MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph. D.
Director

BULLETIN 34

THE LITTLE BEAR RESIDUUM

By
FREDERIC FRANCIS MELLEN, B.S.

UNIVERSITY, MISSISSIPPI
1937

MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph.D.
DIRECTOR

BULLETIN 34

THE LITTLE BEAR RESIDUUM

BY
FREDERIC FRANCIS MELLEN, B.S.

UNIVERSITY, MISSISSIPPI
1937

MISSISSIPPI GEOLOGICAL SURVEY

COMMISSION

STAFF

LETTER OF TRANSMITTAL

Office of the State Geological Survey
University, Mississippi
April 22, 1937

To His Excellency,
Governor Hugh White, Chairman, and
Members of the Geological Commission

Gentlemen:

Herewith is submitted for your consideration a manuscript entitled "The Little Bear Residuum" to be published as Bulletin 34 of the Mississippi Geological Survey. It is by Frederic Francis Mellen who pursued the study during his own time and at his own expense as a thesis problem in partial fulfillment of the requirements for the Degree of Master of Science in the Department of Geology in the University of Mississippi.

Although many competent geologists had labored in this area, some of whom had observed the presence of this formation, it remained for Mr. Mellen by industry, clear thinking, and imagination to determine its origin, its distribution, and, consequently, its economic value, which seems to be great. Thus the fact is established again that pure science is the handmaiden of economic development.

The Director, although intimately acquainted with most of the region, revisited the localities with Mr. Mellen and is in full accord with his major theme. Even though some minor conceptions may be subject to revision, such can be said of almost every original work that represents constructive scientific imagination.

Very sincerely yours,
William Clifford Morse, Director

ACKNOWLEDGMENTS

The writer acknowledges with sincerest thanks the cooperative field study and encouragement lent to him in pursuance of this problem by Dr. W. C. Morse, who, as head of the Department of Geology, suggested its use as a thesis for the degree of Master of Science in the University of Mississippi and who, as director, accepted the manuscript for publication as a bulletin of the Mississippi Geological Survey; and by Prof. F. E. Vestal under whom he has been employed in the field. He is especially indebted to these gentlemen and to Drs. Gordon Rittenhouse, L. W. Stephenson, and P. H. Dunn, and to his father, Prof. F. D. Mellen, all of whom contributed invaluable criticisms and suggestions leading to subsequent revisions of the text. He is further indebted to Dr. M. N. Bramlette, Edward H. Rainwater, Roger F. Rhoades, and Ernest L. Spain. Although some suggestions rendered by the critics have not been adopted, all have been gratefully received and carefully reviewed; the final selection of them has been, of course, the responsibility of the present writer.

In Alabama and Mississippi the distribution of the Little Bear residuum (Fig. 1) has been determined by the writer; in Tennessee, by a slight modification of Dr. Burchard's map of the iron ore fields; and in Kentucky, by a compilation of published maps of the Tuscaloosa formation.

CONTENTS

LIST OF ILLUSTRATIONS

THE LITTLE BEAR RESIDUUM*

BY

FREDERIC FRANCIS MELLEN

INTRODUCTION

Specific reference to the important and valuable massive clays at the contact of pre-Mesozoic and Cretaceous rocks in the eastern Gulf region is conspicuously rare in geologic literature. In 1909 Logan[1] stated that these clays in Mississippi were interbedded with the gravel, sand, and lignite of the Tuscaloosa formation. Ten years later, 1919, the same author in writing of the kaolin deposits of Indiana[2] suggested for the "Tuscaloosa formation" kaolin of Mississippi a mode of origin similar to that of the Indiana clay; namely, by reactions produced by sulphur bacteria. In 1930 Adams[3] described the white clays of this stratigraphic position in western Alabama as being in the Tuscaloosa formation though contiguously above the Paleozoic rocks. In his article he shows that the clays cannot be of marine origin and attempts to show that deposition in shallow fresh-water lakes followed by an alteration process in the zone of weathering probably in Wilcox (Eocene) time may account for their massive, non-fossiliferous, character. In 1931 Sutton[4] identified a sub-Tuscaloosa "hard, arenaceous shale" in western Kentucky as an ancient soil. Bramlette wrote the author of the present paper on August 26, 1935, that he had examined the clays of Marion County, Alabama, during the year before.[5] He said: "Though these clays previously had been included in the Tuscaloosa, I concluded that they were actually residual clays formed from the Paleozoic rocks before the deposition of the Tuscaloosa formation. Beside field observations suggesting this fact, I noted under the microscope that the sand in these 'basal' clays was a quartz sand such as formed the underlying Paleozoic, whereas the sands in the overlying Tuscaloosa had a great deal of feldspar and other minerals with the quartz."

Early in 1934 the present writer became interested in the origin of the clays in northeastern Mississippi and northwestern Alabama. At various times throughout that and the following years he has studied outcrops of these clays not only in this region, but in the western Highland Rim of Tennessee, and as far south as Guin, southern Marion County, Alabama. His conclusions accord with those of Sutton and Bram-

*A recently recognized Comanchean formation in the eastern Gulf region.

lette, that the insoluble materials herein described do not belong genetically to the Tuscaloosa formation; further, that to distinguish them a name of formational rank must be provided.

The iron ore and its clay matrix of the Russellville district were assigned to the Tertiary period by Eckel,[6] a conclusion resulting partly from the identification of the overlying gravel as LaFayette, a conception held for a time by him, Smith, and others, and partly from correlation made with the Brandon formation of Vermont. Later work of Coastal Plains specialists showed the gravel to be of Tuscaloosa age. Burchard,[7] however, now argues that the concentration of the ore was during Tertiary peneplanation, an hypothesis involving a change to the idea that the ore formed subsequent, rather than prior, to the sedimentation of the over-lying strata.

Adams[8] has written a good discussion of the brown iron ores of Alabama in which he assigned a Tuscaloosa age but without attention to the concentration processes.

Of prime importance in explaining the source of thick bodies of residual material is recognition of the fallacy of the idea that soils (residual) are the insoluble residues of the underlying strata; the residual bodies are, in fact, the decomposition products of pre-existing superjacent strata which may, or may not, have been of the type of those on which the residual material is now lying. Thus it is, with reasons contended, (1) that the brown ore and its embodying clay of the Russellville district, resting on Bangor limestone, were derived from Pennington and Pottsville iron-bearing shales; (2) that the fatty sub-Tuscaloosa clays of the Tishomingo County area, lying on the Iuka chert, and the red prairie soil of the Margerum-Decatur traverse, lying on Tuscumbia limestone and chert, have been formed from Chester shales and sandstones similar to those which are still exposed in the adjoining region; and (3) that the thick ore-bearing clays of the Highland Rim geosynclinal area of west Tennessee were formed from pre-existing overlying Chester clastic material, a conclusion which can be safely drawn.

DESCRIPTION AND DISTRIBUTION

The materials of the Little Bear formation originated in situ from the decomposition of Paleozoic strata. Outcrops are subjacent to the Tuscaloosa formation, extend from Kentucky to west central Alabama (Figure 1), and perhaps extend to central and eastern Alabama, and western Georgia, if not farther.

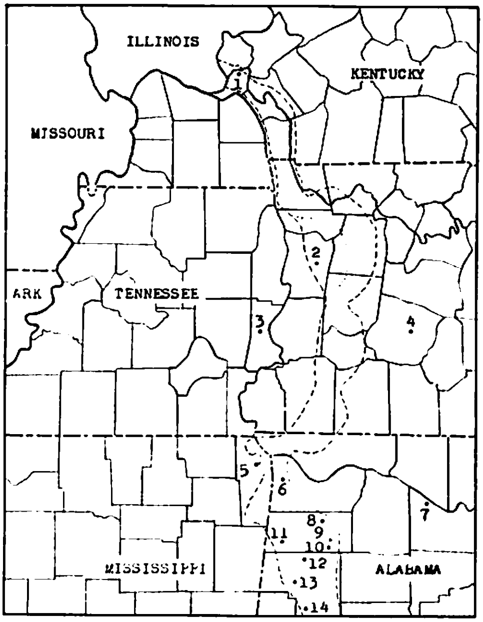


Figure 1.—Map of known distribution of the Little Bear residuum.

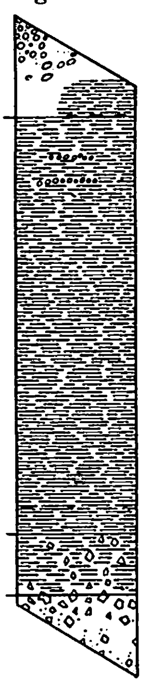
1.	Smithland, Ky.	8.	Russellville, Ala.
2.	Waverly, Tenn.	9.	Spruce Pine, Ala.
3.	Parsons, Tenn.	10.	Phil Campbell, Ala.
4.	Columbia, Tenn.	11.	Vina, Ala.
5.	Iuka, Miss.	12.	Hackleburg, Ala.
6.	Margerum, Ala.	13.	Hamilton, Ala.
7.	Decatur, Ala.	14.	Guin, Ala.

As mentioned above, Sutton reported an ancient soil on the Paleozoic surface beneath the Tuscaloosa gravel near Smithland, Livingston County, Kentucky. At Waverly, Humphreys County, Tennessee, the Little Bear residuum, a mottled clay containing lumps of limonite, lies on Meramec chert. It is exposed, as a ferruginous clay beneath the gravel, at several localities along the Nashville highway in the vicinity of McEwen and Tennessee City. The brown iron ore and small quantities of manganese oxide of the western Highland Rim, together with their matrix of red clay, were primarily concentrated during the Little Bear age, and are in that formation. No exposure of the residuum has been found west of the Tennessee River in Tennessee, though at Parsons, Decatur County, the thin Tuscaloosa formation is superjacent, but undisturbed, to the Decaturville formation which is deeply leached to chert and argillaceous tripoli.

In Tishomingo County, Mississippi, the formation attains its most interesting development, where, from the drainage area of Little Bear Creek, heading one mile northeast of Iuka, the residuum receives its name. Also just across the line in Colbert, Franklin, and Marion counties, Alabama, the formation is developed. It may be exposed, too, in the eastern halves of Itawamba and Monroe counties, Mississippi.

In Tishomingo County the dissected Highland Rim plain surrounding the Nashville Basin loses its identity as it plunges beneath the Mesozoic sediments to the west and south across the bevelled edges of formations ranging in age through the entire series of the Mississippian system. Superimposed on the Paleozoic rock is a cover of clay attaining a maximum thickness of at least 70 feet. Above the clay lie gravels of Tuscaloosa age containing massive or laminated lenses of reworked and transported clay. In the eastern part of the county, north of the Southern Railroad, there are more than 40 major outcrops of Little Bear clay, and in the southern two-thirds of the county there are at least half that number.

Five miles northeast of Iuka (S.E.¼, Sec. 34, T. 2 S., R. 11 E.) along the road leading down to the old Fishtrap Ford, the succession



Feet	
100	Covered interval: gravel, sand, and clay; possibly includes all of the Tuscaloosa formation and a small part of the Little Bear
59	Little Bear residuum: clay, red, white, brown, and mottled; and a few streaks of small colluvial chert pebbles near the top
8	Contact zone: admixture of deep red and mottled clay and rough chert fragments
60	Iuka (Tuscumbia) formation: chert, large blocks, and pulverulent silica–to level of Bear Creek

Figure 2.—Stratigraphic section of the Little Bear formation near (SE.¼, Sec.34, T.2 S., R.11 E.) old Fishtrap Ford, Miss.

of strata shown in Figure 2 is exposed. The thick chert and tripoli bear testimony to the intense weathering of the Iuka (Tuscumbia) limestone by pre-Tuscaloosa meteoric waters; and they also indicate the former presence of overlying silica-bearing beds (Chester series), a fact confirmed by the presence within eight miles of shale and sandstones above the unreplaced, unusually pure, Iuka (Tuscumbia) limestone, and further substantiated by the immense thickness of overlying paleo-residual clay in the section, highly siliceous near the bottom and very aluminous near the top.

Figure 3.—Contact (paper) of the Little Bear residuum and the Tuscaloosa formation at the head (SW.¼, Sec.4, T.3 S., R.11 E.) of a small branch of Little Bear Creek, Tishomingo County, Miss.

Within a half mile, either south or southwest of this place, tributary streams, flowing southward, make up part of the Little Bear Creek drainage system. Outcrops (Secs. 3, 4, 5, 8, 9, 10, 15, 16, 17, and 18, T.3 S., R.11 E.) in this drainage system show various parts and phases of the Little Bear residuum. Here, as elsewhere, numerous springs issue at the contact of the loose gravel and the underlying dense clay, in places welling into artificial basins cut into the firm and ancient terra rosa (Figure 3).

Several samples from the residuum of this area were washed in alkaline solutions and the screenings were examined under medium-powered binoculars by the writer and Dr. Paul H. Dunn, Head of the Department of Geology, Mississippi State College. In each case only small particles of soft limonite, disintegrating fragments of chert, and beautiful minute double-ended quartz crystals built up on sand grains remained. There were no fossils or soluble minerals. It has not yet been convenient to carry out further laboratory examinations of Little

Figure 4.—Little Bear clay in the channel of a small tributary of Indian Creek one mile north of Iuka, Miss. It is covered by darker creep material from the Tuscaloosa which conceals an additional 20 feet of clay.

Bear samples collected throughout its extent, or of sand washings from the Tuscaloosa at contiguous stations, or of the residual soils of recent origin in adjacent territory. The samples from this one locality yielded no rock or mineral substances that the overlying Chester and underlying Meramec beds could not have contributed on their decomposition.

There are numerous exposures on the tributaries of Indian Creek, also. One mile north of Iuka (NW.¼, Sec. 18, T.3 S., R.11 E.) the clay is wonderfully exhibited for 400 yards along the bottom and sides of the bed of a small branch of Indian Creek and in nearby Indian Creek itself (Figure 4). On a minor tributary of Pickens Branch (SW.¼, Sec. 36, T.2 S., R.10 E.) the basal relationship of the clay in contact with

Figure 5.—Admixture of residual chert and clay along the contact zone of the underlying Tuscumbia chert and the 30-foot bed of overlying red residual clay in the Southern Railroad cut two miles southwest of Tuscumbia, Ala.

the Iuka (Tuscumbia) chert is well seen. The clay is here known without question to be residual from the fact that the angular chert blocks of all sizes are mixed at random with the massive clay, and that neither the chert nor the clay in the zone exhibits the faintest indication of water-wear or of assortment by any transportation agency (Compare with Figure 5).

The northernmost known exposure of the clay south of the Tennessee River and east of Yellow Creek is on Short Creek (SW.¼, Sec.6, T.2 S., R.11 E.); and the northernmost known exposure south of the river and west of the creek is in a series of cuts on Highway 25 (Sec.21,

Figure 6.—Contact of Iuka chert and Tuscaloosa formation in a gravel pit (SE.¼, Sec.17, T.2 S., R.10 E.) ten miles northwest of Iuka, Miss. The Little Bear residuum was swept away by the swift currents which rolled in the large chert blocks and pebbles of the Tuscaloosa, but Little Bear material from a nearby area was later reworked and redeposited here as the lens of clay (light color) in the Tuscaloosa gravel.

T.1 S, R.10 E.) 1 to 1 ½ miles south of the Tennessee-Mississippi line where the Little Bear residuum is largely a thorough mixture of residual clay and residual Iuka chert. At least in some places beyond these cuts, the clay has been swept away to be redeposited as lenses in the Tuscaloosa (Figure 6) or to be thoroughly disseminated through the gravels.

In this northern section of Tishomingo County another phase or an earlier period of weathering of the Paleozoic rocks into residual material, which has been, perhaps, somewhat arbitrarily eliminated from the discussion of the Little Bear residuum but which has been described by Morse,[9] should be mentioned here. Perhaps no better exposure of this phase is known than that of the top of the argillaceous Carmack limestone underlying the Iuka chert in the bed of a small branch of Yellow Creek (SE.¼, Sec.21, T.1 S., R.10 E.) about 1 ½ miles south of the Tennessee-Mississippi line. Here directly beneath the Iuka chert the upper part of the Carmack has been leached to a yellow clay and underneath this in turn to a white clay. In his paper Morse has suggested the possibility of one or more periods of weathering of the upper part of the Paleozoic rocks. The relationship between the weathered upper Carmack and the overlying basal chert and the present valley at this place would seem, according to him, to indicate pre-Iuka weathering and erosion and a pre-Iuka valley from which the present stream has removed most of the overlying Tuscaloosa and Iuka until the present valley is almost coincident with the old pre-Iuka valley.

In the vicinity of Gravel Siding southeast of Iuka the Tuscaloosa gravel, to a thickness of over a hundred feet, has filled what is probably an ancient valley. Along the bases of the walls of the gravel pits bodies of mottled red-and-white clay extend abruptly into the coarsely clastic sediments. It is probable that these masses belong to the scarified upper part of the original Little Bear.

In the southern part of the county the clay is well exposed in gullies and valleys of Cripple Deer, Bear, and Mackeys creeks. In this area the clay overlies Chester formations.

Perhaps one of the most instructive exposures in the whole of Tishomingo County is that along the headwaters of a small stream (below the barn of Sam Southward, NW.¼, Sec.8, T.5 S., R.11 E.) which empties into Southward Pond and ultimately into Bear Creek. In it in ascending order are fresh blue shales, a thin bed of fresh limestone, perhaps Southward Pond limestone C, a thin shaly sandstone, and fresh blue shales, all of Chester age. The fresh blue shales grade upward into leached light-colored shales and these in turn into 15 feet of "fat" kaolinitic clay, the Little Bear residuum. The unconformity with the Tuscaloosa is definitely marked by a conglomerate sheet over which one or more springs emerge.

Colbert County, Alabama, which adjoins Tishomingo on the east, provided some of the most important field evidence of any used in arriving at the conclusions expressed in this paper. About one third of the county is overlain by Cretaceous sediments. From a point 3 miles east of Margerum to a point beyond Decatur, Morgan County, Alabama, the red prairie of the Tuscumbia (Iuka) limestone slopes gradually southward to the contact with the Chester series at the base of Little Mountain, which is the high scarp of a cuesta having a back slope inclined southward. The Chester beds of Little Mountain are a succession of thin limestones, thick shales, and sandstones. It would seem obvious, even to the casual observer, that the blanket of red prairie soil having a maximum thickness of 65 to 75 feet could not have resulted from the decomposition of an underlying limestone, whose purity averages 95 percent lime carbonate and whose entire thickness is less than 200 feet. It is observed in this region that so long as the underground drainage afforded by the cavernous Tuscumbia (Iuka) limestone exists, the finely clastic materials of the Chester are weathered into a heavy red soil which is little affected by erosion until the up-dip contact with the argillaceous non-cavernous Fort Payne (Carmack) limestone is approached. By the time the Fort Payne is exposed most of the red soil will have been removed by surface streams. This soil (which is remarkably similar to some of the Little Bear samples taken north of Iuka) is traceable westward along the regional strike to its lateral contact with the Little Bear residuum in the vicinity of Margerum. It is more than coincident, therefore, that the red prairie soil and the Little Bear formation have the same topographic range, approximately 460 to 540 feet (Figure 7).

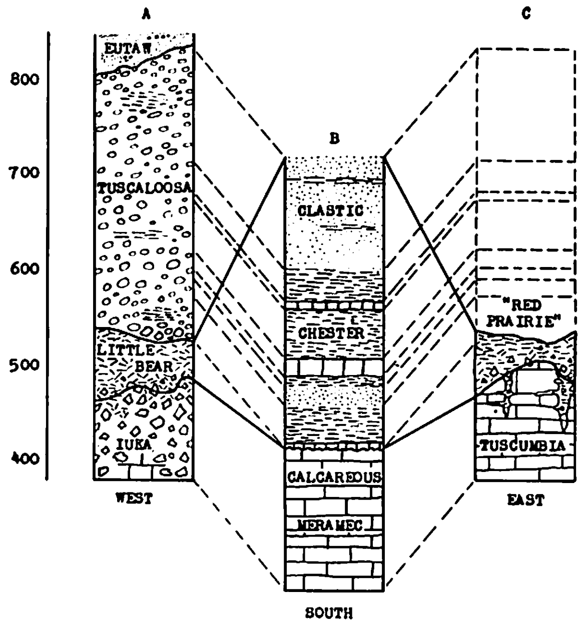


Figure 7.—Diagram to show the source of Comanchean (Little Bear) and Recent ("red prairie") residual materials in the vicinity of the Mississippi-Alabama line near Margerum, Ala.

In further comparison of the two soils the following similarities have been noted:

1. Both are non-fossiliferous massive clays, without aqueous bedding.
2. Both contain colluvial gravel in small quantity near the upper surfaces, pebbles being found more than 12 feet down in the red prairie soil near Tuscumbia.
3. Both have a ragged contact with the underlying chert (or limestone pinnacles) characterized by admixture of angular, unassorted chert blocks with the clay (Figure 5).
4. Both consist entirely of the more nearly insoluble mineral constituents: oxides of iron and manganese, free silica as quartz sand grains and "rotten chert" particles, and clay minerals.

And there are the following differences:

1. Although the dominant and original color of both is red, mottled phases* are found but rarely in the red prairie soil, whereas they prevail in the Little Bear formation (Figure 8), indicative of a more thorough and intense leaching.[10]
2. No bauxite or kaolin is found in the present-day residuum.

Figure 8.—Leaching of the red clay to a white clay along joint planes in the Little Bear residuum on Booker Branch (NE. Cor., Sec.10, T.3 S., R.11 E.) of Little Bear Creek, Tishomingo County, Miss.

West of Russellville, Franklin County, Alabama, the Tuscaloosa overlies red residual clays and brown ore which rest on the Bangor limestone. A study of the stratigraphy at the edge of the plateau south of the town reveals as much as 45 feet of red and green shale (Pennington) heavily charged with iron in the form of well-disseminated oxide and numerous small concretions of carbonate. Moreover, the basal Pottsville is largely shale at this point containing fairly large concretions of rather pure siderite. It is known that where rocks decompose superjacent to more soluble rocks, such as pure limestones,

*Slow drainage and intense leaching are not conflicting elements of the phenomena of mottling. Increased acidity and long duration of time are the important factors in differential or complete removal of iron.

the insoluble minerals are concentrated in proportion to their protection from mechanical and chemical erosion.

Several miles south of the edge of the plateau, at Spruce Pine, Alabama, the Tennessee Sand and Gravel Company mines sand from a decomposed Pennsylvanian conglomerate immediately below the Cretaceous gravel. An adjoining pit in the Tuscaloosa gravel is underlain by clay which is used in the manufacture of pottery. This clay is undoubtedly reworked from the pre-Tuscaloosan regolith as it contains excellent angiosperm leaves and exhibits lamination by fine quartz sand. Less than a mile south of Spruce Pine, around Phil Campbell, near Vina, and especially along the state highway for the entire distance from Phil Campbell to Guin, the clays, sands, and coal smuts beneath the Tuscaloosa are unquestionably residual, or sub-residual, products of pre-Upper Cretaceous weathering. At Chalk Bluff, four miles southeast of Hackleburg, Marion County, the well-known kaolin is overlain by several feet of disintegrated sandstone, which is separated from the overlying Tuscaloosa gravel by a distinct unconformity (Figure 9). The kaolin merges downward into a bituminous phase, derived from the decomposition of a coal seam.

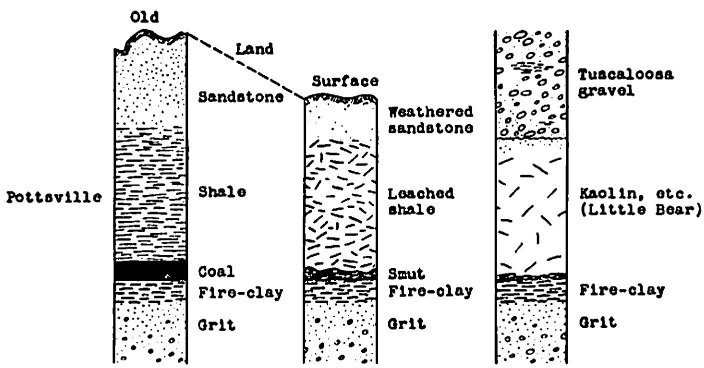


Figure 9.—Generalized columnar sections of the Pottsville, Little Bear, and Tuscaloosa formations on Camp Creek in Marion County, Ala. The Little Bear materials, which have heretofore been considered sedimentary, are residual, being derived from the sandstone, shale, and coal of the original Pottsville.

Because of the decreasing intensity of weathering in depth, any contact fixed between the Pottsville and the Little Bear must be more or less arbitrarily placed. The shales of the Coal Measures lose their identity more rapidly than the sands, and the effect of present day weathering on fresh shale is a tendency to bleach it and to start the process of kaolinization.

The products of Little Bear weathering are so numerous and varied that a summation of them can be expressed best in tabular form:

Location	Product of Weathering	Source of Mineral Matter
Western Kentucky	"A rough, hard arenaceous shale"	Pottsville series and Chester series
Western Highland Rim, Tennessee	1. Brown ore, mottled clays	Pottsville series (?) and Chester series (now missing)
	2. Chert	Chester and Meramec series
	3. Phosphate	Mississippian and pre-Mississippian limestones and shales
Iuka-Margerum, Mississippi-Alabama	1. Ochres, kaolin, porcelain clay, bauxitic clay, bauxite	Chester series
	2. Chert and tripoli	Chester and Meramec series
Russellville, Alabama	Brown ore and red clay	Upper Chester and basal Pottsville shales
Plateau area, Alabama	Potter's clay, kaolin, sands	Pottsville shales and sandstones

MINERAL CONCENTRATION AT THE PALEOZOIC-MESOZOIC UNCONFORMITY

While the phosphate, chert, and tripoli, whose concentration is here assigned to the Little Bear weathering conditions, can be in no wise considered a part of the residuum, they bear discussion as showing the intensity of the activity of the meteoric waters and the nature of their work.

PHOSPHATE

The geographic and stratigraphic relation of the Tennessee phosphate to the Little Bear residuum is at once suggestive of chronogenesis and should not pass without mention (Figure 10). The deposits are all on the western Highland Rim or in the edge of the Central Basin, and lie not more than several hundred feet below the original pre-Tuscaloosa land surface. Groundwater passing downward and westward obviously had some phosphate in solution as there is little left in the residuum or chert. Those who have worked in the western Highland Rim are acquainted with the great depths to which the Mississippian limestones have been destroyed by removal of their more soluble compounds. It is reasonable, therefore, to suppose a re-precipitation of the less soluble of the substances removed from these limestones as well as from the shales of the Chester which produced the residuum. Smith[11] came to the conclusion that organisms of the phosphate-bearing strata did not form tests or shells of calcium phosphate, but, normally, of calcium carbonate, and that the phosphatization of these shells is a replacement process, begun by bio-chemical or physico-chemical agency on the sea

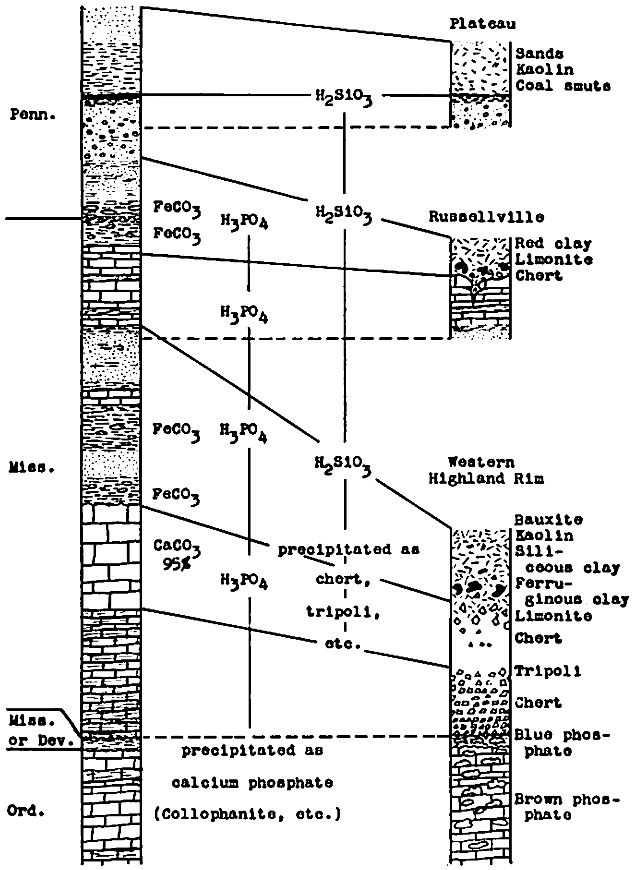


Figure 10.—Genesis of the Little Bear and subjacent mineral materials in the western Tennessee Valley region.

floor at time of deposition, and consummated by a cycle of weathering begun in the Pliocene and still in force. In explaining why the phosphate is not found on the eastern side of the Nashville Basin he states that: "The phosphatic horizons are absent, or, if present, their character has changed so that they are not phosphatic limestones."[12] Although such an explanation must be given due consideration, it does not appear entirely logical that phosphate concentration should have taken place in five formations, the Chattanooga of the Mississippian or the Devonian system, and the Bigbee, Cannon, Leipers, and Hermitage formations of the Ordovician system, all on the western side of the Basin, and not in these same formations or any other on the eastern side. In connection it must be remembered that the early Cretaceous land surface was comparatively close, vertically, to these formations in the west, while in the east it was high above them, on the Pottsville series.

CHERT AND TRIPOLI

Chert is present in some quantity in all limestones of the Little Bear outcrop region; in places whole formations have been reduced to thicknesses of angular or roughly bedded chert. This is especially true of the Iuka (Tuscumbia) formation in Mississippi and in the extreme northwestern part of Alabama, and of the Decaturville, Fort Payne, Warsaw, and St. Louis formations in west-central Tennessee. Intercalated with the chert near the base of the Iuka (Tuscumbia, Warsaw) formation in Tishomingo County, Mississippi, Colbert and Lauderdale counties, Alabama, and in Wayne County, Tennessee, are large quantities of very fine pulverulent silica and tripoli, much of which is over 98 percent silica. It is believed here that chert is almost, if not quite, invariably a replacement of limestone by metasilicic acid produced on the ionization of siliceous substances: that the silica may be contained in some cases in the limestone (indigenous) as impurities in granular, combined, or colloidal form; or that it may pass downward from overlying strata (non-indigenous) and be precipitated where the more soluble calcium carbonate is reached. The fact that great thicknesses of Iuka chert in Tishomingo County, recorded by Morse,[13] are far in excess of the siliceous impurities of its equivalent, the Tuscumbia limestone, just across the state line in Colbert County, seems to be a point of evidence of an extraneous source for the silica. While the processes of rock disintegration and of soil formation were proceeding on the pre-Tuscaloosa land surface, the lower vadose groundwater was engaged in removing calcium carbonate to the drainage areas and precipitating silica as chert and tripoli. Figure 6 shows by the unbroken bedding and undisturbed assortment of Tuscaloosa material that the chert below was a detrital accumulation before deposition of the Tuscaloosa began. In contrast to this, Figure 11, a photograph of the wall of an ore pit at Russellville, shows the disturbance of assortment in the Tuscaloosa occasioned by solution and collapse of underlying limestone. Since the calcareous fossils of these Paleozoic formations were preserved in the cherts as siliceous molds or as pseudomorphs, they may be correlated with their limestone equivalents and are arbitrarily omitted from the Little Bear residuum.

Figure 11.—Tuscaloosa gravel in the wall of an old ore pit about one mile northwest of Russellville, Ala. The differential settling of the beds and the mixing of the assorted material were caused, after the solution of the limestone beneath the gravel and ore bed, by the collapse of the cavern roof.

IRON ORE

Beginning with Dr. E. A. Smith, Alabama geologists have felt that any final explanation of the origin of the bauxite or limonite in the northern part of the state would involve processes common to each. The end product of the weathering of rocks, having iron or alumina bases, is one or the other of their respective hydroxides. The alkaline earths will have been removed long since, and only the most nearly insoluble of constituent mineral forms remain.

Nevertheless, the questions of origin have progressed largely along different lines. Some Tennessee geologists admit the iron ore-bearing clay to be residual without question, and Hayes and Ulrich[14] report a probable thickness in the Nunnally workings of more than 120 feet of ore-bearing clay which they ascribe to the decomposition of the St. Louis limestone. Eckel,[15] however, has shown graphically that the appreciable contribution of limestones to ore accumulations is, under the most ideal of conditions, out of the question. Granted that the material accumulated residually in a great sink area, it would require a tremendous thickness of a very impure limestone to yield such a body of clay. Such impurity is not characteristic of the Warsaw and St. Louis limestones as known in northern Alabama and in the western Highland Rim. The origin of these clay bodies is not discussed by Burchard[16] who accepts the idea of derivation from limestone. He suggests that the decomposition of glauconite in Cretaceous or Eocene sediments which possibly once overlay this horizon by hundreds of feet contained the iron that later, after many successive stages, concentrated at its present base, leaving as evidence of its passage the limonite matrix of conglomerate in the gravel.* Such an hypothesis would arouse a number of objections, among which would be that erosion of the exposed strata would remove most of the iron, that precipitation of the iron in commercial quantity would likely have been in effect previously on sedimentary clays lying beneath the glauconite-bearing beds, and that the iron is not found in any quantity where the residual clay is not thick. In the author's opinion, therefore, the ore is syngenetic with the residual clay of the Little Bear formation.

BAUXITE AND CLAYS

In the vicinity of Margerum, Alabama, the presence of two areas of bauxite which are intimately associated with ocherous, bauxitic, and kaolinitic clays establishes a common origin with the similar ocherous, bauxitic, kaolinitic, and siliceous clays of the same, sub-Tuscaloosa, horizon in Tishomingo County, Mississippi. These deposits, potential economic reserves, are erratic in areal extent and composition. The formation of bauxite is generally considered to be a surface weathering phenomenon which would not likely take place in the present climate of the region even with the most effective meteoric solvents.

*A bed of terrace gravel on the west side of the Buttahatchee River between Gattman and Greenwood Springs, Monroe County, Mississippi, has as great an accumulation of iron-cemented conglomerate as any the author has yet seen in the Tuscaloosa. An adequate source for this iron is the silt which overlay the gravel, and the coating of "stream varnish" with which each pebble was originally coated.

The aluminous and siliceous clays of Tishomingo County are fusible only at high temperatures. Although they have frequently attracted the attention of brick and pottery manufacturers, this high fusibility has rendered them unsuitable for firing in ordinary kilns. Their components are erratically distributed and proportioned, particularly with reference to the iron content. Local ocherous phases are reported to be suitable paint pigments, while other phases are partly or entirely leached of iron and constitute high grade refractory and porcelain clays.

Years ago, Logan,[17] who contributed most to our knowledge of the composition of these clays, wrote that: "The Tuscaloosa clays are the most refractory clays that exist in the state. Some of them are infusible at exceedingly high temperatures. In degree of whiteness after burning, they are superior as a rule to the other clays of the state. In chemical composition they exhibit an exceedingly high aluminum content in most outcrops, though some outcrops contain a high percentage of silica." More recently F. E. Vestal, Assistant Geologist, Tennessee Valley Authority, submitted several samples from the Little Bear residuum to R. L. Copson, Chemical Engineer, Wilson Dam, Alabama, and to the Ceramics Laboratory, Norris, Tennessee. Copson's results[18] are available and are given after the analyses quoted from Logan.

Analyses of Little Bear clays of Mississippi by W. N. Logan

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
H_2O	.58	.58	.48	.59	.48	1.11	.97	1.19
Vol.	5.20	4.78	4.82	8.00	15.01	13.88	11.96	8.00
SiO_2	70.81	79.23	80.03	66.85	44.23	42.92	38.11	39.35
Fe_2O_3	11.20	.67	1.68	3.77	.81	.61	11.73	9.39
Al_2O_3	11.20	13.91	12.00	20.54	38.82	41.30	36.42	38.73
CaO	.60	.59	.26	.21	.19	.37	.60	.34
MgO	.50	.21	.00	.18	.13	.13	.14	.23
SO_3	tr.	tr.	tr.	tr.	.45	.18	tr.	.51
Na_2O								.35
K_2O								.12
Total	100.09	99.97	99.27	100.14	100.12	100.50	99.93	98.21
Clay substance	28.00	48.22	30.41	52.05	98.21	104.48	92.20	87.99
Free silica	53.86	41.36	61.62	35.34				
Fluxing impurities	12.30	1.47	2.18	4.16	1.58	1.29	12.47	10.94

No. 1, Public road, near the fishpond at Iuka
No. 2, Public road, about two miles south of old Eastport
No. 3, R. W. Paden farm, four miles southwest of Tishomingo City
No. 4, James Turner farm, Sec. 15, T.4 S., R.11 E.
No. 5, Starkey farm, near Mingo bridge
No. 6, John Walker farm, four miles north of Iuka
No. 7, R. F. Thorne farm, six miles north of Iuka
No. 8, Tilman Brown farm, four miles north of Iuka

Tests made by R. L. Copson

Analysis	Clay No. 1A	Clay No. 6A	Clay No. 1M
Ign. loss	14.3	13.1	8.6
SiO_2	44.7	56.3	71.6
Al_2O_3	35.3	26.7	16.8
Fe_2O_3	1.3	1.8	1.7
TiO_2	2.8	1.2	0.8
CaO	0.4	0.1	0.3
MgO	0.1	0.2	0.2
K_2O	0.2	....	0.2
Na_2O	0.5	....	0.1
Total	99.6	99.4	100.3
Dry color	White	Gray	Light buff
Hardness	Medium hard	Medium hard	Soft
Fineness	100% through 200 mesh	100% through 200 mesh	.4% on 10 mesh .2% on 20 mesh 1.3% on 60 mesh 1.1% on 100 mesh 2.6% on 200 mesh 94.4% through 200 mesh
Visible impurities	Small soft red particle, argillaceous properties, hematite	None	Quartz grains stained with limonite
General plasticity	Good	Very good	Fair
Extrusion	Poor	Not tested	Fair
Defloculation	Readily with .4% electrolyte	Difficult .6-.7% electrolyte	Very good .4% electrolyte
Drying behavior	No cracks, slight warpage	Moderate warpage	Good
Dry strength	Fair	Very good	Poor
Linear drying shrinkage	3%	8.1%	3.4%
Remarks	Slakes very slowly	Quite uniform slakes readily	Wet clay when wedged has a rubbery plasticity. When slicked with spatula through specimens become soft and rubbery, were difficult to handle.

Drying shrinkage	1.1%
Firing shrinkage	7.9%
Apparent porosity	0.01%
Absorption	0.0%
Transverse strength in pounds per square inch	4944
Color	Light gray

No. 1A. W. L. Thomas property, 4 miles southeast of Hackleburg, Marion County, Alabama

No. 6A. W. L. Thomas property, 4 miles southeast of Hackleburg; 4 feet of ball clay overlying 1A.

No. 1M. One mile north of Iuka, Tishomingo County, Mississippi; sample from outcrop shown in Figure 4

OTHER CONSIDERATIONS

The possibility has been considered that the Little Bear clays may have been produced from sub-Tuscaloosa materials through the removal of their soluble mineral matter by descending water after it had passed through the Cretaceous clastic sediments, for the reason that mineral water is yielded locally by aquifers. At Iuka, Mississippi, the famous mineral springs of very shallow depths draw their water from the basal Eutaw beds. At Amory, Monroe County, and at West Point, Clay County, both in Mississippi, mineralized water is reported from wells reaching the Tuscaloosa while those terminating in the Eutaw glauconitic sands produce soft water. This may be due more to local structural influence than to any general hydrological condition. In the belt of outcrop, the water produced by springs and wells from the Tuscaloosa is the softest available.

Objections to this theory are as follows:

1. If it be postulated that descending waters altered material to clays of their present nature, the theory must offer an original source of the clay substance. Whether it be contended that the clays were derived from the Paleozoic beds or from the lower Tuscaloosa does not alter any of the foregoing and assumed evidence of their residual character, nor does it change the fact that residual origin implies loss of most soluble and some relatively insoluble mineral material, concurrently producing total loss of bedding and causing differential settling which would be reflected in the overlying strata, the Tuscaloosa gravels. Evidence of such collapse is nowhere to be seen.
2. Similarly, the Paleozoic limestones were reduced to chert before deposition of the Tuscaloosa.
3. Bauxite and iron ore (brown) would not have been formed. Laterized substances are produced sub-aerially.
4. If this theory were true there probably would remain no "feldspar and other minerals" in the Tuscaloosa above the clays as Bramlette reported.
5. Bramlette[19] has observed some evidence that there were at least local marshes and little, if any, deposition before the Tuscaloosa in Marion County.
6. The "Tuscaloosa red beds," which may be partly early Mesozoic, encountered in deep borings nearer the Gulf Coast must be considered evidence of proximity to a rapidly disintegrating and oxidizing land surface.

CONDITIONS OF ORIGIN

Knowledge of the general aspects of pre-Tuscaloosa topography and climatography is as yet somewhat vague. The maximum relief of the Margerum-Iuka section was probably only a little less than that today; the whole area was nearer sea-level. There is evidence afforded by the elevations, conditions of preservation, and types of pebbles in the Tuscaloosa that both the Tennessee and Moulton valleys had begun their development–rather, were terminating their Comanchean history near the margin of an encroaching sea. Much of the topographic diversity of the Little Bear surface can be explained by the arching that terminated the Little Bear age and inaugurated the cycles of sedimentation which filled the Mississippi embayment, beginning with the removal of the residuum and chert from the Nashville dome to produce the Tuscaloosa formation.[20] That part of the residuum which was left undisturbed constitutes the Little Bear formation. Intensive study of its surface can disclose much regarding the paleo-topography of the whole region. Many of the plant fossils found in the Tuscaloosa formation are, without doubt, remains of plants which grew on the Little Bear regolith; and from them Berry[21] has drawn conclusions not only as to the age of the Tuscaloosa, but as to the conditions under which the flora lived: "A low coastal land of rather uniform topography–a land favored with an abundant and well-distributed rainfall, with equable temperatures within the limits embraced between warm temperate and sub-tropical, and with slight seasonal changes."[22] The formation of kaolin and laterized substances in the Little Bear confirms this interpretation of middle Cretaceous conditions in this area.

Newmann[23] has explained how similar conditions of rock decay were operative in the Atlantic Piedmont region, but contended that the white clays of the Middendorf formation are the product of stream erosion and marine deposition. In two articles Burt[24] described the Brandon "residual-formation" consisting of kaolin, ochre, quartz sand, iron and manganese ores, and lignite. There is striking similarity between the Brandon residuum and the Little Bear residuum; yet the Brandon has been identified on the basis of plant fossils on its surface as Tertiary, Miocene at least in part. Should all geologic literature be examined there would be found, perhaps, citation to numerous other similar formations. Although not yet popularly regarded as such, the bauxitic, kaolinitic, and ocherous beds on the Midway-Wilcox (lower Tertiary) unconformity in Mississippi and Alabama constitute another residuum to which neither the Porters Creek not Ackerman formational names are applicable. Furthermore it is not improbable that residuums will be found to make up a larger proportion of the Mississippi Embayment strata than previously supposed. Nor is it necessary that all references should be to geological antiquity, since the reader is reminded of the laterites and iron ores now forming in many of the low latitude countries.[25]

CONCLUSIONS

The Little Bear formation is, for the most part, Comanchean in age. Possibly the formative process began in the early Mesozoic, or even the late Paleozoic, and continued into the Cretaceous. The degradation of the main land mass, however, had not proceeded beyond the stage of late maturity, unless part of the field evidence is that of rejuvenation. Under these conditions sufficient time elapsed, before subsidence of the embayment area and corresponding uplift of the land mass, to allow the laterization of the soil, formation of which is characterized by the subordination of mechanical erosion to chemical erosion. There appear to be no criteria to determine within relatively narrow limits the duration of time required to produce residual deposits; it is, therefore, a theoretical assumption to assign the process in this case to any very definite time, inasmuch as only its termination is known. However, for purposes of tentative correlation it is reasonable, perhaps, to assign the process to the Comanchean or Early Cretaceous period, for, in the same sense that our present day soils are recent (though they may have been forming for hundreds of thousands of years) the Little Bear soils were recent at the time they were covered up by the first of the Cretaceous sediments.

Students of Coastal Plains stratigraphy have been taught that from the close of Paleozoic sedimentation in this region, until the beginning of Cretaceous sedimentation, the area was above sea-level, subject to the normal processes of degradation. According to this conception, it would not be surprising, then, to find that the land surface was covered with soil, and that, especially as parts developed into maturity and old age, even approximating a peneplain, the soil cover increased in thickness and progressed in degree of weathering. The great Pottsville-Cretaceous hiatus was such only in matter of sedimentary record, for the reason that during this time a regolith was forming which was not entirely removed when a sudden arching of the land mass resulted in the immediate removal of previously formed chert for deposition as the deltaic Tuscaloosa formation, a geologic event followed by swampy and brackish conditions, terrigenous sedimentation, and eventually by marine deposition. Thus it is that the Gulf series presents a complete example of transgressive sequence.

ECONOMIC GEOLOGY

In the light of the foregoing discussion on the origin of the Little Bear residuum certain conclusions can be drawn which are of fundamental importance in economic consideration: (1) there is great variety in composition at different localities; (2) the clays have been freed from soluble mineral matter by weathering agencies, thereby eliminating low fusibility; (3) due partly to the nature of the underlying rock and partly to the nature of the contributing beds, the residuum accumulated to great thicknesses; (4) because of the irregularities of the surface on which the clay was developed and because of the erosion during its formation and terminating it, abrupt changes in thickness are found in short distances.

The meagre and preliminary tests that have been made of various samples of these clays suggest their use for (1) refractory or structural material, (2) a body for porcelain or tableware, and (3) red or red-brown paint pigments.

Perhaps the largest portion of the clay mass is best suited for refractory or structural material. However the clays, which may well be thought of as kaolin, variously siliceous or ferruginous, seem to have a low dried strength, a feature generally objectionable for ceramic use. Notwithstanding this fact, most samples are extremely plastic, and because the component free silica is usually microscopic or ultra-microscopic, the addition of coarser material as grog may be found necessary in the production of certain types of materials. Indeed, the possibility of their use as a bond for such refractory substances as the Mississippi baukite is recommended for investigation. Mr. Chad Archie, Superintendent of the Corinth Brick Company, stated orally to the writer that he had tried samples from several of the clay outcrops and that they were entirely too refractory to be adequately burned in his kilns which reach 2000 degrees Fahrenheit. The low porosity and high strength of fired samples indicate suitability for roofing, flooring, or other high-grade tile.

Considering accessibility, tonnage, overburden, and apparent uniformity, the following localities (Plate 1) are recommended: (1) one mile north of Iuka (West ½, Sec.7, T.3 S., R.11 E.), an outcrop of which is shown in Figure 4 and an analysis, No. 1M, is given in the Copson table; (2) Lake Como Valley within the corporate limits of Iuka (SE. ¼, Sec.18, T.3 S., R.11 E.), analysis No. 1, Logan; (3) in Indian Creek drainage area, about 5 miles north of Iuka (SE. ¼, Sec.19, and NW. ¼, Sec.30, T.2 S., R.11 E.); (4) at Eastport school, 5 miles northeast of Iuka (Corners of Secs. 27, 28, 33, and 34, T.2 S., R.11 E.), analysis No. 2, Logan; (5) at the headwaters of a small branch of Indian Creek, about 4 miles northeast of Iuka (SE. ¼, Sec.32 and SW. ¼, Sec.33, T.2 S., R.11 E.); and (6) at the headwaters of a branch of Little Bear Creek, about 3 miles northeast of Iuka (SE. ¼, Sec.5, T.3 S., R.11 E.).

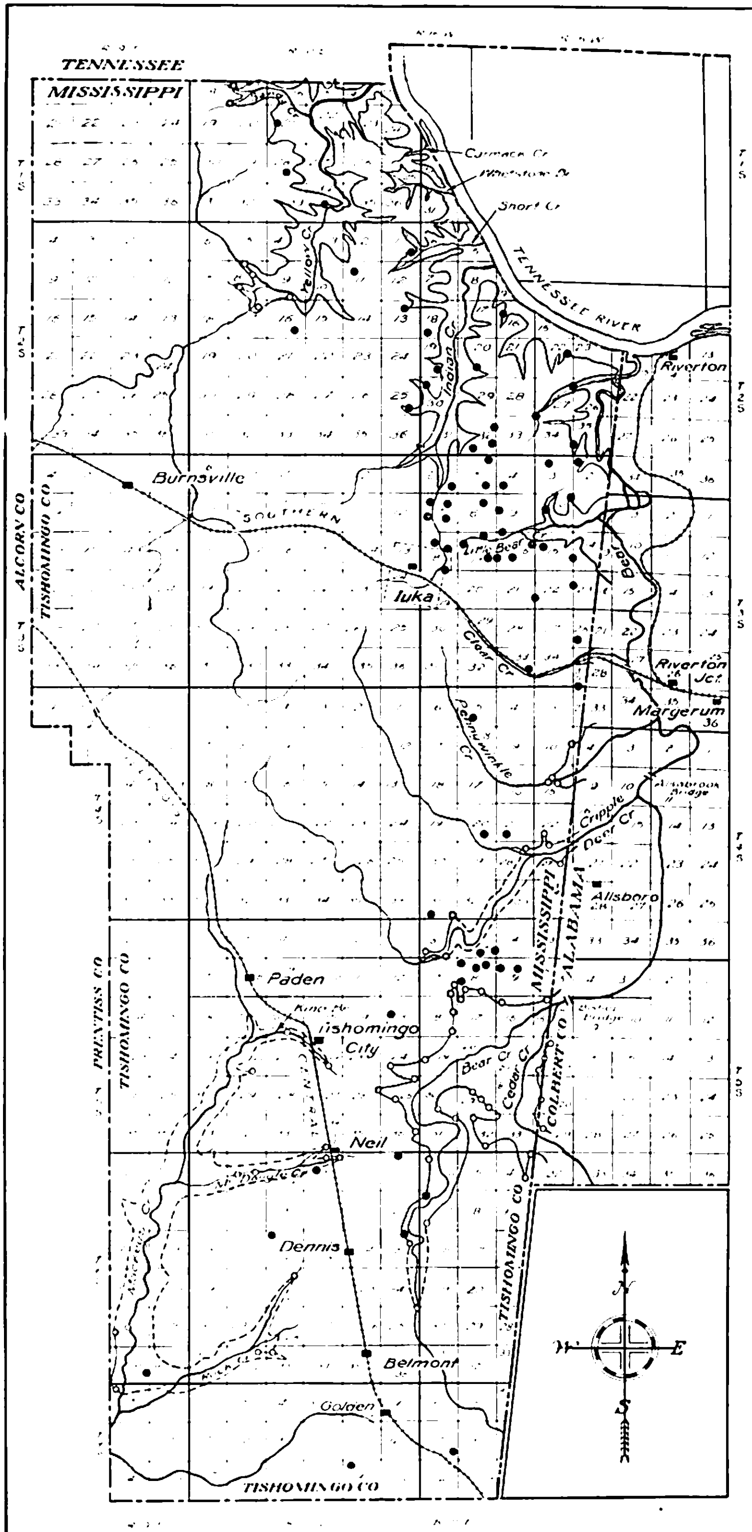
Some of the clay that is comparatively free from iron has been successfully made into tableware. An interesting set, cup, saucer, and plate, was made and presented to Mrs. A. F. Whitehurst of Iuka by a Mr. Craddock who took the clay from the Craddock farm at the head of Little Bear Creek. These white phases of the Little Bear residuum are much more restricted in area than the mottled clays are, and are in smaller quantities. The best outcrops are: (1) on the Sam Southward farm (NW. ¼, Sec.8, T.5 S., R.11 E.); (2) at Eastport school (Corners of Secs. 27, 28, 33, and 34, T.2 S., R.11 E.), analysis No. 4, Logan; and (3) in a branch of Little Bear Creek, about 2 miles east of Iuka (NE. ¼, Sec.17, T.3 S., R.11 E.).

Thirty-five or forty years ago Ed Hess prepared these clays for use as ochre by kiln drying them, grinding them in a hand mill, and mixing them with linseed oil and turpentine. This product is still remembered in Iuka as "Hessite," although that is a mineralogical term for silver telluride. Some of the ochre was used regularly in the local wagon factory of W. J. Dugger where it proved very satisfactory as a body paint. The material used came partly from (1) Short Creek (SW. ¼, Sec.6, T.2 S., R.11 E.); (2) a north tributary of Morgan Branch (NW. ¼, Sec.30, T.2 S., R.11 E.); (3) a head branch of Little Bear Creek (NE ¼, Sec.17, T.3 S., R.11 E.); and (4) Lake Como Valley (SE. ¼, Sec.18, T.3 S., R.11 E.). A partial analysis of a sample from the Short Creek location, made by the Nichols Laboratories, Knoxville, Tennessee, for Major E. C. Eckel, Chief Geologist, Tennessee Valley Authority, shows the percentage composition to be silica 34.80, alumina 34.86, ferric oxide 21.94. Of the ochre from the four locations perhaps that from the first and second only is in sufficient quantity and concentration to be commercially important for large production.

Because of its origin, estimates of the quantity of the Little Bear residuum have to be made in the most general terms. Thicknesses determined by hand-levelling an outcrop longitudinally are unreliable. Accurate measurements can be obtained only by vertical drilling. However, it is safe to say on the basis of the numerous long and thick exposures and the wide distribution of outcrops, that the quantity is very great. An estimate of 100,000,000 tons is considered, by the writer, to be conservative. The outcrop shown in Figure 4, one mile north of Iuka, is part of a nearly vertical exposure, at the edge of a hill, measuring 18.5 feet to the top of the face and extending, perhaps, 3 feet higher. At the base of this outcrop an auger-hole was put down 7 feet and was stopped in clay of the same character (rather dry, tough, mottled, and exceedingly plastic), making the total thickness of measured clay

Plate 1.—Map of Tishomingo County, Miss., showing by means of black disks exact locations of outcrops of economic clays of the Little Bear residuum.

The base of this map is Plate 1 of Bulletin 23 in which Morse used it to show the limits of distribution of the Paleozoic rocks in Mississippi. The northeast quarter he copied from the Iuka topographic map; the remainder, especially the part south of Pennywinkle Creek, from an outline map on the back of the letter head of the late Dr. F. T. Carmack. Beyond the boundaries of the Iuka sheet the exact locations of the railroads and stations are not accurate at all places, though approximately so. Furthermore the railroad branch from Riverton Jct. to Riverton has been abandoned since the base map was made.


TENNESSEE
MISSISSIPPI
Cormack Cr
Short Cr
TENNESSEE RIVER
Yellow Cr
Indian Cr
Riverton
Burnsville
SOUTHERN
Iuka
Bear Cr
Clear Cr
Riverton Jct.
Margerum
Pennywinkle Cr
Cripple Deer Cr
Allsboro
MISSISSIPPI
ALABAMA
ALCORN CO
TISHOMINGO CO
PRENTISS CO
TISHOMINGO CO
Paden
Tishomingo City
Bear Cr
Cedar Cr
COLBERT CO
Neil
Dennis
Belmont
Golden
TISHOMINGO CO
TISHOMINGO CO
N
W
E
S

25.5 feet. It was reported that the clay body at the headwaters of a branch of Little Bear Creek (SE. ¼, Sec.5, T.3 S., R.11 E.) has a thickness of 70 feet, as tested by trenches and auger-holes. From field relations and surface indications at this place, the writer believes that report to be plausible, but more probably somewhat exaggerated.

Transportation facilities are unusually good in Tishomingo County. The county is crossed diagonally northwest-southeast by two important railway lines, the Illinois Central and the Southern, and no point is more than 11 miles distant from a railroad. Most of the clay is considerably closer. State Highway 25 traverses the county from north to south, and Federal Highway 72 crosses from east to west. In addition, water transportation at an early date is assured. Much of the clay is within one mile, all of it, at most, only a few miles from the proposed Pickwick Dam Lake. With such convenient methods of transportation, reasonable rates for shipment of raw material or finished products are virtually assured.

Labor and power facilities, too, favor the location of clay-working industries in this area. Skilled labor is on hand ready for employment. The low industrial rates offered by the Tennessee Valley Authority for current generated at its nearby hydro-electric plants are effective throughout the county and surrounding territory.

The development of these clays appears to be contingent on the rising demand for ceramic products, on the derivation and circulation of information concerning their value and use as compared with other clays of the same type, and on the cooperation of citizens of the community with interested industrialists. With the ever-increasing depletion of forest resources in the South, there is now being felt, as a phase of a general industrial revival, a greater than capacity demand for the more permanent building materials, such as stone, brick, tile, etc. The culture of the South appears to be renascent. There is being incorporated in the newly constructed homes and buildings modesty, coupled with beauty and durability. It yet remains for the ceramic technologist to determine exactly what can be produced from clays of the Little Bear residuum. It is unfortunate, from one viewpoint, that experiments conducted by private companies, and by technical laboratories for private individuals, are, in general, lost to the public. The need of State-owned or Federally-supported laboratories for the testing of clay materials is very urgently felt.

BIBLIOGRAPHY

1. Logan, W.N., The pottery clays of Mississippi.—Mississippi Geol. Surv., Bull. 6, pp. 106 ff, 1909.
2. Logan, W.N., Kaolin of Indiana.—Indiana Dept. of Conservation, Division of Geol., pp. 74-75, 1919.
3. Adams, G.I., Origin of the white clays of Tuscaloosa age (Upper Cretaceous) in Alabama, Georgia, and South Carolina.—Economic Geol., XXV, No. 6, 1930.
4. Sutton, A.H., A pre-Cretaceous soil horizon in western Kentucky. —Amer. Jour. Sci., XXII, No. 131, 1931.
5. Bramlette, M.N., U. S. Geol. Surv.
6. Eckel, E.C., Iron ores, fuels, and fluxes of the Birmingham District, Alabama.—U. S. Geol. Surv., Bull. 400, p. 149, 1910.
7. Burchard, E.F., The Brown iron ores of west-middle Tennessee. —U.S. Geol. Surv., Bull. 795, pp. 53-112, pp. 74-79, 1927. Certain brown ores in Alabama. Economic Geol., XXIII, pp. 454-459, 1928. The brown iron ores of the western Highland Rim, Tennessee. Tennessee Division of Geol., Bull. 39, pp. 33-36, 1934.
8. Adams, G.I., The occurence and age of certain brown iron ores in Alabama and adjacent states.—Economic Geol., XXIII, pp. 85-92, 1928.
9. Morse, W.C., Paleozoic rocks.—Miss. Geol. Surv., Bull. 23, 1930.
10. Woolnough, W.G., Origin of white clays and bauxite, and chemical criteria of peneplaination.—Economic Geol., XXIII, pp. 887-894, 1928. This author states that in the later stages of base-levelling the iron of the soils is gradually and eventually removed.
11. Smith, R.W., Geology and origin of the phosphate deposits of Tennessee.—Engineering Min. Jour., CXXXII, pp. 58-62.
12. Op. cit., p. 59.
13. Morse, W.C., Paleozoic rocks.—Mississippi Geol. Surv., Bull. 23, pp. 74-94, 1930.
14. Hayes, C.W., and Ulrich, E.O., Geological atlas, Columbia folio, No. 95, p. 6, U.S. Geol. Surv., 1903.
15. Eckel, E.C., Iron ores, fuels, and fluxes of the Birmingham District, Alabama.—U.S. Geol. Surv., Bulletin 400, pp. 147, 148, 1910.
16. Burchard, E.F., The brown iron ores of the western Highland Rim, Tennessee.—Tennessee Division of Geol., Bull. 39, 1934.
17. Logan, W.N., The pottery clays of Mississippi.—Mississippi Geol. Surv., Bull. 6, 1909.

18. Copson, R.L., Tabulated results of tests conducted on eleven Alabama, Tennessee, and Mississippi clays.—Manuscript without title.
19. Bramlette, M.N., Letter to the author dated January 2, 1937.
20. Wilson, C.W. Jr., Pre-Chattanoogan development of the Nashville dome.—Jour. Geol., XLIII, pp. 449-481, 1935. Wilson, C.W. Jr., and Spain, E.L. Jr., Upper Paleozoic development of Nashville dome, Tennessee.—Bull. A.A.P.G., XX, pp. 1071-1085, 1936. See for treatises on the flexibility of the Nashville dome in uplift and subsidence.
21. Berry, E.W., The delta character of the Tuscaloosa formation.—Johns Hopkins Univ. Cir., New Ser., No. 3, p. 21, 1917. Mr. Berry writes: "This long interval (Pottsville-Upper Cretaceous) resulted in the nearly complete baselevel known as the Cumberland peneplain. There must have been some regional uplift or warping at the beginning of Tuscaloosa time to account for the sudden augmentation in river action and the inauguration of the large delta or series of deltas along the southwestern margin of the land mass."
22. Berry, E.W., Upper Cretaceous floras of the eastern gulf region in Tennessee, Mississippi, Alabama, and Georgia.—U.S. Geol. Surv., pp. 112, 1919.
23. Newmann, F.R., Origin of the Cretaceous white clays of South Carolina.—Economic Geol., XXII, pp. 374-387, 1927.
24. Burt, F.A., The origin of the Bennington kaolins.—Report of the State Geol. of Vermont, pp. 65-84, 1928. The geology of the Vermont ochre deposits.—Report of the State Geol. of Vermont, pp. 106-136, 1930.
25. Russell, I.C., Classic dissertation on subaerial decay of rocks and origin of the red color of certain formations.—U.S. Geol. Surv., Bull. 52, 1889. Mr. Russell discusses the deep decomposition of exposed rocks in the warmer latitudes of the earth, especially in the southern Appalachian region, and furnishes an exhaustive bibliography.
26. Hilgard, E.W., Report on the geology and agriculture of the State of Mississippi, pp. 30-46, 1860. Because Hilgard included his somewhat detailed description of the extent and value of the clays in Tishomingo County under the title "Useful materials of the Orange Sand formation," then classed as Pleistocene, the writer did not discover until this paper had been completed that the clays Hilgard thus described really belong, in part, to the Little Bear residuum.