5	34.3	Brown and black	2.2
7	32.7	Brown and black	2.2
9	34.0	Black	1.9
The burned pieces are weak.			

Fusion test: It deforms at cone 28.

SUMMARY

This clay has a medium high strength tested alone and a medium bonding strength. This is particularly interesting because the screen test shows the presence of a high content of fine-grained sand which does not impair its working properties. The drying shrinkage is medium. It shows a very open burning body at all temperatures with low burning shrinkages. The fusion test indicates a refractory clay.

Such open burning refractory clays having good plasticity and strength are of value used alone or in mixtures in the manufacture of refractory wares.

the valley from a point near Ohio River for about a quarter of a mile in the SW. ¼ SW. ¼ SE. ¼ sec. 4, T. 15 S., R. 2 E., there occurred outcrops of gray and white clay of Cretaceous age. The section exposed follows.

Strata Exposed at Outcrop 44

		Thickness Feet
5.	Silt, brown, clayey (loess)	15–40
4.	Gravel, brown, chert, locally cemented by iron oxide	3–5
3.	Sand, medium-grained, clayey, yellow	7
	Covered, section offset, vertical interval not known	
2.	Clay, sandy, partly cemented by iron oxide to make a hard, shelly stratum	¼–1
1.	Clay, light gray to white, micaceous, interbedded with thin sand layers ⅛ to 1/16 inch thick	20±
	Covered	

Because of the likelihood that the sediments have been disturbed by slumping, there is a possibility that the thickness given for bed 1 may be greater than the normal undisturbed thickness.

In the same vicinity it is reported[15] that "on the O. C. Field property pits have been dug in lenses of clay in the NE. ¼ sec. 9, T. 15 S., R. 2 E., where sample PS-38 was taken.[16]

Both the bottom and the top of the clay are irregular, the top rising backward into the hill. A thickness of 20 feet of 'black fat' clay has been exposed and is said to be underlain by blue and pink clay. The overburden of 3 feet of iron-cemented sand and gravel capped by loess thickens back over the ridge to a maximum of 15 feet. Clay has also been worked just above water level in Ohio River."

From the foregoing it appears that there are several types of clay present in the vicinity of Grand Chain Landing. Most of the deposits have a relatively heavy overburden. Shipment by water is probably feasible.

Results of tests on sample PS-38 follow.

[15] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 67.

[16] Later information suggests that the Field pits were located near the center SW. ¼ SE. ¼ sec. 4.

Outcrop 45

Outcrop 45 includes deposits in portions of the E. ½ sec. 4 and the W. ½ sec. 3, T. 15 S., R. 2 E., northeast of Grand Chain Landing. The region is underlain by Cretaceous sediments, and prospecting which was carried out years ago rather widely in this area has revealed the presence of an irregular and lenticular clay bed which reaches a maximum thickness of 12 feet. It is usually underlain by sand and overlain by gravel and loess. In the N. ½ SE. ¼ sec. 4, where a number of pits were opened, the overburden averages about 15 feet. The clay exposed was white and was said to resemble the clay from the Kaolin district.[17]

A chocolate colored lignitic clay was found on the J. B. Hays property in the SW. ¼ sec. 3.[17]

Sample PS-37 was taken from a stock bin containing clay from several pits in secs. 3 and 4. Results of ceramic tests follow.

Outcrop 46

The old Schick pottery and pit are reported to have been located at the base of the Ohio River bluff at the center of the south line, SW. ¼ SW. ¼ SE. ¼ sec. 2, T. 15 S., R. 2 E., on the Douglas property near Douglas Landing. The clay deposit worked is said to have consisted of three beds, each 3½ feet thick, being respectively from the bottom upward black fat clay, gray clay, and white clay. More recently the exposure consisted of the following.

Strata Exposed at Outcrop 46

		Thickness Feet
4.	Silt, brown, clayey (loess)	20+
3.	Gravel and clay, red, sandy	5
2.	Sand, fine-grained	4
1.	Clay, gray, mottled, locally contains thin streaks of fine sand	3
	Covered	

Results of tests on sample L-307 taken from bed 1 follow.

[17] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 67.

SAMPLE NO. PS-38.—CRETACEOUS CLAY

This is a soft shaly material of a brownish color. It has good plasticity and flows smoothly through the die when a suitable amount of water is added.

Water of plasticity ..... *percent* 38.6

Shrinkage water ..... *percent* 24.6

Pore water ..... *percent* 14.0

Modulus of rupture ..... *lbs. per sq. in.* 164.8

Slaking test ..... *min.* 50

Screen test:

Mesh	Residue *percent*	Character of residue
20	0.27	Rock particles
40	0.25	Rock particles and sand
80	0.16	Rock particles and sand
120	1.69	Rock particles and sand
200	1.52	Rock particles and sand

Drying shrinkage:

Linear; wet length ..... *percent* 7.25

Linear; dry length ..... *percent* 7.8

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
04	33.4	White	1.8	
02	24.7	Cream	3.4	Hackly fracture
2	18.1	Cream	6.0	
5	16.5	Cream	5.6	Hackly fracture
9	14.0	Cream	6.0	Hackly fracture, vitreous
13	3.7	Stoneware, gray	7.0	Smooth fracture
14	2.8	Dark buff exterior, bluestoned	6.2	Appears to be overburned

Fusion test: It deforms at cone 30.

SUMMARY

The dry clay has medium low strength. The amount of residues left on the screens is low. The drying shrinkage is medium. The total shrinkage at cone 9 is medium high. Vitrification is practically complete at cone 13. It is a refractory clay and therefore suitable for use in the manufacture of such wares. The light color of the burned clay and its other properties make it available for architectural terra cotta, stoneware and sanitary ware.

Outcrop 47

At Yates Landing, also believed to be known as Baccus Landing, located in the northwest corner NE. ¼ NE. ¼ sec. 12, T. 15 S., R. 2 E., on Ohio River, an outcrop of clay is described as follows:[18]

"A cliff rising from the beach reveals at the base 8 feet of gray micaceous clay. The bottom of the exposed bed lies 35 feet above low water. Below it the bank is strewn with masses of conglomerate. The clay is overlain with 17 feet of sandy clay, pebbles, and loess.

[18] Purdy, R. C., and F. W. DeWolf, op. cit., p. 153.

Sample No. PS-37.—Cretaceous Clay

This is a soft clay containing a few nodules of carbonaceous matter. It is of a light gray color. It flows through a die fairly satisfactorily.

Water of plasticity ..... *percent* 30

Shrinkage water ..... *percent* 21.6

Pore water ..... *percent* 8.4

Modulus of rupture ..... *lbs. per sq. in.* 487.2

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 249.7

Slaking test, average ..... *min.* 7

Screen test:

Mesh	Residue *percent*	Character of residue
20	Trace	
40	Trace	
60	Trace	
80	Trace	
120	.02	Quartz and mica particles
200	.07	Quartz and mica particles

Drying shrinkage:

Linear; wet length ..... *percent* 6.6

Linear; dry length ..... *percent* 7.1

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
2	15.9	Cream	4.95	
5	9.6	Darker cream	5.7	
9	1.7	Gray	10.1 ?	Conchoidal vitreous fracture
12	.57		5.6	Conchoidal vitreous fracture
13½	18	Tan exterior; bluestoned interior	4.34	

Fusion test: It deformed at cone 28.

SUMMARY

The strength of the unburned clay is medium high. Its bonding strength is medium. There is only a trace of residues on the screens. The drying shrinkage is medium. The total shrinkage at cone 9 is high. Vitrification is practically complete at cone 9. The sample is apparently overburned at cone 13½ although it is thought this appearance may be due to the peculiar shattering of the clay during the firing. It is a refractory clay.

Suggested uses: For refractories, particularly those of a dense character such as crucibles; also architectural terra cotta, stoneware, and sanitary ware.

Sample No. L-307

Plasticity ..... excessive, resembling ball clay

Water content required ..... *percent* 36.0

Molding properties ..... laminates badly

Modulus of rupture of dry body:

No. tests 10

Arithmetic mean 841

Linear drying shrinkage 11.1

Volume drying shrinkage 42.8

Pyrometric cone equivalent 28

Firing Tests:

Cone fired	Color	Hardness	Porosity	Linear shrinkage	Volume shrinkage
08	Very light buff		27.4	1.5	4.8
06			27.1	1.2	5.3
04			24.8	1.8	8.5
02		Steel hard	23.0	3.4	10.1
1			23.0	2.5	9.6
3	Light buff		14.6	5.5	17.9
5			13.8	5.2	18.3
7	Grayish buff		9.4	5.8	19.1
9	Buff gray		4.7	6.8	21.8
11	Gray		1.9	6.8	22.1

The clay contains some salts, probably of vanadium, which produce a greenish discoloration after wetting on surfaces of the burned clay fired at cone 1 or below. At cone 3 or above this does not appear.

The clay is too plastic to be used alone. It burns to a very light color, has a high strength and a fair refractory value. It may be used in refractory bodies when a dense-burning bond clay is desired.

"This locality formerly furnished potters clay, which supplied a local plant. Raw clay was also shipped on the river."

Other later reports indicate the likelihood that the pit operated at the above location was known as the Vanderbilt pit in which it is said 18 feet of "high grade clay" was exposed.

Another outcrop in the same general vicinity occurred just north of the center, E. line, NE. ¼ sec. 12, at the intersection of the east county line with Ohio River. Grayish-white clay was exposed in the river bank for a distance of about 100 feet but was visible only at times of low water.

Sample D-33 was taken from the clay at Yates Landing. Results of tests follow. A chemical analysis is given in table 2, p. 18.

Sample No. D-33.—Cretaceous Clay

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.08
60 mesh	0.21
100 mesh	1.02
150 mesh	3.52
200 mesh	2.38
Passing 200 mesh	92.90
	100.11

PYROMETRIC TESTS

This clay started to bend at cone 24 but was not quite touching the plaque at cone 28. In the preliminary test it was vitrified at cone 20.

BURNING TESTS

When molded into briquettes by the plastic "stiff mud" process and burned at 1120 degrees centigrade in an open kiln, this clay was hard, nearly vitrified, and had a good buff color.

SUMMARY

This clay is high in silica yet fine grained. Its refractory value is low. In fusibility it lies near the lower limit of refractory fire clays. It is possibly of value for the manufacture of stoneware, terra cotta, building and paving brick, and No. 2 fire brick. It is reported in the field that the clay, although making excellent stoneware by turning, is not suited for jiggering because it sticks to the molds.

ALLUVIAL CLAYS

The bottoms of the Cache and the Mississippi River valleys, including their terraces and the valley flats of many of the larger tributary valleys, are underlain at numerous places by silt, probably deposited in slack water during glacial times. The clay content of this silt varies, but in some places it is enough to make the silt of possible importance for the manufacture of clay products. No extensive study was made of these materials, but two deposits are described below which give a general idea of their character. It is believed that the deposits, although usually noncalcareous at the surface, may become limy at depth.

Outcrop 48

On the eastern outskirts of the village of Ullin in the SE. ¼ sec. 23, T. 14 S., R. 1 W., the Egypt Brick and Tile Company formerly operated a plant manufacturing building brick and drain tile from a clayey alluvial silt obtained from a nearby pit in the flat of Cache River. The character of the material used is not now evident in detail; but in 1922 when the plant was operating, the following section was exposed in the pit.[19]

Strata Exposed at Outcrop 48

		Thickness Feet
4.	Soil, brown	⅔
3.	Silt, gray, plastic	4
2.	Silt, brown, sandy	4
1.	Sand	

The silt of bed 3 is said to have cracked on drying, and that of bed 2 lacked sufficient bond to work well. A combination of the two in equal parts is reported to have given a satisfactory mix and yielded a product described as of better than average strength and of fine red color.

Only a small amount of silt had been removed from the deposit when the plant was abandoned some years ago. A large quantity of similar clay is doubtless available in this area and more generally in the region.

Outcrop 49

Along a road about two miles southeast of Karnak at the center of the south line, SE. ¼ SW. ¼ SE. ¼ sec. 26, T. 14 S., R. 2 E., 5½ feet of tough waxy noncalcareous silty clay, from which sample B-3 was taken, is exposed in the east bank of a drainage ditch known as Post Creek cutoff. The noncalcareous clay stratum is covered by 7 to 10 feet of silt and is underlain by calcareous clay. Some of the silt overburden on the noncalcareous clay probably was overcast when the ditch was dug, and it is believed that the normal overburden is about 1 to 2 feet of silt and silty soil. A large quantity of noncalcareous clay is believed to be available in the general vicinity of the outcrop.

Probably this clay would be suitable for making clay products such as common brick and drain tile. The following tests indicate it may have possibilities for bonding clay for molding sands.[20]

Bonding Clay Tests on Sample B-3
8 percent Clay with Ottawa Bonding Sand

Water percent	Green compressive strength *lb. per sq. in.*	Dry compressive strength *lb. per sq. in.*
3.9	2.1	
3.3	3.3	
3.2	3.5	86.2
2.6	5.1	
2.4	5.4	
2.3		51.8
1.8	6.9	
1.7		35.2
1.2	7.7	22.3

[19] Krey, Frank, Geology and mineral resources of the Dongola quadrangle: Illinois Geol. Survey, unpublished manuscript.

[20] Grogan, R. M., and J. E. Lamar, Illinois surface clays as bonding clays for molding sands: Illinois Geol. Survey, Rept. Inv. 104, pp. 23 and 37, 1945.

LOESS

The uplands of Pulaski are commonly mantled by a wind-deposited brown clayey silt called loess. This material reaches an observed thickness of about 40 feet in places but is probably generally not this thick. All the loess noted was noncalcareous. Tests on the loess in Pulaski County and in other parts of southern Illinois suggest it may have possibilities for the manufacture of building brick and tile.

Outcrop 50

The best loess exposure noted occurred in a cut along the Illinois Central Railroad about half a mile south of the station at Villa Ridge near the center E. ½ sec. 3, T. 16 S., R. 1 W., where the following section was exposed.

Strata Exposed at Outcrop 50

		Thickness Feet
5.	Loess, buff	30±
4.	Loess, brown, iron-stained zone	2±
3.	Loess, buff, grades into bed below	12±
2.	Sand, red, cemented by iron oxide, with 1 to 6 inch beds of brown and white chert gravel	10–15
1.	Gravel, brown, chert, cemented by iron oxide	8
	Covered	

Outcrop 51

In the bluffs on the east side of Cache River in the northwest corner, sec. 18, T. 16 S., R. 1 W., about 1½ miles south of Unity, 15 feet of loess was exposed above Lafayette gravel in a small gravel pit. The loess was gray and brown in color and is believed to be typical of the material which mantles the uplands on the east side of Cache River in the westernmost part of Pulaski County. Results of ceramic tests on sample L-32, taken from this deposit, follow.

Sample No. L-32.—Loess

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	9.91
Linear drying shrinkage	*percent*	3.42
Water of plasticity	*percent*	24.71
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	247.0
Bulk specific gravity		1.72

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
04	.14	.47	39.96	Light brown	Granular
2	9.84	3.40	30.01	Brown	Granular
3	26.49	9.75	7.24	Dark brown	Vitreous
6	28.19	10.45	.38	Dark brown	Vitreous
8	15.79	7.79	Badly bloated		Vitreous
9½			Badly bloated		Vitreous

Fusion test: Clay not refractory.

Summary: Drying shrinkage medium high, modulus of rupture medium, oxidizing conduct poor, vitrification complete at cone 6, shrinkage at cone 6 medium, overburned at cone 8. It is not refractory.

Suggested uses: Building brick. Possibly quarry tile, roofing tile, flower pots, drain tile.

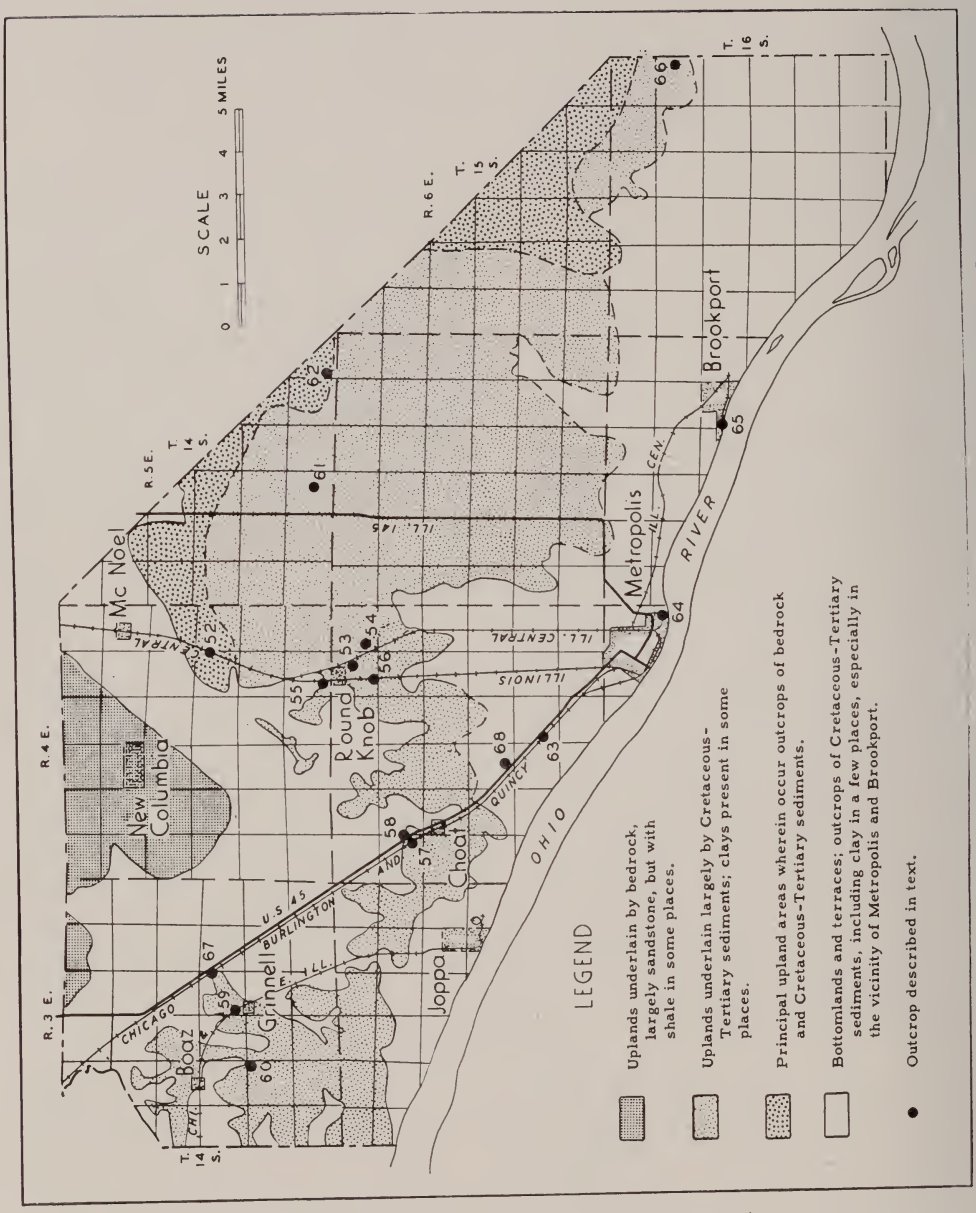

FIG. 8.—Generalized map showing clay and shale resources of Massac County.

CHAPTER 5—MASSAC COUNTY RESOURCES

The clay and shale resources of Massac County include bedrock shales, Cretaceous clays, residual clays, alluvial clays and loess clays.

GEOLOGY IN RELATION TO RESOURCES

In preglacial times the present upland areas shown in figure 8 were doubtless then also upland areas, but their relief was probably considerably greater than now. In the bottomland and terrace areas (fig. 8), it is likely there were also hills and valleys, probably a part of a dissected topographic level. The valleys were much deeper than at present and the hills probably did not reach much above an elevation of 360 feet above sea-level. During glacial time the bottomland and terrace areas were submerged by gacial waters which deposited sand, gravel, and clayey silt in enormous quantities as a fill. The last flood deposits were a considerable thickness of silt. Thus the uplands areas virtually stood up above a "sea" of silt, and still do. Since glacial times erosion by streams has removed some of this silt fill and exposed the crests of hills or upland tracts which originally rose above the general level of the preglacial lowland. Thus between Metropolis and Brookport there are outcrops of Lafayette (Tertiary) gravel at a number of places along Ohio River, and at these towns outrops of Cretaceous clay also occur along Ohio River. A similar situation with respect to the Lafayette gravel or Cretaceous sediments is known to occur in a few other parts of the county.

From the standpoint of Cretaceous or bedrock clay resources therefore, the areas of uplands shown in figure 8 in general offer the greatest promise, but in some places deposits may occur in the bottomland and terrace areas.

BEDROCK CLAYS AND SHALES

The principal area of bedrock outcrops in Massac County is in the upland tracts in the vicinity of New Columbia (fig. 8). Most of the rocks exposed are Chester sandstones but in the lower slopes of some of the bluffs bordering the uplands outcrops of shale, usually associated with limestone, are visible. Commonly these shales are calcareous. Some of the shale would probably be suitable for making common brick and tile. Overburden would be heavy in most places. Most promising areas for finding shale with moderate or thin overburden are in the hill land in sec. 19, the low hill land in sec. 18, and possibly an area in the NE. ¼ sec. 10 and the SE. ¼ sec. 3, all in T. 14 S., R. 4 E.

Other outcrops of bedrock occur in the uplands facing McNoel, in a few places east and north of Boaz, and at scattered points in the eastern part of the county. Mostly these outcrops are sandstone and limestone; one that includes shale and is located along a railroad is described below.

Outcrop 52

A cut along the Illinois Central Railroad known as Rineking cut, in the NE. ¼ SE. ¼ NE. ¼ sec. 23, T. 14 S., R. 4 E., exposed beds of shale, clay, sand, and sandstone overlain by gravel or sandstone rubble and by loess. The cut is about 1600 feet long. There was considerable variation between the exposures in the east and west sides of the cut, and local distortion of the strata was evident. The shale and associated sandstones are probably of Chester age. The shale contains plant spores of Mississippian age[1] and molds of ostracods which are common in the Paint Creek formation of Chester (Upper Mississippian) age.[2]

Following are three sections of the beds exposed. Sections A and C include the best outcrops of shale and clay, but section B is typical of the more sandy portions of the cut. The bridge crosses the railroad at the center S. line, SE. ¼ NE. ¼ NE. ¼ sec. 23.

[1] Kosanke, Robert M., Illinois Geol. Survey, personal communication, 1945.
[2] Cooper, Chalmer L., Illinois Geol. Survey, personal communication, 1945.

Strata Exposed at Outcrop 52

Section A, east side of cut, 625 feet south of bridge

		Thickness Feet
3.	Silt, brown, clayey (loess)	12
2.	Sandstone, brown, fine-grained	15
1.	Shale, light gray, gritty with local, thin, sand partings and lenses (Sample L-97)	26
	Covered	

Section B, west side of cut, 900 feet south of bridge

5.	Silt, brown, clayey (loess)	11
4.	Sandstone, angular blocks, and clay	5
3.	Sand, pink and yellow	5
2.	Sandstone, fine-grained, brown	5
1.	Shale, laminated gray	9

Section C, east side of cut, 1335 feet south of bridge

5.	Silt, brown, clayey (loess); upper 4 feet darker than lower 4 feet	8
4.	Sandstone, angular blocks, and clay	5½
3.	Clay gray, with interbedded sandstone, layers ½ to 2 inches thick	4
2.	Clay, with interbedded white sand layers	5
1.	Sandstone, white, fractured, in beds about 3 inches thick	6
	Covered	

The extent of the shale and clay beds exposed in the cuts is problematical. Probably they are present in the lower slopes of the hills adjoining the cut in secs. 23 and 24, but are apt to have heavy overburden. Possibly hills in the N. ½ sec. 26 may be underlain by these beds with thinner overburden.

Results of ceramic tests of sample L-97 taken from bed 1 of section A follow. The material as judged by the tests is not an unusual ceramic material. The clay mineral present in the shale is doubtless illite.

CRETACEOUS CLAYS

The principal outcrops of Cretaceous clays close to rail or water transportation occur chiefly in the uplands of the west half of Massac County. The clays occur in association with Cretaceous silts and sands, and outcrops of the latter are more common than those of the clays, because the Cretaceous sediments include a greater thick-

Sample No. L-97.—Chester Shale

Kind of material		shale
Drying conduct		good
Volume drying shrinkage	*percent*	23.22
Linear drying shrinkage	*percent*	8.436
Water of plasticity	*percent*	34.1
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	214.7
Bulk specific gravity		1.79

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Fracture
04	21.25	7.66	35.85	Salmon	Smooth
02	10.85	3.76	13.87	Tan	Smooth
2	26.70	9.84	.82	Dark tan	Smooth
3	26.80	9.88		Dark tan	Smooth
5	24.40	8.90	.89	Brown	Smooth
6	26.82	9.89	.87	Gray	Smooth

Fusion test: Clay not refractory.

Oxidizing conduct: Poor.

Summary: Drying shrinkage medium, bonding strength medium, vitrified at cone 2, shrinkage at cone 2 is medium, overburned at cone 8. It is not refractory.

Suggested uses: Building brick, possibly quarry tile, roofing tile, and hollow tile.

ness of sand than they do of clay. Mostly the clay outcrops noted were in railroad cuts or road-cuts. The Cretaceous sediments generally slump readily so that outcrops soon become obscured where they are not being actively eroded; likewise most of the visible clay deposits show more or less disturbance, probably due to settling and creep.

Many of the outcrops of Cretaceous clay have an overburden of Cretaceous sand above which is a variable thickness of brown chert Tertiary (Lafayette) gravel capped by 5 to 25 feet of clayey silt (loess). Usually the gravel is not more than 20 feet thick and it is generally less. In some places it is cemented to a conglomerate. This gravel is in evidence at many places in the uplands of most of the county. Exposures of sand, probably of Cretaceous age also occur at many places but less commonly than the gravel.

The Cretaceous clays of Massac County are believed to be composed mineralogically of a mixture of the clay minerals kaolinite and illite in varying proportions. Some of the clays are nonrefractory; others, especially those which contain considerable quartz, are refractory. Many of the clays are buff or light burning. Results of tests suggest that the clays include materials suitable for face brick, paving brick, roofing tile, terra cotta, stoneware, flue lining, sanitary ware, certain kinds of refractories, and for other purposes.

Round Knob District

In the vicinity of the village of Round Knob (fig. 8), in sec. 2, T. 15 S., R. 4 E., and especially to the south, clay has been dug from Cretaceous deposits at a number of places and is said to have been shipped years ago to Metropolis in Illinois, Paducah in Kentucky, and to other points where it was used as a potter's clay, chiefly for the making of stoneware. There has been no consistent production of clay from this area for some time, and most of the pits are obscured. The following discussion of the Round Knob district is compiled from older reports[3] with modifications and additions based on later work. A number of the locations in the older reports are believed to be incorrect and corrections have been made insofar as is possible.

[3] Purdy, R. C., and F. W. DeWolf, op. cit., pp. 149–151. Parmelee, C. W., and C. R. Schroyer, op. cit., pp. 64–67.

Extent of Clays

The outcrops of clay reported in the vicinity of Round Knob occur mostly in hills in the S. ½ sec. 2, T. 15 S., R. 4 E., but other hills in this general area also may be underlain by similar sediments. The clays of this area probably do not occur as a continuous clay stratum underlying the region but rather as a zone, comprised largely of more or less discontinuous clay beds, that is to be found at a roughly constant stratigraphic position. As most of the clays contain considerable sand or silt, it is possible that they constitute clayey beds in a formation which is principally sandy or silty. The clay zone appears to lie normally below an elevation of about 420 to 440 feet in this area, as strata exposed above this elevation in a cut along the Illinois Central Railroad near the center of the north line of sec. 11 are all sand, although some highly clayey sands also occur which may be the stratigraphic equivalent of clay present elsewhere.

Character of the Clays

Many of the Round Knob clays are more or less sandy or silty. At some places they contain thin strata of sand, or relatively thick strata of clayey sand, at others sand is rather uniformly scattered through the clay. The clays vary in color; those lying immediately below the brown Lafayette (Tertiary) gravel or its associated red sands are usually brown or slightly yellow in color. Deeper clays are commonly gray or light brown.

The thickness of the clay formerly worked ranged from 6 to about 20 feet, the maximum thickness being reported in the NW. ¼ SE. ¼ sec. 2. The overburden on the Round Knob clays consist of Cretaceous sand, Lafayette gravel and sand, and brown clayey silt (loess) in ascending order. The thickness of the overburden varies from 10 to about 100 feet and depends largely on the topographic position of the clays. Most of the development

which has taken place has occurred on relatively gentle slopes where the overburden is comparatively thin. The maximum overburden is probably under the highest parts of the main hills of the district.

USES

The principal use of the Round Knob clays has been for the making of stoneware and pottery. Tests suggest that the clays may also be suitable for brick, tile, building block, terra cotta, certain kinds of refractories, and possibly for paving brick, flue linings, hollow tile, quarry tile, roofing tile, and sanitary ware.

Outcrop 53

At the NE. ¼ NW. ¼ SE. ¼ sec. 2, on the farm of Henry Grothman, are a series of pits from which clay is said to have been shipped to potteries at Paducah. Seven feet of clay was exposed in the southernmost pit and was gritty, brown to buff in color, and locally speckled yellow by iron oxide. Five feet of clay was exposed in the northernmost pit and was sandy, with interbedded layers of very fine-grained sand. The color of the clay was similar in both pits.

Overburden is roughly the same at both pits and consists of 2 to 7 feet of red, medium-grained sand, locally cemented to a sandstone, above which is ½ to 2 feet of brown chert gravel, topped by 3 to 20 feet of loess.

The clay in these pits is said to have been worked to a depth of 20 feet, but recently only the upper parts of the beds have been exposed. The clay in the south pit is reported to have been too "fat" and that in the north pit too "lean," but a mixture of the two clays is reputed to have yielded a satisfactory product.

In order to determine the character of the clay exposed in these pits, two samples were taken, L-91 from the clay in the southernmost pit and L-92 from the clay in the northernmost pit. Results of ceramic tests follow.

Probably occurring in the same area as the outcrops described above are deposits mentioned in earlier reports as occurring in the N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E.[4] It is believed that the section should be 2 instead of 8. Three pits, two abandoned and one operating, are described. The operating pit furnished stoneware clay to the Ohio Pottery Company at Paducah. The following section was exposed.

STRATA EXPOSED IN THE VICINITY OF OUTCROP 53

		Thickness Ft.	In.
Stripping			
14.	Loess	6	
13.	Clay and ferruginous sandstone, all stained deep red	1	
12.	Clay, sandy, with a few sandstone concretions	7	
	Total stripping	14	0
Commercial portion			
11.	Clay, sandy, drab, thinly laminated	1	11
10.	Sand, fine, thinly laminated in brown, yellow and white streaks	1	4
9.	Clay, brown to gray, banded with gray sand layers ¼ inch thick	1	10
8.	Sand, white and yellow, becoming red at bottom	1	2
7.	Clay and sand, interbedded, gray and drab	0	4½
6.	Sand, thinly laminated, drab	1	2
5.	Clay, gray to brown, fat	1	0
4.	Sand, fine, fluffy, gray	0	7
3.	Clay, dark gray, with a few sand streaks	0	4
2.	Sand, very ferruginous	0	¼
1.	Clay, sandy, gray	0	11
	Total commercial portion	10	7¾

The sand of beds 2 and 4 of the above section was excluded from the clays shipped from this pit and was likewise omitted from sample D-29 which was taken from this pit.

Roughly 200 yards southwest of the Ohio Pottery Company pit an abandoned pit showed 6 feet of clean fat plastic light brownish-gray clay. It is reported that the working face of this pit was 27 feet high at one time. The clay was shipped to Paducah for the manufacture of stoneware and was used in a blend with other clays. Sample D-30 was taken from the clay exposed.

A few rods northwest of the Ohio Pottery Company pit and stratigraphically higher was another abandoned pit in which the following section was exposed.

[4] Purdy, R. C., and F. W. DeWolf, op. cit., pp. 149, 150.

Strata Exposed in the Vicinity of Outcrop 53

		Thickness Ft.	In.
5.	Clay, sandy	2	0
4.	Ferruginous plates	0	2
3.	Clay, gray, but stained yellow and brown	1	9
2.	Clay, gray, sandy	1	0
1.	Clay, sandy, white	6	6
		11	5

Sample D-31 was taken from beds 1 and 2.

Results of ceramic tests on samples D-29, D-30 and D-31 follow. Chemical analyses are given in table 2, p. 18.

Sample No. L-91.—Cretaceous Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	22.72
Linear drying shrinkage	*percent*	8.30
Water of plasticity	*percent*	32.0
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	484.20
Bulk specific gravity		1.87

Screen test:

Mesh	Percent residue retained
28	0.1
48	0.1
65	0.1
100	0.9
200	60.2

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
02	22.75	8.25	17.40	Light buff	Smooth
2	12.00	4.17	15.49	Light buff	Smooth
3½	16.08	5.68	12.50	Light tan	Smooth
8	23.02	8.84	1.43	Light tan	Smooth

Fusion test: P.C.E. 20–26.

Summary: Drying shrinkage medium, bonding strength medium high, vitrification nearly complete at cone 8. It is a nonrefractory clay. Burning shrinkage at cone 8 is medium.

Oxidizing conduct: Poor.

Suggested uses: Building brick, possibly stoneware, architectural terra cotta, sanitary ware, flue lining, and stove lining.

Sample No. L-92.—Cretaceous Clay

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	21.25
Linear drying shrinkage	*percent*	7.64
Water of plasticity	*percent*	26.48
Bonding strength—Modulus of rupture	*lbs. per sq. in.*	427.9
Bulk specific gravity		1.93

Screen test:

Mesh	Percent residue retained
28	0.1
48	0.1
65	0.3
100	0.8
200	76.7

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity	Color	Fracture
02	9.17	3.15	16.96	Cream (reduced)	Granular
2	8.92	3.06	18.33	Cream	Granular
3	9.76	3.37	13.99	Dark cream	Granular
6	13.77	4.82	11.11	Light tan	Granular
8	17.33	6.15	10.45	Light tan	Granular
13	26.35	9.69	7.88	Bluestoned	Granular

Fusion test: Fusion point P.C.E. 26.

Oxidizing conduct: Medium.

Summary: Drying shrinkage medium, modulus of rupture medium high, vitrification incomplete at cone 13, shrinkage at cone 8 is medium low. It is nonrefractory.

Suggested uses: Brick, stove linings, possibly flue linings, hollow tile, quarry tile, roofing tile, architectural terra cotta, sanitary ware.

Outcrop 54[5]

A pit located about 60 feet above the railroad in the SW. ¼ sec. 1 (probably the SW. ¼ SW. ¼ sec. 1), T. 15 S., R. 4 E., had a face of 6 feet of light gray clay overlain by an approximately equal thickness of soil and iron-stained clay. Clay 7 feet thick was exposed in another pit nearby with an overburden up to a maximum of 18 feet. The clay from the first pit was at one time shipped to Metropolis where it was found to be of high quality for the manufacture of stoneware, inasmuch as it dried evenly without cracking and took a good glaze.

More clay is available in the vicinity of this outcrop but overburden is apt to be heavy.

Results of ceramic tests on a sample D-28 taken from the clay at this outcrop follow.

[5] Purdy, R. C., and F. W. DeWolf, op. cit., p. 149. Parmelee, C. W., and C. R. Schroyer, op. cit., pp. 64, 65.

Sample No. D-29.—Cretaceous Clay

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.19
60 mesh	0.35
100 mesh	0.94
150 mesh	2.01
200 mesh	1.48
Passing 200 mesh	95.01
	99.98

PYROMETRIC TESTS

This sample began to fuse at cone 28. In preliminary test it was vitrified at cone 20.

BURNING TESTS

The clay was molded into briquettes by the plastic or "stiff mud" process and burned in an open kiln at 1120°C. with the following results: Porous buff brick.

SUMMARY

This clay is high in silica but it is relatively fine, as shown by the large percentage of material that passes a 200-mesh sieve. On the basis of pyrometric tests it falls into the class of refractory clays. The low fusion point and slow rate of vitrification is a leading characteristic.

USES

The preliminary experiments here recorded would seem to indicate the following possible uses for the clay: stoneware, terra cotta, No. 2 fire brick, building brick, refractory ware in which low vitrification is not injurious and possibly paving brick at a higher temperature than 1120°C.

Sample No. D-30.—Cretaceous Clay

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.52
60 mesh	0.41
100 mesh	0.77
150 mesh	1.11
200 mesh	0.76
Passing 200 mesh	96.46
	99.97

PYROMETRIC TESTS

The test piece started to bend at cone 23, and was touching the plaque at cone 28. In the preliminary test it was vitrified at cone 18.

BURNING TESTS

The clays were molded into briquettes by the plastic or "stiff mud" process and burned in an open kiln at 1120°C. with the following results: Vitrified nicely to a buff brittle brick.

SUMMARY

This clay is high in silica but it is relatively fine, as shown by the large percentage of material that passed the 200-mesh sieve. The plasticity varies considerably. On the basis of pyrometric tests it falls into the class of refractory clays. The low fusion point and slow rate of vitrification is a leading characteristic.

USES

The preliminary experiments here recorded would seem to indicate the following possible uses for this clay:—stoneware, terra cotta, No. 2 fire brick and building brick, paving brick possibly, through perhaps too brittle at 1120°C.

A chemical analysis is given in table 2, p. 18.

Outcrop 55[6]

The section given below is reported to have been exposed in a road gutter in the N. ½ SW. ¼ sec. 8, T. 15 S., R. 4 E., half a mile west of Round Knob. Probably the location was intended to be SE. ¼ SW. ¼ sec. 35, T. 14 S., R. 4 E., about half a mile northwest of Round Knob.

Strata Exposed at Outcrop 55

		Thickness Feet
4.	Gravel, rises with hill	2–6
3.	Clay, red	4
2.	Clay, white and pink, sandy, laminated, stains of iron oxide	6½
1.	Sand, red and white	1½

[6] Parmelee, C. W., and C. R. Schroyer, op. cit., pp. 65, 66.

Results of tests on sample PS-46 from the clay of bed 2 follow.

Outcrop 56

In the S. ½ sec. 2 and the N. ½ sec. 11, T. 15 S., R. 4 E., south of Round Knob, cuts along Illinois Central Railroad expose Tertiary, and later sediments. These cuts were examined in detail in 1926 when the sediments were well exposed, and the data presented below were obtained at that time. More recently settling and creep, and vegetation have so obscured the original exposures that their details are no longer visible.

The Cretaceous sediments exposed in the cuts were principally sand, varying from

Sample No. D-28.—Cretaceous Clay

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.28
60 mesh	0.23
100 mesh	0.35
150 mesh	0.73
200 mesh	0.46
Passing 200 mesh	98.00
	100.05

PYROMETRIC TESTS

This clay began to bend over at cone 26, but did not touch the plaque until after cone 32 was down. In preliminary test a sample gave evidence of incipient fusion at cone 20.

BURNING TESTS

The clay was molded into briquets by the plastic or "stiff mud" process and burned in an open kiln at 1120°C., with the following results: Porous buff brick.

SUMMARY

This clay is high in silica but it is relatively fine, as shown by the large percentage of material that passed the 200-mesh sieve. On the basis of the pyrometric test it falls into the class of refractory clays. The low fusion point and slow rate of vitrification is a leading characteristic.

USES

The preliminary experiments here recorded would seem to indicate the following possible uses for this clay: stoneware, terra cotta, No. 2 fire brick, building brick, refractory ware in which low vitrification is not injurious, and possibly paving brick at a temperature higher than 1120°C.

fine-grained clayey sand to coarse-grained sand, though in a few places clays were noted. Given below are three representative sections.

Strata Exposed 2550 Feet North of the Road Bridge at the Center of Sec. 11

		Thickness Feet
5.	Silt, clayey, brown (loess)	4
4.	Conglomerate, brown chert pebbles in a ferruginous sand matrix	1–1½
3.	Sand, red, medium-grained, angular. Locally contains rounded masses of white clay or very fine-grained sand, usually less than 3 inches in diameter	7
2.	Clay, yellow	⅓
1.	Sand, very fine-grained, white, micaceous, containing beds of sandy clay; locally banded yellow and brown by iron oxide	13½

Sample No. D-31.—Cretaceous Clay

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.06
60 mesh	0.17
100 mesh	0.88
150 mesh	1.34
200 mesh	1.03
Passing 200 mesh	96.50
	99.98

PYROMETRIC TESTS

At cone 28 this clay was almost touching the plaque. In preliminary test it was vitrified at cone 20.

BURNING TESTS

The clay was molded into briquettes by the plastic or "stiff mud" process and burned in an open kiln at 1120°C. with the following results: Porous buff brick.

SUMMARY

This clay is high in silica but it is relatively fine, as shown by the large percentage of material that passed the 200-mesh. On the basis of pyrometric tests it falls into the class of refractory clays. The low fusion point and slow rate of vitrification is a leading characteristic.

USES

The preliminary experiments here recorded would seem to indicate the following possible uses for this clay: stoneware, terra cotta, No. 2 fire brick and building brick, paving brick possibly, at a higher temperature than 1120°C.

Strata Exposed 2250 Feet North of the Road Bridge at the Center of Sec. 11

		Thickness Feet
7.	Silt, brown, clayey (loess)	12
6.	Conglomerate, brown chert pebbles in a ferruginous, sandy matrix	2½–3½
5.	Clay, sandy, mottled white, yellow, and red	2±
4.	Sand, red, medium-grained, angular	13
3.	Sand, fine-grained, white, micaceous	14
2.	Sand and clay interbedded; sand yellow, clay, white	4
1.	Sand, red, with interbedded white clay layers ¼ to 3 inches thick and fine-grained, white sand layers 1 to 3 inches thick	11
	Covered	

Strata Exposed 450 Feet North of Road Bridge at the Center of Sec. 11

		Thickness Feet
4.	Silt, brown, clayey (loess)	7
3.	Clay, silty, red	2½±
2.	Clay, yellow, ocherous	5
1.	Clay, yellow and white and gray	4½–5
	Covered	

Sample No. PS-46.—Cretaceous Clay

This is a soft, very sandy clay, containing much mica. It is a cream color, mottled with brown and pink. When mixed with sufficient water, it develops a fair degree of plasticity and will flow through a die satisfactorily.

Water of plasticity ..... *percent* 22.2

Shrinkage water ..... *percent* 11.6

Pore water ..... *percent* 10.6

Modulus of rupture ..... *lbs. per sq. in.* 217.4

With 50% standard sand—Modulus of rupture ..... *lbs. per sq. in.* 214.0

Slaking test, average ..... *min.* 27

Screen test:

Mesh	Residue *percent*	Character of residue
20	Trace	Pyrites, sandstone and mica
40	Trace	Pyrites, sandstone and mica
60	2.9	Mica and sand
80	1.7	White sand
120	36.2	White sand
150	13.5	White sand
200	5.9	White sand

Drying shrinkage, linear ..... *percent* 2.9

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Remarks
08	36.7	Light brownish red	+0.5	
06	35.4	Light brownish red	+0.6	
04	35	Light brownish red	+0.8	
02	36.8	Light brownish red	+0.6	The clay expands during burning
1	34.9	Light brownish red	+0.8	
3	36.5	Light brownish red	+0.6	The burned pieces are very weak
5	36.3	Darker brownish red	+0.5	
7	35.3	Darker with iron specks	+1.0	
9	36.0	Darker with iron specks	+0.7	
11	35.5	Darker with iron specks	+0.9	

Fusion test: It deformed at cone 31.

SUMMARY

This is a clay of medium strength, much higher than might be expected considering its very sandy character. The bonding strength is medium. The percentages of screen residues are high. The drying shrinkage is low. Because of its sandy nature, the clay has a high and nearly constant porosity at all temperatures showing no sign of vitrification. This also explains the reason for the fact that it does not shrink but expands slightly at all temperatures.

Suggested uses: The lack of strength of the unburned clay will restrict its usefulness to admixtures with other clays. Such sandy clays often have a distinct usefulness. Because of its high fusion test it should be of use in refractories.

The thickness of the clay described above is the greatest noted in any of the railroad-cuts in secs. 2 and 11. It may be abnormal as a result of settling and creep.

Choat District

In the SE. ¼ SE. ¼ sec. 7, T. 15 S., R. 4 E., about ⅝ mile northwest of Choat, is a roughly east-west ridge which is cut by the Chicago, Burlington and Quincy Railroad and is crossed by U. S. Highway 45. Exposures of Cretaceous clay were observed in the railroad-cut and in a pit operated by the Paducah Pottery Company of Paducah, Kentucky. The ridge has a spur continuing northward and is part of a larger ridge to the west. There is no evident reason why the outcropping clays should not also be present in the higher parts of these adjacent ridges, although prospecting would be necessary to establish this.

Outcrop 57

The following strata are exposed on the northeast side of a cut along the C. B. and Q. Railroad in the SE. ¼ SE. ¼ SE. ¼ sec. 7, T. 15 S., R. 4 E.

Strata Exposed at Outcrop 57

		Thickness Feet
6.	Silt, brown, clayey (loess)	3–10
5.	Gravel, brown chert, with a few white chert pebbles; locally contains irregular masses of sandstone with ferruginous cement	⅓–⅚
4.	Clay, brown, sandy, becoming red near the gravel	2–3
3.	Clay, white, gritty, upper two feet iron stained	10–12
2.	Sand, cemented by iron	1–3
1.	Sand, medium-grained, cross-bedded, yellow	3
	Covered	

Beds 1 to 4 inclusive above are regarded as of Cretaceous age.

The beds exposed on the southwest side of the cut have evidently been disturbed and the relationships of these strata to those on the northeast side of the cut are not clear.

Sample L-203 was taken from bed 3 above. Results of ceramic tests follow.

Outcrop 58

Prior to the construction of U. S. Highway 45 the Paducah Pottery Company is said to have operated a pit of considerable size in the E. ½ SE. ¼ SE. ¼ sec. 7, and east of the railroad-cut described as Outcrop 56. In the spring of 1918 shipment of clays from this pit is said to have averaged 1 to 2 cars per week.[7] More recently a smaller pit has been operated on the east side of Highway 45 at about the same location. The strata exposed in the pit when the face was well exposed in 1928 were as follows.

Strata Exposed at Outcrop 58

		Thickness Feet
6.	Silt, brown, clayey (loess)	8
5.	Gravel, brown chert	⅙
4.	Clay, iron-stained	3
3.	Clay, gray, with sandy, micaceous layers	8
2.	Clay, gray, less sandy and micaceous than above	8
1.	Ferruginous band	⅙
	Covered	

The clay utilized commercially was obtained from beds 2 and 3. Beds 1 to 4 inclusive are regarded as of Cretaceous age.

An examination of an earlier pit[8] describes 14 feet 4 inches of greenish-white laminated clay of lenticular character. The clay was overlain by 2 feet 10 inches of reddish-brown clay, which was discarded in mining, and was underlain by sandstone cemented by iron. The reddish clay was overlain in some places by iron-cemented sandstone above which was loess; in others the entire clay bed was cut out so that the upper sandstone rested on the sandstone which is normally below the clay. Under this condition gravel and red clay lay above the sandstone and below the loess.

Grinnell District

The Grinnell district includes two outcrops, one about a fifth of a mile northwest of the village and the other about 1½ miles west. Both outcrops occur at an elevation somewhat below 400 feet above sea-level in ridges of considerable extent. Prospect-

[7] Parmelee, C. W., and C. R. Schroyer, op. cit. p. 64.
[8] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 64.

SAMPLE NO. L-203.—CRETACEOUS CLAY

Kind of material ..... clay

Drying conduct ..... safe

Volume drying shrinkage ..... *percent* 17.4

Linear drying shrinkage ..... *percent* 6.2

Water of plasticity ..... *percent* 27.5

Transverse strength—Modulus of rupture ..... *lbs. per sq. in.* 498

Bulk specific gravity 1.811

Percent residue on 100-mesh sieve ..... none

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness
06	0.7*	2.5	29.8	Cream	
04	2.8	0.95	29.1	Cream	
02	3.5	1.2	26.9	Cream	
1	5.9	2.0	25.7	Cream	
2	2.96	0.99	26.2	Light tan	
4	9.88	3.41	31.7	Light tan	
6	7.1	2.43	21.9	Light tan	Steel hard
8	18.03	6.41	10.1	Light tan	Steel hard

Fusion test: P.C.E. cones 18–19.

Summary: This clay may be brought to a satisfactory plastic condition. It dries safely with medium shrinkages. Its dry strength is medium high. It is an open burning clay showing a decided tightening, i.e., increase of vitrification at cone 8. The low burning shrinkage at the lower cone temperature is notable. It is not a refractory clay.

Suggested uses: Face brick, architectural terra cotta, stoneware.

* Expansion.

ing in these ridges at about this elevation may find additional deposits.

Outcrop 59

About a fifth of a mile northwest of Grinnell, a little north of the center of the SW. ¼ SW. ¼ sec. 22, T. 14 S., R. 3 E., the following beds were exposed in a cut along the Chicago, Burlington and Quincy Railroad.

STRATA EXPOSED AT OUTCROP 59

	Thickness Feet
4. Silt, brown, clayey (loess)	5–15
3. Gravel, brown chert, sandy, locally cemented to conglomerate	5–7
2. Clay, very sandy, red, micaceous; with white disc-shaped clay masses	3–6
1. Sand, very fine-grained, micaceous, mostly white but partly yellow and red; high in clay and only slightly more sandy than the bed above	11
Covered	

No sample was taken from this deposit but it is possible that bed 1 might yield a material of similar character to some of the very sandy clays of the Round Knob district, also in Massac County.

Outcrop 60

Considerable prospecting for clay has been done in the NE. ¼ sec. 29, T. 14 S., R. 3 W. One of the first test-pits in the E. ½ NE. ¼ NE. ¼ exposed 20 inches of well-bedded gray clay. The exposure occurred in a gully on the east side of a north-

south ridge. The total thickness of the clay was not visible. Sample L-250 was obtained from the deposit.

A test-pit in the E. ½ NE. ¼ of the section is reported to have shown 8 to 12 feet of light gray silty clay. Another pit, half way up the hill in the E. ½ SE. ¼ NW. ¼ NE. ¼, is said to have revealed the following strata.[9]

Strata Exposed at Outcrop 60

		Thickness Feet
4.	Silt, brown, clayey (loess)	6+
3.	Clay, gray	5–6
2.	Clay, yellow	2½–3
1.	Sand, clayey, white	6
	Covered	

[9] Howe, S. W., personal communication, 1939.

Bed 3 is probably the same stratum as that from which sample L-250 was taken.

On the top of the ridge at the center NE. ¼ of sec. 29 it is reported to be 12 feet to clay like bed 3 above and the clay is said to be 10 to 12 feet thick.

Results of tests on sample L-250 follow.

Miscellaneous Outcrops

Outcrop 61[10]

Four feet of clay cropped out along Massac Creek on the farm of William Kortie in the SE. ¼ (probably the NW. ¼ SE. ¼) sec. 33, T. 14 S., R. 5 E., and 3 feet more are reported to have been found in a test-pit dug below water level. The clay is overlain by 5 feet of gravel, clay, and

[10] Purdy, R. C., and F. W. DeWolf, op. cit., p. 151.

Sample No. L-250.—Cretaceous Clay

Kind of material ..... clay

Drying conduct ..... Good. Did not warp or crack

Volume drying shrinkage ..... *percent* 32.8

Linear drying shrinkage ..... *percent* 12.4

Water of plasticity ..... *percent* 31.8

Transverse strength—Modulus of rupture ..... *lbs. per sq. in.* 322

Percent residue on 100-mesh sieve ..... trace only

Character of residue ..... micaceous

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness	Remarks
3	16.3	5.7	11.35	Red brown	Steel hard	1 cracked
5	16.2	5.7	14.2	Bright gray	Steel hard	
7	18.6	6.6	10.0	Light gray	Steel hard	
9	20.8	7.4	.6	Light gray	Steel hard	2 cracked
13	10.9	3.6	19.8	Red brown	Steel hard	Began to overburn

Fusion test: P.C.E. 28–29.

Oxidation conduct: Good.

Summary: A clay of moderate plasticity which dries safely with medium high shrinkage. Its dry strength is medium. It is practically vitrified at cone 9 and overburns at cone 13. Its burning shrinkages are medium high.

Suggested uses: Structural products such as face brick, hollow ware, architectural terra cotta, certain refractories, and stoneware.

loess. It underlies a relatively large area of the creek flood-plain and extends into the adjoining hills.

Sample D-32 was taken from the 4 feet of clay exposed. Results of ceramic tests follow. A chemical analysis is given in table 2, p. 18.

SAMPLE NO. D-32.—CRETACEOUS CLAY

MECHANICAL ANALYSIS

Screen	Percent retained
20 mesh	0.02
60 mesh	0.82
100 mesh	6.32
150 mesh	6.50
200 mesh	2.02
Passing 200 mesh	84.35
	100.03

PYROMETRIC TEST

The clay started to bend at cone 26 and at 28 it was touching the plaque. In preliminary tests it was vitrified at cone 20.

BURNING TEST

When molded into a briquette by the plastic or stiff process and burned in an open kiln at 1120° C. it gave the following results: hard buff brick not far from vitrification.

SUMMARY

This clay on the basis of its pyrometric behavior lies close to the lower limit allowed for fire clays of the refractory grade. It would seem to be adapted, so far as these tests go, to the manufacture of stoneware, terra cotta, and No. 2 fire brick, and to have a possible use in making building and paving brick.

Outcrop 62[11]

"A well is reported to have penetrated 30 feet of clay on the C. G. F. Obermark farm in sec. 36 (probably the W. ½ SW. ¼), T. 14 S., R. 5 E. A thin sandy horizon lies about 4 feet below the surface and streaks of iron at other horizons. The clay is blue-gray, sandy, and of fair plasticity. The sample (PS-47) was taken by boring in a creek bed. Ten acres or more of this clay is available under an overburden of not more than 6 feet."

[11] Parmelee, C. W., and C. R. Schroyer, op. cit., p. 65.

Outcrop 63

About 2½ miles northwest of Metropolis and between U. S. Highway 45 and the Chicago, Burlington and Quincy Railroad, in the NW. ¼ SW. ¼ sec. 27, T. 15 S., R. 4 E., a 22-foot exposure of white clayey silt of Cretaceous age occurred in the road ditch. The upper portion of the deposit is slightly mottled with yellow iron oxide and grades upward into the loess which is about 3 feet thick. The lower 5 feet of the silt is sandy. The total thickness of the silt is not known.

A considerable area in the vicinity of the outcrop appears to be underlain by this silt, and the loess mantle on the average probably does not greatly exceed 5 to 10 feet.

Sample L-215 was taken from the 22 feet of silt mentioned above. Results of ceramic tests follow.

Outcrop 64

A short distance west of Fort Massac, near Metropolis, in the bank of Ohio River in the S. ½ NE. ¼ sec. 12, T. 16 S., R. 4 E., 5 feet of plastic purplish-gray clay was exposed above the water's edge beneath about 8 feet of brown chert conglomerate. The clay is not sandy but contains layers of interbedded white sand. A spring zone at the top of the clay extends for some distance along the bank and suggests that the clay does likewise. The clay is exposed only at relatively low water stages of the river.

Outcrop 65

On the west margin of Brookport in the NW. ¼ SW. ¼ sec. 14, T. 16 S., R. 5 E., dredging operations exposed the following section along Ohio River. The section was visible only at low water.

STRATA EXPOSED AT OUTCROP 65

		Thickness Feet
5.	River alluvium	
4.	Conglomerate, brown, chert	⅔
3.	Sand, fine-grained, yellow, micaceous.	1
2.	Clay, purplish-gray	1½
1.	Clay, black, with white sand layers	1½
	Covered	

The clay of bed 2 resembles that at Fort Massac and may be the same stratum. The

SAMPLE NO. PS-47.—CRETACEOUS CLAY

This is a dark colored, moderately hard clay. It has a medium plasticity when mixed with 28.5% water and in that condition shows rather poor flowing properties when squeezed through a die.

Water of plasticity	*percent*	25.3
Shrinkage water	*percent*	16.0
Pore water	*percent*	9.3
Modulus of rupture	*lbs. per sq. in.*	365.8
Slaking test, average	*min.*	10
Drying shrinkage, linear	*percent*	6.8

Burning test:

Cone	Porosity *percent*	Color	Burning shrinkage *percent*	Total shrinkage *percent*	Remarks
02	20.6	Dark cream	3.2	10.0	
1	20.9	Dark cream	3.2	10.0	
3	19.6	Cream	3.2	10.0	
7	13.9	Gray	3.4	10.2	Conchoidal fracture
9	7.6	Gray	4.4	11.2	
10	9.5	Gray	...	....	No evidence of over-burning

Fusion test: Completely deformed and vesicular at cone 27.

SUMMARY

This clay has a medium strength and medium drying shrinkage. The burning shrinkage at cone 9 is low. It is an open burning clay, which is incompletely vitrified at cone 10. The clay is not refractory.

Suggested uses: Face brick, stoneware, architectural terra cotta, sanitary ware.

black clay of bed 1 appears to be a lens in the overlying gray clay.

Outcrop 66[12]

Two feet of plastic clay was exposed along a small creek on the farm of John Ridenour in sec. 12 (probably the SE. ¼ NE. ¼ or the NE. ¼ SE. ¼), T. 16 S., R. 6 E., and augering indicated an additional 2 feet of clay below the outcrop. Sample D-50 was taken from the exposed clay.

Another outcrop in the same vicinity consisted of 2 feet or more of "sandstone or siliceous fireclay" found in a gully near the Ridenour house. The age of this deposit is uncertain but may be Mississippian. Sample D-51 was taken from this outcrop.

[12] Purdy, R. C., and F. W. DeWolf, op. cit., pp. 158, 159, and 171.

Results of ceramic tests on samples D-50 and D-51 follow. A chemical analysis of sample D-50 is given in table 2, p. 18.

RESIDUAL CLAYS

Outcrop 67

Clay, residual from the weathering of limestone, was observed near transportation only about a mile north of Mermet in the SE. ¼ NE. ¼ sec. 22, T. 14 S., R. 3 E., where the Chicago, Burlington and Quincy Railroad cuts through a hill in which is exposed 25 feet of Ste. Genevieve limestone overlain by about 3 feet of red clay that contains fragments of white chert. The clay grades into and is overlain by sandy loess which is 10 to 15 feet thick at the crest of the ridges and probably thicker on the flanks. The ridge in which the clay occurs

Sample No. L-215.—Cretaceous Clayey Silt

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	9.56
Linear drying shrinkage	*percent*	3.2
Water of plasticity	*percent*	19.4
Transverse strength—Modulus of rupture	*lbs. per sq. in.*	521
Bulk specific gravity		1.866
Percent residue on 100-mesh sieve		4.35
Character of residue		quartz-mica

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness
06	.7*	.22	21.9	Yellow	
04	.4*	.11	22.8	Yellow	
02	...	...	19.3	Yellow	
1	.2*	.48	23.3	Yellow	
2	.9*	.30	23.4	Yellow	
4	.6*	.20	26.4	Yellow	
6½	1.3	.44	24.0	Yellow	
8	.7	.24	23.9	Yellow	Not steel hard

Summary: This is a plastic material which dries safely with a low shrinkage. Its dry strength is medium high. It is open-burning and has a very low shrinkage.

Suggested uses: Face brick, stoneware, architectural terra cotta, flue linings.

* Expansion.

extends west from the railroad-cut. The extent of the clay beneath the ridge is not known.

Results of bonding clay tests on sample B-8 taken from the clay in the southernmost cut follow.[13]

Bonding Clay Tests on Sample B-8

Water *percent*	Green compressive strength *lbs. per sq. in.*	Dry compressive strength *lbs. per sq. in.*
5.6	1.8	
4.0	2.4	
3.4	4.0	58.1
3.3	4.1	
2.5	6.4	
2.4	6.8	28.1
2.2		32.9
1.9	9.4	
1.8		20.7
1.2	11.2	7.3

[13] Grogan, R. M., and J. E. Lamar, Illinois surface clays as bonding clays for molding sands: Illinois Geol. Survey, R. I. 104, p. 23, 1945.

Sample L-207 was taken from the same deposit. The ceramic tests which follow indicate that the clay is not unusual ceramic material. The clay mineral in the clay is probably illite, with lesser amounts of kaolinite and halloysite.[14]

ALLUVIAL CLAYS

As indicated at the beginning of the discussion of Massac County resources, it is believed that during glacial times a large part of the county was inundated by flood waters from Ohio River, and also possibly from Mississippi River. There are two principal parts of the county which were so affected, one in the northern part and the other along Ohio River. The northern area extends from Cache River, in the northwest

[14] Grogan, R. M., and J. E. Lamar, idem, p. 19.

SAMPLE NO. D-50.—CRETACEOUS CLAY

MECHANICAL ANALYSIS

Sieve	Percent retained
20 mesh	0.89
60 mesh	5.45
100 mesh	4.32
150 mesh	2.75
200 mesh	0.79
Passing 200 mesh	85.80
	100.00

PYROMETRIC TESTS

In the preliminary test this clay had fused to a globule at cone 16. From its appearance it was conjectured that the influence of the reducing fire had very materially lowered its fusion point, and it was suspected that in an oxidizing fire its fusion point would be very much higher. This conjecture was based on the fact that the way the cone bent over gave evidence of the presence of but very little active flux other than ferrous iron.

The correctness of this theory was proven by the second test in an oxidizing fire. It did not begin to bend until cone 22-24 was reached, and was not fused to a bead until cone 26 was reached. The character of the fire gases made a difference of 10 cones, or approximately 200 degrees centigrade in the pyrometric value of this clay.

BURNING TEST

This clay burned into a hard tough brick, though far from vitrification at the kiln temperature.

SUMMARY

Although of fair refractoriness under oxidizing conditions this clay would be very treacherous in places where reducing conditions might occur. Burning tests, however, warrant the assumption that the clay might be suitable for stoneware or paving brick.

SAMPLE NO. D-51.

PYROMETRIC TEST

While this material is very short and sandy, it is sufficiently plastic to mold into cones without the use of dextrine. In the preliminary test it burned white and at cone 20 stood without sign of vitrification. In the final test it was dry and infusible at cone 29.

SUMMARY

This would be a most excellent refractory material for places where acid operations are conducted. Its slight plasticity would permit of its being molded into bricks without much trouble. It might be used to advantage in the silica brick industry, and would seem to have an advantage over other material which usually requires hydrated lime or a similar bond to render the mass plastic.

corner of the county, southeast along Main Ditch and then northeast along Columbia and Bear Creek ditches to the northeast corner of the county (fig. 8). Much of this tract was at one time swampy and occupied by cypress. The southern area borders Ohio River throughout the county, being widest near Metropolis and east of this place.

During the floods sand, silt and locally gravel were deposited, but the last deposits were mostly clayey silt of which there is a considerable thickness.

When the flood waters drained away, the streams began to cut into the deposit of silt and removed some of it to make a flood-plain, thus producing a terrace.

Conditions which gave rise to terraces appear to have existed at two different times and, as a result, there are present two different terrace levels, one at an elevation of about 360 to 380 feet and another at an elevation of about 340 to 350 feet. This coincides with the conclusions of a general study of southern and western Illinois that there are two valley fillings marked by terraces, the tops of which are vertically 10 to 20 feet apart.[15]

The present flood-plain of Ohio River in Massac County is also covered at many places with alluvial silt that contains more or less clay.

Outcrop 68

Northwest of Metropolis at the center S. ½ S. ½ sec. 21, T. 15 S., R. 4 E., a cut along the concrete road exposed the following beds. The top of the outcrop is a little below an elevation of 360 feet.

STRATA EXPOSED AT OUTCROP 68

		Thickness Feet
4.	Silt, clayey, buff	10
3.	Silt, buff and gray mixed	10
2.	Gravel, pebbles mostly less than ½ inch in diameter	¼–¾
1.	Sand, gray, very fine-grained, clayey. Covered	3

It is believed that beds 1 to 3 are terrace materials; bed 4 may be loess or terrace material. Sample L-214 was taken from

[15] Shaw, E. W., Newly discovered beds of extinct lakes in southern Illinois and adjacent states: Illinois Geol. Survey Bull. 20, Yearbook for 1910, p. 155, 1915.

Sample No. L-207.—Residual Clay

Kind of material ..... reddish brown clay

Reaction for carbonates ..... none

Hardness ..... soft

Drying conduct:

Linear drying shrinkage ..... *percent* 8.8

Water of plasticity ..... *percent* 30

Percent residue on 100-mesh sieve 18.6

Character of residue ..... quartz sand, mica flakes

Burning test:

Cone	Porosity *percent*	Linear shrinkage *percent*	Color	Hardness
06	30.6	1.9	Light red	Not steel hard
2	28.7	3.2	Dark red	
4	29.0	2.8	Dark red	

Suggested uses: Structural materials such as common and face brick.

beds 3 and 4. The clay mineral in the sample is probably illite. Results of ceramic tests follow.

LOESS

Brown clayey silt (loess) mantles the upland of much of Massac County and reaches an observed thickness of 20 feet and is probably thicker in places. It resembles the loess found elsewhere in southern Illinois and probably has the same ceramic and other possibilities as the loess described in Alexander and Pulaski counties.

SAMPLE NO. L-214.—CLAYEY SILT

Kind of material ..... clay

Reaction for carbonates ..... none

Color ..... yellow

Hardness ..... fair

Water of plasticity ..... *percent* 23.0

Transverse strength tests of unburned clay:

Without sand

Number of briquets 13

Modulus of rupture ..... *lbs. per sq. in.* 813

Drying:

Air shrinkage: Linear ..... *percent* 52 Volume ..... *percent* 15

Drying conduct ..... safe

Bulk specific gravity 1.842

Burning test:

Cone	Porosity *percent*	Color	Hardness	Burning Shrinkage	
				Linear	Volume
06	25.6	Salmon red		.9	2.7
04	23.4	Salmon red		1.6	4.7
02	20.1	Salmon red		1.81	5.3
1	19.5	Salmon red		2.64	7.7
2	20.6	Salmon red		2.15	6.3
4	19.8	Salmon red		3.02	8.8
6½	14.7	Salmon red		3.74	10.8
8	18.1	Salmon red	Not steel hard	3.39	9.8

This is a material which has a fair degree of plasticity. Its drying shrinkage is low and its drying conduct is good. Its dry strength is high. When burned its shrinkage is low medium and it does not vitrify up to cone 8. Soluble salts are present.

Suggested uses: Structural materials such as brick, both common and face, hollow ware.

CHAPTER 6—JOHNSON, POPE, AND HARDIN COUNTIES[1]

The clay and shale resources of Johnson, Pope, and Hardin counties are principally bedrock clay and shale, alluvial clays, and loess. Locally residual clays are present, and clays probably of Cretaceous age are known in a limited area in southern Pope County. The bedrock strata exposed near transportation range from lower Mississippian to Pennsylvanian in age. The most important sources of clays and shales are the Chester and Pennsylvanian strata. The shales and clays occurring in the Chester series are often associated with limestone and are apt to be calcareous, although nonlimy clays and shales also are present. The shales and clays of the Pennsylvanian system are commonly not calcareous but many of them are sandy or gritty. Several tests indicate that the noncalcareous bedrock clays and shales are probably suitable for making the more common types of structural clay products such as brick and tile. Some of the less calcareous clays and shales can also be used for this purpose.

The distribution of the bedrock formations in the three counties is relatively complex, especially in Hardin County where extensive faulting is present. For much of the counties there exist geologic maps[2] and no attempt is therefore made here to detail such information.

Alluvial clayey silt occurs in the floodplains and in terraces along the major streams of all counties, especially Pope and Johnson counties, and some of it is probably suitable for making brick and tile. Loess, a brown clayey silt, is also widely present in the uplands of the counties and is generally similar to the loess found elsewhere in southern Illinois. The thickness varies but a common range is believed to be 10 to 25 feet. No tests were made on loess deposits in the counties but it is probably suitable for the same purposes for which the loess elsewhere in southern Illinois is suited which includes brick and tile and possibly other products.

[1] Includes a discussion of two outcrops in Jackson County.
[2] See bibliography (p. 11) under "General geology of extreme southern Illinois."

JOHNSON COUNTY

BEDROCK CLAYS AND SHALES

Outcrop 69

A cut along the Chicago and Eastern Illinois Railroad about a mile north of West Vienna in the SW. ¼ NW. ¼ SW. ¼ sec. 26, T 12 S., R. 2 E., showed Chester shales as follows.

Strata Exposed at Outcrop 69

		Thickness Feet
6.	Brown, clayey silt (loess)	3
5.	Shale, light gray	12
4.	Limestone, dark gray, coarse-grained	⅔
3.	Shale, black, laminated	8
2.	Limestone, gray, medium-grained	1⅙
1.	Shale, black, laminated	10
	Covered	

The hill in which this exposure occurs rises to the west and the shale probably has heavy overburden. The limestone interbedded with the shales would be a handicap to their use for the making of clay products.

Outcrop 70

About 1¼ miles north of West Vienna along the main north-south wagon road on the east side of the railroad at the center N. line, SW. ¼ sec. 26, T. 12 S., R. 2 E., the section, including Chester shales, given below was exposed in a ditch.

Strata Exposed at Outcrop 70

		Thickness Feet
5.	Silt, brown, clayey (loess)	6
4.	Shale, sandy, greenish-yellow	25
3.	Shale, calcareous, greenish	3
2.	Shale, dark gray	5
1.	Limestone, dark gray, medium-grained, granular	4
	Covered	

This exposure occurs in a hill that rises to the north, and overburden doubtless thickens to the north. The strata dip in a general northeast direction. A red clay, possibly residual from the weathering of limestone, was also seen along the same road but its extent and relation to the bedrock is not clear.

Outcrop 71

Ten to 12 feet of clay of Chester age was exposed in a road gutter near the base of the south valley-wall of Grasshopper Creek about two miles northeast of Buncombe in the SW. ¼ SE. ¼ NE. ¼ sec. 11, T. 12 S., R. 2 E. The clay is purplish in color, indistinctly bedded, has an irregular fracture, and is apparently an outcrop of a soft shale somewhat modified by weathering. The hill in which the clay occurs rises to the south and is capped with beds of Pottsville age.

Sample L-216 was taken from the outcrop. The results of preliminary tests show it to have possible value for the making of common and face brick.

Outcrop 72

About three miles south of Goreville, along the Chicago and Eastern Illinois Railroad, the following Pennsylvanian clay and shale beds were exposed in a cut along the right of way in the S. ½ SW. ¼ SE. ¼ sec. 35, T. 11 S., R. 2 E. The outcrop occurs in a cut through a saddle in a NW-SE trending ridge.

Strata Exposed at Outcrop 72

		Thickness Feet
4.	Silt, brown, clayey (loess)	12
3.	Sandstone, yellow, medium-grained	10–15
2.	Clay, white and yellow	½–1½
1.	Shale, black, laminated	9
	Covered	

Outcrop 73

About a mile and a quarter north and somewhat east of Vienna in the center W. ½ sec. 33, T. 12 S., R. 3 E., between the concrete highway and the Cleveland, Cincinnati, Chicago and St. Louis Railway, 6 feet of buff shale with black streaks was exposed in a creek. A test-pit dug for coal encountered below an additional 5 feet of shale which was bluish-black in color and broke readily into small thin fragments. The outcrop occurred well down the slope of a large hill and overburden is likely to be heavy. Tests showed the shale to be of possible value for the making of clay products such as brick and tile.

Outcrop 74[3]

Fire clay of Pennsylvanian age is reported to occur about two miles southeast

[3] Parmelee, C. W., and C. R. Schroyer, *op. cit.*, pp. 145–146.

Sample No. L-216.—Chester Shale

Kind of material ..... clay

Drying conduct:

Volume drying shrinkage ..... *percent* 26.1

Linear drying shrinkage ..... *percent* 9.1

Water of plasticity ..... *percent* 30.2

Percent residue on 100-mesh ..... none

Burning test:

Cone	Linear shrinkage *percent*	Porosity *percent*	Color	Remarks
06	8.6	21.4	Light red	
2	...	1.9	Dark red	Over fired

Suggested uses: Common and face brick.

of Ozark, on the Illinois Central Railroad, in the NW. ¼ NW. ¼ sec. 35, T. 11 S., R. 4 E., where the following strata were exposed in a test-pit.

Strata Exposed at Outcrop 74

		Thickness Ft.	In.
8.	Soil, yellow	1–5	
7.	Shale, chocolate, siliceous	4	2
6.	Mud, red, merely a streak		
5.	Oil shale	2	9
4.	Coal, bituminous		1½
3.	Coal, cannel		4
2.	Coal, with peacock-colored blotches		2
1.	"Fire clay," white Covered	5+	

Results of tests on sample PS-C-18-1 taken from the "fire clay" which follow indicate that it is probably suitable for making brick.

POPE COUNTY
BEDROCK CLAYS

Outcrop 75

The following upper Chester clay, shale, and sandstone were exposed in a cut through a relatively large hill along the Illinois Central Railroad about 1½ miles west of Glendale in the NW. ¼ SE. ¼ sec. 19, T. 12 S., R. 5 E.

Strata Exposed at Outcrop 75

		Thickness Ft.	In.
10.	Silt, brown, clayey (loess)	8	
9.	Sandstone	5	
8.	Clay, gray		8
7.	Clay, red	1	2
6.	Shale, gray, poorly-bedded at top, well-bedded at base	10	

Sample PS-C-18-1.—Pennsylvanian "Fire Clay"

This sample is medium hard, gray colored clay, mottled with brown, which latter color may be due to the presence of organic matter. It has rather poor plasticity.

Water of plasticity	*percent*	22.09
Shrinkage water	*percent*	9.20
Pore water	*percent*	12.89
Modulus of rupture	*lbs. per sq. in.*	147.3
Slaking test, average	*min.*	8
Drying shrinkage, linear	*percent*	4.4

Burning test:

Cone	Porosity *percent*	Color	Total shrinkage *percent*	Remarks
04	18.7	Light tan	8.3	Earthy fracture
01	16.4	Light tan	7.3	
1	17.9	Gray	9	
5	9.4	Dark gray	11.5	
7	3.1	Dark gray	7	Shows signs of overburning

Fusion test: It fuses at cone 16.

SUMMARY

The clay has a medium low strength and a medium drying shrinkage. The burning shrinkage at cone 5 is medium high. It seems to be overburned at cone 7. The trial pieces have the appearance of having been subjected to reducing conditions at and above cone 5. The clay is nonrefractory, in fact, it is very fusible.

Suggested uses: Brick.

5.	Shale, greenish-gray, sandy	1	
4.	Sandstone	1	
3.	Shale, greenish-gray, sandy		2
2.	Sandstone	1	6
1.	Shale, greenish-gray, sandy	6	
	Covered		

The best location for open pit working of the clay and shale of this deposit is probably in the slopes of the hill. The sandstone present would ordinarily be a handicap to development.

Sample L-218 was taken from beds 6, 7, and 8 and results of tests which follow indicate it may be suited to the making of brick, quarry tile, and roof tile.

Outcrop 76[4]

Four feet of homogeneous siliceous clay of Chester age was exposed beneath a thin horizontally bedded sandstone on the southeast slope of Flick Hill in the S. ½ sec. 35, T. 12 S., R. 6 E. A second bed of gray shale may be seen 15 feet lower and possibly is slump from the higher bed. The deposit probably would have to be worked by subsurface mining. Sample D-X[5] was taken from this outcrop.

[4] Purdy, C. R., and F. W. DeWolf, op. cit., p. 171–172.
[5] This sample number assigned by present writer.

SAMPLE NO. L-218.—CHESTER SHALE

Kind of material		clay
Drying conduct		good
Volume drying shrinkage	*percent*	24.9
Linear drying shrinkage	*percent*	9.1
Water of plasticity	*percent*	29.8
Transverse strength—Modulus of rupture	*lbs. per sq. in.*	542
Bulk specific gravity		1.969
Percent residue on 100-mesh sieve		none

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness	Remarks
06	26.2	9.65	.72	Brown red	Steel hard	
04	27.1	9.99	.82	Brown red	Steel hard	
02	26.2	9.64	1.63	Brown red	Steel hard	
1	12.8	4.47	.90	Brown red	Steel hard	
2	21.6	7.77	1.27	Brown red	Steel hard	Over fired
4	12.2	4.24	19.6	Brown	Steel hard	
6½	22.1*	8.0	14.9	Brown	Steel hard	
8	33.6*	12.8	13.8	Brown	Steel hard	

Summary: This is a plastic material having a medium high shrinkage and dries safely. Its dry strength is medium high. It burns dense at a very low temperature and overfires at a low temperature (cone 2).

Suggested uses: Structural material, useful for brick, quarry tile, roof tile.

* Expansion.

Outcrop 77[6]

"Limestone Hill" in sec. 26, T. 13 S., R. 6 E., west of Golconda, includes outcrops of both shale and limestone. Sample Bu-21 was taken from a 5- to 6-foot roadside exposure of a bed of shale which is probably 25 feet thick. Sample Bu-22 was obtained from 5½ feet of shale of the same stratum in a prospect hole and Bu-23 from 6½ feet of the shale exposed in a prospect pit. Overburden on the shale ranges up to 40 feet and includes limestone.

Chemical analyses of the three samples are given in table 2, p. 18.

Outcrop 78

In the portals of the tunnel of the Illinois Central Railroad about two miles northwest of McCormick in the NW. ¼ SE. ¼ NW. ¼ sec. 18, T. 11 S., R. 5 E., the Pennsylvanian shales indicated below were exposed.

Strata Exposed at Outcrop 78

		Thickness Feet
6.	Silt, brown, clayey (loess)	
5.	Sandstone	40
4.	Coal	⅓
3.	Shale, black	10
2.	Coal	⅙
1.	Shale, black, becoming sandy at base Covered	25

[6] Bleininger, A. V., E. F. Lines, and F. E. Layman, Portland cement resources of Illinois Geol. Survey, Bull. 17, p. 111. 1912.

This deposit probably would have to be mined by subsurface methods to obtain the exposed shales in quantity. However, the shales presumably come to the surface at some point south of the tunnel, and if their outcrop can be located and if they do not pinch out, it may be that they can be stripped there.

Sample L-217 was taken from bed 1 and the results of preliminary tests indicate that this material is probably suited to making common and face brick.

Sample No. D-X.—Chester Clay

LABORATORY TESTS

Incomplete tests were made on this clay, but the results may be of some value to those interested in the possibilities of the Mississippian clays.

FUSION AND BURNING TESTS

The sample fused down flat on the plaque at cone 18, but retained sharp edges. In the kiln it burned at 1120 degrees C. to a fine buff color.

SUMMARY

This clay is evidently low in iron except that in lump form. An eye examination does not reveal the condition of the iron. So far as the evidence here obtained goes, the clay would be regarded by potters as a No. 2 fireclay, possibly of value for stoneware and building brick.

Sample No. L-217.—Pennsylvanian Shale

Kind of material ..... clay

Drying conduct:

Linear drying shrinkage ..... *percent* 4.4

Water of plasticity ..... *percent* 20.6

Fineness ..... sample does not slake

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color
06	.....	4.4	18	Light brown red
2	.....	7.2	12.0	Dark brown red

Suggested uses: Structural materials, i.e., brick, common and face.

CRETACEOUS CLAYS

Outcrop 79[7]

Clay outcropping along a branch of Robinette Creek on the C. Wolff farm in sec. 26, T. 14 S., R. 5 E.,[8] is probably of Cretaceous age. Five feet of clay were exposed and an additional two feet is said to lie below it. Appreciable quantities of clay can probably be obtained in this area from open pits by stripping off the overburden which consists of 7 feet of loess and gravel. The deposit is about 7½ miles from the Illinois Central Railroad at Round Knob and six miles west of Ohio River.

[7] Purdy, R. C., and F. W. DeWolf, op. cit., pp. 154–156.
[8] Purdy and DeWolf give the location of this deposit as sec. 27, but it is believed more likely to be sec. 26.

SAMPLE NOS. D-34 AND D-35.—CRETACEOUS CLAYS

MECHANICAL ANALYSIS

Sieve	Percent retained D-34	Percent retained D-35
20 mesh	0.10	0.16
60 mesh	0.14	0.18
100 mesh	0.59	0.85
150 mesh	2.40	1.99
200 mesh	1.42	1.33
Passing 200 mesh	95.35	95.49
	100.00	100.00

PYROMETRIC TESTS

D-34. This clay started to bend at cone 24, but did not touch the plaque until cone 30 was reached. In preliminary test it was vitrified at cone 20, but not melted to a globule.

BURNING TESTS

These clays were molded into briquettes by the plastic "stiff mud" process and burned in an open kiln at 1120°C. Under this treatment they became hard, nearly vitrified, and exhibited a good clean buff color.

SUMMARY

These clays are comparatively fine-grained, relatively high in fine silica and fairly plastic, i.e., plastic enough for fire brick purposes but perhaps not plastic enough for retort manufacture.

On the basis of pyrometric behavior under favorable conditions D-34 falls in the refractory fire clay class, while D-35 belongs more closely with those of nonrefractory value. It seems possible that the clay of the combined samples may well be of value for fire brick or for stoneware and terra cotta and building brick, though distance from transportation facilities would seem to prohibit its development at present.

Sample D-34 representing the top 3 feet of the bed and sample D-35 the succeeding 2 feet were obtained by means of an auger. Results of ceramic tests follow and show that the combined samples may be suited for making stoneware, terra cotta, and brick. Chemical analyses are given in table 2, p. 18.

Outcrop 80[9]

An ash-colored sandy laminated clay, interbedded with seams of limonite, was exposed along the road on the west line sec. 9, T. 15 S., R. 6 E. The clay is probably of Cretaceous age. Sample PS-48 was taken from this deposit and results of tests follow

SAMPLE NO. PS-48.—CRETACEOUS CLAY

This is a gray colored clay mottled with brown. It contains much mica.

Slacking test, average.....12.5 min.
Fusion test.....No deformation at cone 27

SUMMARY

Insufficient material was received for complete test. However, it was found to be a refractory clay. The mode of occurrence with seams of limonite will prevent its use unless some method of purification is employed.

CLAY OF UNCERTAIN AGE

Outcrop 81[10]

Samples of clay obtained from a considerable amount of similar material in the dump of a mine in the W. ½ NE. ¼ SE. ¼ sec. 16, T. 12 S., R. 6 E., about two miles northwest of Raum have been identified by X-ray[11] and the petrographic microscope[12] as composed of halloysite type clay mineral. The material in the dump is reported to have come from a deposit of the clay about 10 feet thick, encountered in a shaft sunk near the northwest valley-wall of Lusk Creek for the production of fluorspar and other minerals. As the shaft had become filled with water, first-hand examination of the deposit was impossible. This is the only

[9] Parmelee, C. W., and C. R. Schroyer, op. cit., pp. 65–67.
[10] Lamar, J. E., Halloysite clay in Illinois, Illinois Geol. Survey, Cir. 83, June, 1942.
[11] Identification by W. F. Bradley, Illinois Geol. Survey, 1942.
[12] Identification by R. E. Grim, Illinois Geol. Survey, 1942.

known occurrence of any considerable thickness of halloysite clay in Illinois.

Halloysite clay has no extensive commercial use at present, chiefly because of the relative rarity of sizable deposits of the clay. It can be used like kaolin for ceramic purposes and has other possible uses.

The clay in the mine dump has a waxy luster and subconchoidal fracture when fresh but weathers to a white mass devoid of these characters and resembling an ordinary clay. It is white to light blue in color though locally it is stained yellow or brown by iron oxide.

The location of the deposit and the character of the clay correspond closely with the location of the old "clay diggings" near Raum and the "kaolin" they are reported to have contained. In a report dated 1866, Englemann[13] describes the "diggings" in "the east part of sec. 16, T. 12 S., R. 6 E., near Lusk Creek" as follows:

"The pure portions of this clay—some of it mechanically mixed with extraneous impurities, which deteriorate its quality—are purely white or have a slightly bluish tint. It is from uneven to subconchoidal in fracture, without the least grit, unctuous to the touch and adheres vigorously to the moist tongue. When moist it is translucent, and by long exposure and working it becomes plastic, which it is not when it is newly dug.

"It is exposed on the side of the hill, about 15 feet thick; but the excavation is not sufficient to determine the true character of the deposit. Perhaps it is an altered shale of the Chester series, intercalated between the limestones, which has assumed its present condition through the same agencies which caused the mineralization of the limestones, at the time when the galena and fluorspar were deposited . . . . Perhaps, however, it is only a deposit on the side of the hill and in immediate connection with the fault which passes there through the formation."

In 1907 a later examination of what is believed to be the same deposit afforded the following data:[14]

The old "clay diggings" have "been abandoned for many years, but apparently once contained a deposit of considerable commercial value. The clay is gray, waxy or greasy, and grades abruptly from its purer form into the associated red sandy clay. No considerable quantity of the better material now remains exposed . . . . There is apparently a fault here which brings St. Louis limestone into contact with Mansfield sandstone (Pennsylvanian). While the relations are obscure, the kaolin appears to occur along the fault zone, as though a decomposition product of older rocks or a secondary deposit intimately related to the faulting."

The occurrence of halloysite clay in the shaft dug recently suggests that the abandonment of the deposit sometime between 1866 and 1906 was not necessarily due to its exhaustion. The quantity of clay remaining is not known and can probably be determined only by test-drilling or test-pitting.

The clay, as has been intimated above, probably is associated with a fault occurring at or near the deposit. There are possibilities that in other parts of Hardin and Pope counties of southern Illinois similar geologic conditions may exist and that other deposits of halloysite clay may be found in some such places.

No data are given in the reports previously cited as to the use made of the clay but it was probably used for ceramic purposes, possibly for making pottery, stoneware, or similar clay products. The results of ceramic tests[15] on a sample, D-56, ob-

[13] Englemann, Henry, in Geological Survey of Illinois, vol. I, p. 483, 1866.

[14] Purdy, Ross C., and F. W. DeWolf, Preliminary investigation of Illinois fireclays: Illinois Geol. Survey Bull. 4, pp. 172-173, 1907.

[15] Purdy, R. C., and F. W. DeWolf, op. cit., p. 173.

SAMPLE NO. D-56

PYROMETRIC TESTS

D-56. Infusible and dry at cone 29. In the preliminary test it exhibited a glassy sheen at cone 20, showing that vitrification had taken place to a considerable extent. There is no evidence at hand from which to judge the character of the fire gases in the preliminary test, but from the two tests studied together it is readily seen that the conditions of the fire gases, i.e., where they are reducing or oxidizing, will make some difference in the pyrometric value of this clay.

SUMMARY

The plasticity of D-56 was graded as B. Judging from the chemical analysis and pyrometric test there can be no doubt that this clay is of high refractory value.

tained about 1907 are given. A chemical analysis is given in table 2, p. 18.

HARDIN COUNTY

Parts of Hardin County contain outcrops of bedrock shale and clay of the same general character as those mentioned in Johnson and Pope counties. The alluvial silt and loess are believed to be similar to those in Pope County. Clays residual from the weathering of limestone are found in some places. Two of the better outcrops are discussed below.

RESIDUAL CLAYS

Outcrop 82

In a gully on the west side of the highway, two and three tenths of a mile north of Eichorn, at the center S. ½ S. ½ SW. ¼ SE. ¼ sec. 26, T. 11 S., R. 7 E., the following materials were exposed.

Strata Exposed at Outcrop 82

		Thickness Feet
5.	Soil	½
4.	Silt, brown, clayey	6
3.	Gravel, angular, chert	½–¾
2.	Clay, red plastic; contains a few chert fragments. A yellow zone occurs 3½ feet from the top	7
1.	Clay, mottled red and reddish-brown; silty, firm, with scattered chert fragments	3
	Covered	

Beds 1 and 2 are thought to be residual clay.

Sample B-21 was taken from bed 2. A chemical analysis is given in table 2, p. 18; results of bonding tests follow. The clay mineral in the clay is probably principally kaolinite and illite with lesser amounts of montmorillonite and halloysite.

Bonding Tests with 8 Percent Clay

Water	Green compressive strength	Dry compressive strength
percent	*lb. per sq. in.*	*lb. per sq. in.*
5.6	1.8	
4.0	2.4	
3.4	4.0	58.1
3.3	4.1	
2.5	6.4	
2.4	6.8	28.1
2.2		32.9
1.9	9.4	
1.8		20.7
1.2	11.2	7.3

Outcrop 83

In the NW. ¼ NW. ¼ NW. ¼ sec. 36, T. 11 S., R. 7 E., several road-cuts along the northeast slope of a ridge exposed red clay containing chert fragments. A maximum thickness of 6 feet was exposed and from this exposure sample B-52 was taken. Results of bonding and ceramic tests follow.

Bonding Tests with 8 Percent Clay

Water	Green compressive strength	Dry compressive strength
percent	*lb. per sq. in.*	*lb. per sq. in.*
4.3	3.1	42.6
3.2	5.0	30.2
2.2	9.3	17.0
1.7	11.1	8.7
1.3	7.4	

JACKSON COUNTY

No special studies of the clay and shale resources were made in Jackson County as it was outside the area covered by this study. However, two deposits are described because one was sampled in Jackson County but extends into Union County and the other adds to the general body of data on alluvial clays.

BEDROCK CLAYS

Outcrop 84

In the west wall of Drury Creek valley about 1¼ miles south of Makanda in the SE. ¼ SW. ¼ sec. 33, T. 10 S., R. 1 W., and in the NE. ¼ NW. ¼ sec. 4, T. 11 S. R. 1 W., there was exposed 10 to 20 feet of white to buff, plastic clay, locally containing beds of sandstone about ¼ inch thick or thin beds of sandy clay. The clay is of Pennsylvanian age and lies between two massive sandstones. The lower of these forms the bluffs along Illinois Central Railroad, which follows the creek valley, and the higher crops out in the upper slopes of the valley wall. For the most part the clay is covered by debris from overlying formations, but search of the gullies of the valley wall usually reveals one or more outcrops about a third of the way down the bluff.

SAMPLE NO. B-52.—RESIDUAL CLAY

Kind of material ..... ferruginous surface clay

Color ..... yellowish red

Hardness ..... readily crumbles between fingers

Reaction for carbonates: Hot ..... negative. Cold ..... negative

Reaction for pyrite ..... negative

Working properties ..... good, a little too fat

Drying shrinkage: Linear ..... *percent* 11.7 Volume ..... *percent* 39.5

Drying conduct ..... Fair. Can be dried safely with reasonable care

Fineness ..... 10.1% retained on 35-mesh sieve

Burning test:

Cone	Absorption *percent*	Porosity *percent*	Color	Hardness	Burning shrinkage		Remarks
					Linear	Volume	
06	19.5	35.3	Yellow red	5	6.3	17.7	No scumming
3	10.1	23.0	Red orange	8	7.1	19.7	No scumming
7	9.2	21.1	Purple red	9	7.1	19.8	No scumming

Oxidation conduct: Very easy to oxidize.

Suggested uses: The clay is easy to work and it can be dried with reasonable care. It is very easy to burn, having a very low firing shrinkage and a long burning range. It fires to red colors, to shades becoming darker with increasing temperatures. The clay has a "sanded appearing" texture when burned. It would be suitable for the manufacture of common or face brick. It could be used as a coating to furnish red surfaces to some face brick.

The clay bed crops out at intervals for about half a mile in the valley wall. The strata in this general area are rising toward the south, and it is possible that the clay will be found without bedrock overburden at some point in the NW. ¼ sec. 4, although it was not there observed because of a loess covering 15 to 25 feet thick. It is thought possible that a large body of clay may be present in secs. 4 and 33.

Sample L-219 was taken from outcrops near the south line of sec. 33. Results of ceramic tests which follow show that the clay has possibilities for the manufacture of face brick, quarry tile, architectural terra cotta, and stoneware.

ALLUVIAL CLAYS

Outcrop 85

About three miles northeast of Carbondale, in tributary gullies on the east side of Crab Orchard Creek, 6 to 10 feet of sticky dark gray nonbedded alluvial clay was exposed in the NW ¼ NW. ¼ sec. 13, T. 9 S., R. 1 W. This clay is part of the later valley filling in the Big Muddy River and its tributaries. The terrace in which the clay occurs has a covering of 1 to 3 feet of brown clayey silt, probably loess.

The outcrop is significant not only because it is a part of a relatively large area in sec. 13 that is probably underlain by this

Sample No. L-219.—Pennsylvanian Clay

Kind of material		clay
Drying conduct		safe
Volume drying shrinkage	*percent*	18.6
Linear drying shrinkage	*percent*	6.6
Water of plasticity	*percent*	26.1
Transverse strength—Modulus of rupture	*lbs. per sq. in.*	363
Bulk specific gravity		1.866
Percent residue on 100-mesh sieve		.25

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Hardness
06	7.87	2.66	19.2	Cream	
04	12.0	4.17	18.7	Cream	
02	9.4	3.24	19.5	Cream	
1	16.4	5.80	10.7	Cream	
2	15.5	5.4	12.2	Cream	
4	19.1	6.81	9.0	Olive	
6½	22.2	8.04	2.6	Olive	Steel hard
8	20.6	7.39	.16	Olive	Steel hard

Summary: This is a plastic material which dries safely with a medium shrinkage. Its dry strength is medium. It is practically vitrified at cone 8. Its burning shrinkages are low to medium.

Suggested uses: Face brick, quarry tile, architectural terra cotta, stoneware.

clay, but also because it is more or less typical of the valley-fill clays found elsewhere in abundance in this general area. Other outcrops were noted in secs. 11, 14, and 24 of the same township, and are doubtless present elsewhere in this vicinity.

Sample L-202 was taken from a 9-foot exposure of the valley-fill clay, and results of tests suggest that the clay may be used for making face brick, common brick, and other structural materials. The loess overburden on the clay could probably be mixed with it to advantage in the making of clay products.

SAMPLE NO. L-202.—ALLUVIAL CLAY

Kind of material ..... clay

Drying conduct ..... poor

Volume drying shrinkage ..... *percent* 40.5

Linear drying shrinkage ..... *percent* 15.9

Water of plasticity ..... *percent* 47.3

Transverse strength—Modulus of rupture ..... *lbs. per sq. in.* 728.9

Bulk specific gravity 1.882

Percent residue on 100-mesh sieve ..... none

Burning test:

Cone	Volume shrinkage *percent*	Linear shrinkage *percent*	Porosity *percent*	Color	Remarks
06	9.7	3.3	20.2	Salmon red	
04	18.4	6.5	8.5	Brown red	
02	20.4	7.3	7.3	Brown red	
1	23.1	8.4	4.2	Brown	
2	19.1	6.8	7.5	Brown	
4	21.4	7.7	4.6	Brown	All bars broken during cooling Overburned

Summary: This clay showed a sticky plasticity when wet. The drying conduct was poor and the drying shrinkage was high. It burns to a dense structure at a low temperature with a medium shrinkage. The presence of soluble salts should be noted. Burning conduct good.

Suggested uses: Common brick, face brick and other structural materials.

CHAPTER 7—OCHER AND SIENNA

There occur locally in extreme southern Illinois deposits of colored clay and shale which attract attention as possible sources of ocher or sienna. No special investigation was made of such materials but in the course of this study several samples were collected and submitted to the United States Bureau of Mines who cooperated by testing them. These data have been assembled in a separate chapter in order to present a rounded discussion of mineral pigment possibilities. Although the samples tested are not numerous, they give an idea of the general types of colored pigments potentially available from the clays and shales of extreme southern Illinois. In general, major problems connected with these materials, aside from their suitability as pigments, involve the finding of deposits of such thickness, extent, workability, and color uniformity that they could be economically operated.

The term ocher is loosely used to describe a natural mineral pigment of yellow, orange, or red color. The term is also sometimes applied to gray, cream-colored, and white natural mineral pigments, which are relatively common varieties of clay or shale.[1] Yellow-brown and brown natural mineral pigments are usually designated by special names such as sienna and umber. No deposits of umber were observed in southern Illinois but a few sienna deposits were noted.

Ocher and sienna resources at a number of places in southern Illinois are mentioned below. There are doubtless other deposits.

RED OCHERS

The red Bainbridge-Bailey shale in Alexander County, the red, residual clays found on some limestone deposits in southern Illinois, some of the red Chester shale strata in the same area, and the occasional red clays found with the Cretaceous and Tertiary deposits, all of which owe their color to iron oxide, may in some places be of such character that they may be regarded as red ocher. However, their commercial value is probably limited because most red iron oxide pigments are produced by roasting and calcining iron ore.[2] One sample was tested with the results indicated below.

Four feet of plastic red sandy clay, described as Outcrop 4 (p. 30), is exposed south of Balcom in the SE. ¼ SW. ¼ sec. 11, T. 13 S., R. 1 W., in a cut along Illinois Central Railroad. The total thickness of the clay is not known as its base is covered. Tests on sample L-84A taken from the clay follow.[3]

This material dispersed easily in water and when washed left 47.4 percent of red sand with some white sand. Another sample was likewise ground in the pebble mill because of the abundance of red sand, which should not dilute the color. When dried the fines from the pebble mill gave a hard mass of high shrinkage, requiring 19 drops per gram or 0.44 part by weight of linseed oil to make a poor-working mahogany (60136) paste. When diluted with zinc oxide the color was light pink No. 1 (60013). The ferric oxide determination was likewise low (4.4 percent), and the tinting strength was entirely too weak for a commercial pigment. The pigment was listed as class 1, weak red-brown, burnt ocher.

YELLOW OCHER AND SIENNA

The yellow ocher and sienna found in southern Illinois occur principally in the Cretaceous and Tertiary beds although in some places the residuum from the weathering of limestones is a gritty yellow or brown material. The chief problem involved in connection with any deposits observed is its extent and uniformity of color and texture.

Alexander County

In the Thebes district, Outcrop 25 described earlier, there was 1½ to 2½ feet of yellow clay, and at Outcrop 27 mentioned under the Elco district 3 feet of yellow clay from which sample L-29 was taken. In the same vicinity, but lying about 10 feet above the clay, are irregular deposits of impure yellow, brown, or black iron oxide 6 to 12 inches thick. The yellow clay and the iron oxide suggest that this area

[1] Ladoo, R. B., Non-metallic minerals, p. 375, 1925.

[2] Wilson, Hewitt, Industrial minerals and rocks, p. 494, 1937.

[3] Wilson, Hewitt, Iron oxide mineral pigments in the United States, U. S. Bureau of Mines, Bull. 370, p. 111, 1933.

may be worth prospecting for ocher but there is no assurance of a commercial sized deposit and overburden is likely to be thick. Laboratory tests on sample L-29 follow.[4]

The sample as received could probably be washed damp direct from the mine with a blunger, but the dried sample dispersed with difficulty in water and yielded 34.5 percent of residue containing a large portion of ocherous material. For the final tests another portion was ground in water in a pebble mill and gave a high-shrinking, hard, strong residue after drying. When mixed with 22 drops per gram or 0.51 part by weight of linseed oil the color was a deeper yellow-brown than topaz (60112). When diluted with zinc oxide, the color was near sunset (60038) and chamois (60179). The ferric oxide content was 8.2 percent washed and 10.88 percent ground. This material was grouped with French, class 1, dark-yellow, ochers. The full-strength color varied from the standard toward orange. The dilution test indicated medium tinting strength, and the let-down color varied from light French ocher toward pink. It therefore has possible commercial value if the economic features are satisfactory.

There have been several attempts to develop ocher deposits in Alexander County as in the S. ½ sec. 23, T. 15 S., R. 3 W., where digging exposed a deposit of red sand about 5 feet thick containing large rounded masses of yellow clay. Above the sand was a gravel, locally loosely cemented, consisting of gray and brown chert pebbles, coarse sand, and a few igneous pebbles. It is believed the clay and red sand are probably a part of the Lafayette formation.

It is reported that a small tonnage of ocher was produced from the "Phiester deposit" in the S. ½ sec. 26, T. 15 S., R. 3 W., from a 5-foot bed of yellow clay which rested on plastic white clay. Mining of the yellow clay is said to have been discontinued because of difficulties in supporting the roof of the mine.

Another ocher mine was operated briefly in the bluff of Mississippi River at about track level of the Missouri Pacific Railroad near the center of sec. 28, T. 15 S., R. 3 W. Three to 6 feet of brownish-yellow clay was exposed but the amount available under thin overburden was relatively small. Unconsolidated sediments overlie the ocher, and subsurface mining is reported to have encountered difficult roof conditions. Production of an ocher of uniform color grade may be a problem with this deposit. Results of tests on two samples, L-202 and L-203, taken at different places in this deposit follow.[5]

The 2-pound sample, L-202, as received consisted of soft claylike light-yellow ocher-brown lumps 2 inches or less in diameter. No carbonates were present. After being ground in water the pulverized fines required 19 drops per gram or 0.44 part by weight of linseed oil to produce a gold (60164) paste. When diluted with zinc oxide the color changed to between leghorn (60005) and polar bear (60004). The ferric oxide content was 6.9 percent. This material was grouped with Pennsylvania, class 2, light orange-yellow, ochers, slightly grayed, but was close to the light French class. The dilution test indicated weak tinting strength, but the let-down color had a cream hue. The tinting strength could probably be improved by better preparation; in this test, however, it was too weak for best-grade yellow ochers.

The 25-pound sample, L-203, as received consisted of 12-inch or smaller lumps with a hard, rocklike structure and a dark-brown, sienna color. No carbonates were present. After being ground in water the fines required 20 drops per gram or 0.46 part by weight of linseed oil to produce a dark topaz (60112) paste. When diluted with zinc oxide the color changed to dark sunset (60088). The ferric oxide content was 28.0 percent. This material was grouped with class 1*a*, siennas. The full-strength hue varied from the standard toward orange-brown and was close to French ocher. On dilution it showed a very strong tinting strength and varied from the French color toward cream-pink. It undoubtedly has commercial value if economic and mining conditions are satisfactory.

Pulaski County

In Pulaski County 8 to 12 inches of yellow clay ocher was exposed in a cut along the Cleveland, Cincinnati, Chicago and St. Louis Railway near the center of the north line sec. 32, T. 14 S., R. 2 E. The clay is overlain by 6 to 8 feet of red sand, 3 to 7 feet of brown chert gravel, and 3 to 20 feet of brown clayey silt (loess). As the materials in the cut are somewhat slumped there is a possibility that the ocher bed may be thicker where undisturbed.

Results of tests of sample 82 taken from the ocher stratum follow.[6]

The sample was yellow-brown, hard, and shalelike and required pebble-mill grinding rather than washing. The dry powder was mixed with 25 drops per gram or 0.58 part by weight of linseed oil to make a strong gold-brown topaz (60112) paste. When diluted with zinc oxide (1:9) the color was sunset (60088). The ferric oxide content was 59.2 percent. This material was grouped with class

[4] Wilson, Hewitt, op. cit., p. 112.

[5] Wilson, Hewitt, op. cit., pp. 112 and 113.

[6] Wilson, Hewitt, op. cit., p. 111.

1 dark orange-yellow siennas. The dilution tests indicated a stronger tinting strength than that for the French ochers and at least that of the 28 percent iron oxide artificial ochers This material undoubtedly has commercial value if it can be produced and marketed economically.

Another outcrop of yellow clay in Pulaski County was noted in the floor of a gravel pit on the southeast side of the road near the center SW. ¼ NE. ¼ sec. 23, T. 15 S., R. 1 E., northeast of Olmsted. There was 6 to 10 feet of brown chert gravel in the pit, below which was 1½ feet of gray clay similar to the fuller's earth produced at Olmsted, underlain by 2½ feet of similar clay but yellow in color. The clays are believed to be part of the Porters Creek formation. Sample 83 was taken from the yellow clay.

Another outcrop of similar yellow clay of the Porters Creek formation occurs in Alexander County along the south side of the road in the NE. ¼ NE. ¼ NE. ¼ sec. 13, T. 16 S., R. 2 W., near the bridge over Cache River.

Results of tests on sample 83 follow.[7]

This sample was too hard and shalelike to be washed and was therefore ground in water in the pebble mill; on drying it produced a hard pulverized mass, high in shrinkage. Twenty-five drops per gram or 0.58 part by weight of linseed oil was used to make a stiff paste approaching topaz (60112) in color. When diluted with nine parts of zinc oxide the color was nearly sunset (60088). The ferric oxide content was 17.6 percent, just within Government limits. This material was grouped with Pennsylvanian or class 2, light orange-yellow ochers, slightly grayed. The dilution test indicated medium tinting strength, and the color varied from the standard toward pink. It therefore has commercial possibilities if the economic features are satisfactory.

[7] Wilson, Hewitt, op. cit., pp. 111 and 112.

Johnson County

Sample 111 was obtained from 3 feet of gritty yellow clay, believed to be a residuum from the weathering of cherty Vienna limestone, exposed in a gully near the concrete road about 1 mile north of Vienna in the NW. ¼ sec. 33, T. 12 S., R 3 E., Johnson County. Results of tests follow.[8]

The sample as received was yellow-brown clay which dispersed easily in water after a little soaking and gave 21.1 percent of brown-sand residue. A second portion was ground in water in the pebble mill and gave a high-shrinking hard residue after drying, requiring 20 drops or 0.46 part by weight of linseed oil to make a poor-working olive-wood (60082) paste; when diluted with 9 parts of zinc oxide this gave a champagne (60097) color. The ferric oxide content was only 8.5 percent washed and 10.2 percent ground and the ferrous oxide content 0.09 percent The color strength was below Government requirements. This material was grouped with Georgia class 2*a* light siennas The dilution test indicated weak tinting strength, and the color varied from the standard toward gray. The pigment therefore has the disadvantage of the darker hue of Georgia materials and weak strength, which indicates only limited commercial value.

[8] Wilson, Hewitt, op. cit., p. 112.

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