MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph.D.
Director

BULLETIN 67

CARROLL COUNTY GEOLOGY

by

FRANKLIN EARL VESTAL, M.S.

UNIVERSITY, MISSISSIPPI

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LETTER OF TRANSMITTAL

Office of the State Geological Survey,
University, Mississippi,
June 24, 1950.

To His Excellency,
Governor Fielding Wright, Chairman, and
Members of the Geological Commission

Gentlemen:

Herewith is Bulletin 67, Carroll County Geology by Franklin Earl Vestal, which, although based on a rapid reconnaissance survey, is none the less a valuable stratigraphic report.

In addition to a somewhat detailed description of the geologic formations at the surface, the report deals briefly with climate, physiographic features, structural geology, geologic history, and economic geology.

The broad seemingly flat-lying belt of Zilpha clay extending north by west and south by east entirely across the county and the narrow disturbed belt or fault across Palusha Creek are considered of sufficient importance as a possible indication of an oil structure to warrant the issuance of a memorandum for the press to bear the bulletin date and to be released June 28, 1950.

Very truly yours,

William Clifford Morse
Director and State Geologist

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CARROLL COUNTY GEOLOGY

FRANKLIN EARL VESTAL

INTRODUCTION

Carroll County is an area of 624 square miles[1] in west-central Mississippi, a little northwest of the center of the state (Figure 1). It is bounded on the north by Grenada and Montgomery Counties, on the east by Montgomery and Attala, on the south by Holmes, and on

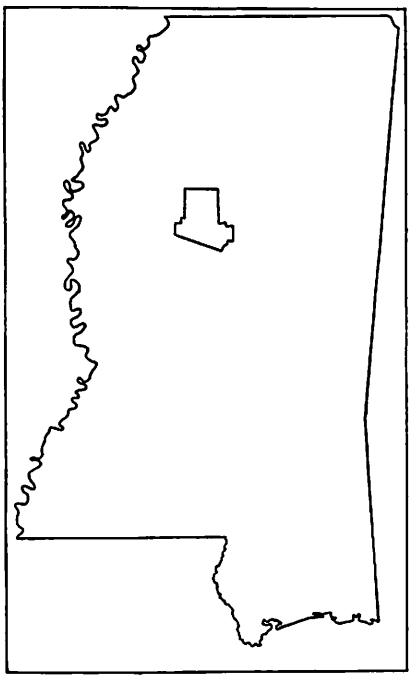

Figure 1.—Location of Carroll county.

the west by Leflore (Plate 1). It lies between the parallels of 33 degrees and 34 degrees north latitude, and is crossed by the meridian of 90 degrees west longitude. The irregular shape of the county, featured by a width of the southern part greater by two-thirds than that of the northern, is due to offsets of the north-south and east-west artificial boundary-lines; to the almost northwest-southeast trend of the southern boundary-line; and to a few miles of natural

boundary provided by the Yalobusha River on the northwest and the Big Black River on the southeast.

The 1940 population[2] of Carroll County (latest figures available) was 20,651. The chief occupations of the people, outside the few small towns and villages, are farming and lumbering, although in the western part of the county digging, washing, and hauling gravel and sand are of some importance. The principal crop is cotton, but corn is a close second, and several other kinds of crops, particularly cover and forage, figure to a greater or lesser extent in the general agricultural economy. Animal husbandry is engaged in, in general, on a small scale only, in connection with other farming activities, but dairying is given some special attention. The lumber business, although not what it once was, is still of some magnitude, as indicated by the considerable number of saw mills and by the many log trucks and lumber trucks on the roads and highways.

The only towns are Carrollton (the county seat) including North Carrollton, and Vaiden. Carrollton and North Carrollton combined have a population of 917, and Vaiden a population of 648. Both are farm towns, having no large industries. Villages and community centers scattered over the county are: Avalon, Teoc, Jefferson, McCarley, Black Hawk, Coila, Beatty, and a few others indicated on the map but not given specific names. The routes of travel and transportation consist of two paved highways, three railroads, and a net of local roads, many of them graveled along the whole or part of their lengths, but others unmetaled and more or less difficult to travel, especially when wet. In fact, all roads except the paved highways are plagued by mud in wet weather and dust in dry weather.

The Columbus and Greenville Railway extends east-west across the county via McCarley and North Carrollton, its right-of-way roughly paralleling the course of Big Sand Creek north of the creek and at no place more than half a mile distant from it except in the Delta. The Illinois Central Railroad lies north-south across the southeastern part of the county through Vaiden and Beatty. The Yazoo and Mississippi Valley Railroad extends across the northwestern corner of the county, through Avalon. U. S. Highway 82, a transcontinental highway, extends east-west across the county almost midway between Grenada and Holmes Counties, at distances ranging from a mile to two miles south of the Columbus and Greenville Railway. U. S. Highway 51, also a transcontinental highway, lies north-south across the southeastern part of the county via Vaiden and Beatty,

west of the Illinois Central Railroad and right alongside it from Vaiden southwards. Mississippi Highway 7, graveled, extends across the northwestern corner of the county, through Avalon, and Mississippi Highway 35 is in Carroll County from Vaiden southeast to the Attala County line.

The Mississippi Power and Light Company transmission line crosses the southwestern and northwestern corners of Carroll County.

CLIMATE[3]

No information is available relating to the climate of Carroll County specifically; but data for Montgomery County apply to Carroll as well. Mean annual temperature is about 63 degrees Fahrenheit. Summers are long, and warm to hot; the average temperature for July, the hottest month, is about 81 degrees, but the extreme high may be more than 100 degrees. The growing season has an average length of seven months, the last killing frost in the Spring now and then being as late as early April, and the first killing frost in the Fall rarely coming till late October. Winters are short and relatively mild, the average temperature being about 45 degrees, and the temperature seldom falling as low as 10 degrees; but the extreme low may be (very rarely) below 0 degrees. Winter weather is very changeable. Precipitation, almost all in the form of rain, is abundant (average annual precipitation more than 50 inches) and fairly well distributed through the year; but it may not be well distributed in a single month. The manner of precipitation is of great significance as affecting run-off and erosion. Much of the rain comes as hard down-pours, and runs off rapidly and almost completely. March and April are the months of greatest precipitation, and October the month of least precipitation. Although very few winters are without snow, heavy snowfalls are very rare. Relative humidity is high.

PHYSIOGRAPHY

PROVINCES

Except the Mississippi River floodplain part of it, a north-south strip a mile to four miles wide between the western boundary of the county and the Mississippi River Valley bluffs, Carroll County is, in general, hilly. The lowland belt belongs to the Mississippi Alluvial Plain physiographic province, the remainder of the county to the Loess or Bluff Hills province and the North Central Hills province. The general character of each of the three provinces is indicated by the name.

TOPOGRAPHY AND RELIEF

Hills and ridges range from high, steep-sided, and rugged, to low and rounded, their contours being governed in large measure by the nature of the underlying rock as affecting its resistance to erosion, also by distance from main streams. Thus, where loess dominates, the topography is in general somewhat rugged—the hills and ridges are narrow or of small summit area and have steep, in many places even vertical slopes; conversely, the ravines and valleys are

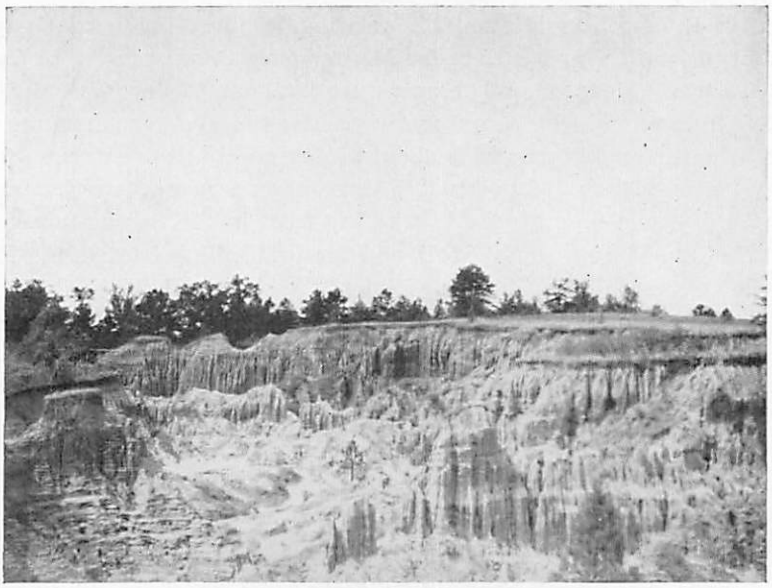

Figure 2.—Erosion in loess and Kosciusko sand, Vaiden-Black Hawk Road (SW ¼, Sec. 13, or NW ¼ Sec. 24, T. 17 N., R. 3 E.)

narrow, steep-walled, and relatively deep; relief is considerable in short distances. Where sand and sandstone are dominant, the topography appears even more rugged, although the relief in a given distance may be less, because sand erodes unevenly and may stand as fluted towers and columns and pinnacles (Figure 2), which give the landscape a very rough and rugged appearance. In general, then, slopes are less steep than in the loess territory, but rougher, partly because sand is less homogeneous of texture than loess and is commonly irregularly consolidated, causing erosion processes to work on it unevenly. In Carroll County the most rugged terrain is in the sand and gravel region, where loess may be absent or very thin, and clay

a minor component quantitatively. The clay beds, where loess and sand are absent or thin, commonly underlie a topography of relatively slight relief, low slopes, or flats.

The maximum relief of the county as a whole may be 265 feet or a little more. The lowest elevation shown on the map of the Seven Pines Quadrangle[4], which includes the southwestern part of Carroll County, is 115 feet, and the highest elevation of the county can not be far under 400 feet, inasmuch as the crest of a ridge at a point (SE 1/4 of NE 1/4, Sec. 31, T. 20 N., R. 3 E.) some two miles north of Malmaison has an elevation of 382 feet, according to the map of the Greenwood Quadrangle[5]. The elevation of Winona (probably in front of the railroad station) is given as 386 feet, and of Carrollton, 229 feet[6].

DRAINAGE

Carroll County is almost entirely in the drainage basin of the Yazoo River system. The southeastern corner drains to the Big Black River. The main Carroll County tributaries of the Yazoo system are, in north-south order: Petacowa Creek, Teoc Creek, Big Sand Creek, Palusha Creek, Coila Creek, and Abiacha Creek. Coila is a branch of Abiacha. The chief Big Black tributaries from Carroll County are Hays and Peachahala Creeks. Of all these streams, Big Sand and Abiacha Creeks are largest. All are permanent streams through most of their length, but their channels are so choked by sand that, in the upper courses during the driest part of the year, water may be present as underflow only. All have relatively wide flood-plains except in their upper courses. A noticeable feature is that these streams have not developed intricate windings, but shallow bends, of which those of Petacowa, Big Sand, Palusha, and Coila are wider than those of Abiacha. Abiacha Creek has a rather peculiar course —first southwest, then northwest at a near right angle to its southwest course, then southwest again at a second near right angle. Its sinuosities are numerous and small.

The larger streams named have so many tributaries that almost every part of the county is reached by drainage courses, the whole describing a dendritic pattern. Erosion processes have been very active, cutting multitudes of gullies, ravines, and valleys, and creating thus a great variety of topographic forms. Many ravines are yawning chasms 30 to 50 or more feet deep (Figure 3), which are widened, lengthened, and deepened by every violent rain. In places areas acres in extent have been not only denuded of all vegetation

and soil, but have been gullied and seamed in a most complicated manner. One of the most outstanding examples of such stripped and gashed areas (Sec. 35, T. 20 N., R. 4 E.), on the west side of a local road some 200 yards north of a road junction, is a big amphitheater where are displayed turrets, peaks, shelves, pinnacles, and almost every other kind of architectural form, modeled from the sand, silt, and clay.

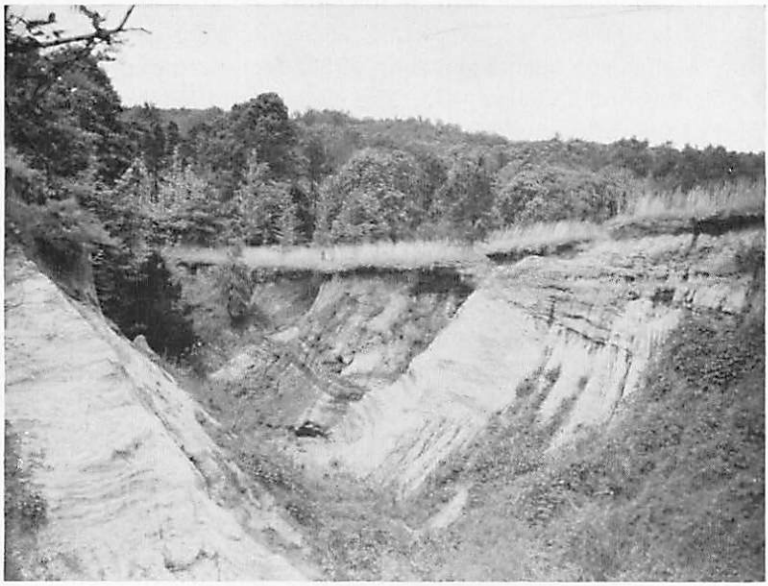

Figure 3.—Huge headward erosion "cove", north side of Vaiden-Black Hawk road (NW ¼, Sec. 16 or NE ¼, Sec. 17, T. 17 N., R. 4 E.)

INTERRELATION OF PHYSICAL ENVIRONMENT AND CULTURE

The interrelation of the geology and topography of the county has been noted briefly. The effect of them and the climate on the culture may be comprehended in some measure by a comparison of the culture map and the areal geology map (Plate 1). It is seen at once that in a wide belt (the Kosciusko sand outcrop belt) extending north-northwest through the central part of the county, the population is sparse compared with that of the eastern and southeastern and western parts of the county. The map gives some clue to the number of people by the number of buildings; but many of the dwelling houses in the belt of rugged country have been abandoned; in fact, one who travels the rough, rutted, and in places washed-out roads of this

region is struck by the number of abandoned houses. Here, too, roads are fewer, and some of them are so little used that almost no effort is made to keep them, and especially the bridges, in usable condition, with the result that they become impassable in a relatively short time. The farm land in this hill belt is, or should be, confined to stream flats, most of which are subject to flash floods and spreading of sand. A saving feature, however, so far as soil fertility is concerned, is that the blanket of loess or loessial material reaches far to the east, and is present in greater or less thickness almost everywhere in the sand belt.

In contrast to the central hill belt, which is the sand region, the county territory east and west of it is more rolling and of lesser relief. The hills in the Zilpha clay outcrop area have lower slopes, and the valleys are wider; relatively a much larger proportion of the surface is arable. Of course, where outliers of sand are present the topography is rougher and the local relief greater. The difference of the general nature of the surface can be readily noticed along east-west roads. For example, as seen from U. S. Highway 82 by one traveling west from Winona, Montgomery County, the rolling type of surface is reached at about a mile or so from the Montgomery County-Carroll County line, west of a belt of sand hill outliers. The more favorable farming conditions of this clay strip are reflected in the relatively much greater area under cultivation, and the more numerous population. However, even in this territory are many square miles without roads, and almost uninhabited, such areas being for the most part more or less deeply eroded sand hills constituting stream divides. The soil types of the clay region are strongly influenced by the scattered sand hills and the thin mantle of impure loess.

As stated, the western, loess or bluff silt belt has a type of topography developed chiefly from the loess, but in part from underlying sand and gravel. It consists of elevations of almost all gradations of contour, but a rather large proportion of steep slopes, and deep narrow ravines and small valleys. The over all loess type of topography is, however, modified by terraces, a conspicuous example of which is south of Palusha Creek where the stream debouches from the hills onto the "Delta"* (Secs. 22, 23, 26, 27, T. 19 N., R. 2 E.); it can be seen best from the road through Sections 23 and 26, by which descent is made across the terrace face to the old Army Air Training Field in the east edge of the "Delta" less than a mile south of U. S. Highway 82.

*The "Delta" is the name used in Mississippi for the Mississippi River Alluvial Plain.

This beautiful little terrace appears to have been developed on the white and gray gravelly sand which crops out in a few places in the terrace face. Other terraces feature the upper part of the bluff farther south, along Dry Creek (Secs. 3 and 10, T. 17 N., R. 2 E) for example.

On the loess controlled topography of the western part of the county, much of the surface is too steep for cultivation of the soil, but the steeper land may be pastured or left in forest. Creek flats and terraces afford relatively extensive cultivable areas, and a noticeable feature of the loess region, especially in the southwestern part of the county, is the considerable area of surface of low relief which is excellent farming country. The loessial soil is fertile, in general, easily cultivated, and produces excellent crops under favorable weather conditions.

The Carroll County part of the Mississippi River alluvial plain is essentially flat except for slight irregularities, which are abandoned natural levees, old distributary channels, and lakes, and old flood deposits. In fact, the elevation along the northern boundary of the county is 130 to 135 feet, and along U. S. Highway 82, at least 10 miles farther south, it averages about the same. The chief elevations are at the debouchures of the principal streams from the bluff onto the floodplain—specifically, Petacowa Creek, almost on the northern boundary of the county, which has built up an alluvial fan which reaches an elevation of 160 feet; Teoc Creek, 160; Big Sand, 165 to 170, and Palusha, 160. The lowest places on this part of the Delta are the back-land swamps, where the elevation is less than 125 feet. The maximum relief, then, of the part of the Delta in Carroll County is between 45 and 50 feet[4] [5]. It will be noted that almost all the main local roads (graveled) are on the divides—the unnumbered highway between Carrollton and Black Hawk; the Carrollton-Vaiden road; the Carrollton-Duck Hill road; and the Carrollton-Grenada County roads. Furthermore, the secondary country roads keep to the divides wherever practicable, and the crossings of the major streams are relatively few. Quite commonly it is necessary for one to travel several miles on a roundabout course in order to get across one of the larger streams. A few of the crossings are fords only, and in places bridges are difficult to maintain. For example, the writer found, on April 20, that the big iron bridge (Sec. 26, T. 21 N., R. 3 E.) which had been providing a means of crossing Petacowa Creek, had been partly carried away or undermined by flood waters and the main

section of it left isolated some distance from the north bank. He was informed that the bridge had been out for a long time and the people of the community obliged to travel many miles away from the usual direct route in order to get to Carrollton. He was turned back in another place or two, also, by want of a bridge, or by a bridge in such bad condition that it appeared to be a poor risk. In fact, maintenance of roads and bridges in Carroll County is a puzzling and ever-present problem—a chronic "headache" for the board of supervisors and the

Figure 4.—Erosion in Kosciusko sand (SW ¼, Sec. 19, T. 20 N., R. 5 E.) on east side of road 0.35-mile SE of road junction.

people. Not only are bridges washed out or reduced to a state of collapse by the sapping of the water, but in numerous places the country roads, and even main graveled highways, are threatened by the headward extension of ravines into the right-of-way (Figure 4), or rendered impassable by submergence of lowland sections or washing away by flood waters. Altering the courses of roads is common, and abandoned roadways which now are gullies or deep ravines may be seen in many places. And it may be added, pertinently, in this connection, that oftener than not, the logging business contributes materially to the early breakdown of country-road bridges, not only by frequent and reckless crossings, but by enormous loads which put

an almost intolerable strain on the bridge timbers. No load limit seems to be set in the back country.

It can not be forgotten, either, that depositional as well as erosional processes have been, and are, speeding this region along the road to ruin. Great volumes of sand, silt, and clay are heaped on, or spread over, the lower areas, burying fertile land, of which there

Figure 5.—Channel of Abiacha Creek (NE ¼, Sec. 13, T. 17 N., R. 1 E.) showing sand bars and pier of old bridge. Shipps Creek shale crops out at foot of cliff just above water-level.

has been always too little, filling roadways and stream channels, effacing bridges, and working havoc in general (Figure 5). The leveling processes work under generally favorable conditions here—copious rainfall, unconsolidated rock materials, a large proportion of steep slopes, and in a regrettably considerable number of places deplorable cutting and burning of the forest cover and cultivation of the slopes.

STRATIGRAPHY

IN GENERAL

The rock formations which crop out in Carroll County may be classified and described as indicated in the following table:

GENERALIZED SECTION OF ROCK UNITS EXPOSED IN CARROLL COUNTY

Classification and description	Feet
Cenozoic group	
Quaternary system	
Holocene series	
Recent formation	140
Soil and subsoil, residual; alluvium, colluvium, talus, etc., transported; all unconsolidated rock debris (mantle rock) above the older, more compact rock formations	
Unconformity	
Pleistocene series	
Peorian[6] stage or formation	40
Loess: silt, massive calcareous, commonly gray to light-brown, but showing other colors in places; contains some fine sand, lime concretions, and shells of land snails; retains vertical walls	
Farmdale (Late Sangamon)[8] stage or formation, up to	4
Loess: non-calcareous silt, weathered; soft; darker of color than the Peorian	
Disconformity	
Loveland[8] stage or formation, 2 to	4
Loess: weathered, non-calcareous, brownish-yellow or yellowish-brown silt, fine sand, and clay	
Disconformity	
Older Pleistocene formation, chiefly terrace	25
Sand and gravel, silt, and a little clay; sand gray, or yellow with limonite stain, loose, fine to coarse; gravel chert and a considerable proportion of glassy quartz	
Unconformity	
Tertiary system	
Pliocene (?) series	
Citronelle formation, 30 to	35
Sand and gravel chiefly; silt, clay: sand brown or red or light of color, coarse to fine; gravel chiefly chert of sizes ranging from cobbles or bowlders several inches in diameter down to pebbles not much larger than grit; large pieces of silicified wood; some crystalline quartz pebbles, most of them colored	

Unconformity
Eocene series
Claiborne sub-series

Wautubbee formation 15

Shipps Creek member: shale, dark-blue to black; laminated; fine white micaceous sand along the laminae planes; very sandy, almost a shaly fine sand

Kosciusko formation, 100 to 150

Sand, sandstone, quartzite, clay: sand white where fresh, but gray, yellow, brown, red-brown to red, with some pink, purple, and other colors where weathered; chiefly fine to medium, but in places coarse, even gritty. Sandstone ferruginous, friable to dense, and extremely tenacious. Some quartzite, especially in the basal zone of the formation. Clay mostly in the lower part, as inclusions in the sand matrix—irregular masses and stringers of various sizes and orientation

Unconformity

Zilpha formation, 40 to 50

Clay and shale, sand, silt, limonitic silt rock, concretions of silty siderite and limonite; interbedded thin beds of fine sand and gray and chocolate-brown silty clay; black clay shale, etc.

Winona formation, 70 to 80

Sands, greenish-gray to green, weathering to deep red; sandstone, red, knobby and ragged; sands massive to poorly bedded; some carbonaceous shale; sands glauconitic and non-glauconitic, fossiliferous in places

Tallahatta formation, 125 to 150

Basic City member: shale, variegated, silty, containing lentils and stringers of fine sand; laminated, with films of fine gray sand along the lamination planes.

All Tertiary strata which crop out in Carroll County belong to the Claiborne sub-series.* The Mississippi Claiborne as a whole seems to have never had any fixed stratigraphic or geographic boundaries. The many geologists who have studied the strata next younger than the Wilcox beds (and they do not agree on the question of the position of the top of the Wilcox) are at variance on several problems, the most vexing of which is the classification. The Claiborne of Alabama (the type section) includes three formations—the Tallahat-

*The term "sub-series" has been applied to the Claiborne in this bulletin, because the rank of "series" hitherto given the Claiborne, has been usurped by the Eocene division, following R. C. Moore's classification, adopted herein.

ta formation or "buhrstone" (lowest), the Lisbon sandy marl (middle), and the Gosport fossiliferous sand (uppermost). Until recently the Mississippi Claiborne was likewise considered to consist of three formations—the Tallahatta, the Lisbon, and the Yegua (Cockfield), correlative with the Alabama units, although the Basic City member of the Tallahatta and the Winona, Zilpha, Kosciusko, and Wautubbee members of the Lisbon were recognized. Grim (1936)[9] assigned the Winona to the Tallahatta as a member, and recognized the Chickasawhay member of the Lisbon instead of the Wautubbee. Foster[10] extended the Claiborne terrain downwards to include part of the Wilcox, the Meridian sand, which he ranked a formation. And Thomas,[11] who made the latest comprehensive study of the Claiborne beds of Mississippi, rejects Foster's new candidate for a place in the Claiborne, and seats one of his own choosing, the Neshoba member of the Tallahatta. Furthermore, he does not recognize the Lisbon at all, but bestows the rank it held on each of its four members—on the principle, perhaps, that the whole is no greater than any one of its parts. At any rate he has simplified the classification somewhat, and his plan is followed in the present paper, except that the present writer has included the Neshoba interval in the Winona.

In fact, if the usual sequence of events of erosion cycles was followed in Mississippi (and the field work to date seems not to have adduced any evidence to the contrary) Mellen's[12] suggested classification is, in the writer's opinion, most logical, most likely to be the grouping that is in accord with the cyclical rhythm of geological events and the resulting repetition of identical or similar types of sediments:

3. Unnamed formation

    Yegua (Cockfield) member
    Wautubbee member
    Kosciusko member

2. Lisbon formation

    Zilpha member, including the quartzite
    of the lower part of the present Kosciusko
    Shipps Creek shale could be a Zilpha equivalent
    Winona member

1. Tallahatta formation

    Basic member, including the Neshoba as a facies
    Meridian member

THE TALLAHATTA FORMATION

The Tallahatta formation as a whole consists of claystone or siltstone, clay, shale, sand, sandstone, and quartzite.

The "Basic (City*) member", according to Thomas,[11] "is composed chiefly of siliceous claystone with interbeds of siliceous siltstone and sandstone. These indurated rocks are the 'buhrstone' of older authors." He states further that shale or blocky clay also is abundant in the Basic City member; the sand includes a basal light greenish-gray glauconitic gravelly sand, and other sand lentils and lenses higher up. In Montgomery and Grenada Counties a "black carbonaceous silty micaceous fissile shale which dries out into a very light-gray or white slightly indurated flaky shale" is interbedded with the siltstone. In the hills east of Grenada the flaky shales and associated beds reach a maximum thickness of 100 feet, and are overlain by 3 to 30 feet of "light greenish-gray glauconitic sand or greensand which is characterized by an abundance of fucoidal structures and small clay inclusions."

Thomas's Neshoba sand member overlies the Basic City member conformably. It is a non-glauconitic to sparingly glauconitic sand, well-sorted, fine-grained, and micaceous. The fresh sand is white, but on the outcrop may be stained various colors. The sand of the upper 5 to 15 feet of the member is dark brick-red and very clayey. Gray clay is abundant as pellets, partings, stringers, and lenses in the sand.

Thomas states that the undifferentiated Tallahatta section in the area around Grenada reaches a maximum thickness of about 200 feet.

Priddy[13] describes the Tallahatta of Montgomery County as "fine-grained to medium-grained micaceous sands interbedded with thin silty micaceous clays and a few thin 'buhrstones' consisting of beds of claystone embedded in sandstone. In addition, one to five clay-shale lenses are developed locally at several horizons . . . . The clay-shales are dark-brown or tan but weather cream-white, have a blocky fracture, and are remarkably light in weight." He gives the thickness of the Tallahatta of Montgomery County as 125 to 150 feet.

The Tallahatta formation is represented at the surface in Carroll County by the Basic City member, which crops out in at least

*"Basic member" has been quite generally used in the literature of the past, but "Basic City" is preferred here to offset possible confusion with "bā'-sic". The formation name is pronounced "Bāss'-ic".

three places in the southeastern corner of the county, east and northeast of Vaiden, and possibly in a place or two in the extreme northeastern corner of the county.

In the north wall of a road cut (NE 1/4, Sec. 17, T. 17 N., R. 6 E.) in the northwest bluff of the valley of Big Black River, the exposed section is:

SECTION OF THE NORTHWEST BLUFF OF BIG BLACK RIVER VALLEY, ALONG THE NORTH WALL OF A LOCAL ROAD CUT

Description of Interval	Feet
Recent and Loess formations	
Thin soil and loessial material, uppermost interval of section	2.0
Unconformity	
Winona formation	
Sand, Indian red	23.0
Tallahatta formation, Basic City member	
Shale, silty, containing lentils and stringers of fine sand; variegated	7.0
Covered, to the level of the river flood-plain, 250 feet east of the base of the exposure	7.0
Total	39.0

The south wall of a cut (NE 1/4, Sec. 27, T. 17 N., R. 6 E.) for a gravel highway, at a place only a few rods west of the Montgomery County-Carroll County line, almost in the northeast corner of the eastward extension of southern Carroll County, shows a section which includes the same contact:

SECTION OF THE SOUTH WALL OF THE HIGHWAY CUT (NE 1/4, SEC. 27, T. 17 N., R. 6 E.)

Description of Interval	Feet
Recent formation	
Soil, silty and sandy loam, and sub-soil, clayey	1.5
Unconformity	
Winona formation	
Sand, Indian red, medium-grained to coarse	9.5
Tallahatta formation, Basic City member	
Shale, light-gray, mottled with iron oxide, laminated, with films of fine gray sand along the lamination planes; contains lentils of brown sand; silty; plastic clay towards the top; to bottom of roadside ditch	5.5
Total	16.5

In neither of these sections does the contact between the Tallahatta and the Winona show evidence of unconformity; in the Big Black River bluff section it is marked by a thin crust of ferruginous sandstone; in the highway cut section the shale contains thin sand lentils towards the top, and the sand contains streaks of shale near its base.

A third outcrop of Basic City is on the west side of the same gravel highway as the section described above, a little more than a mile southwest from it, at a place (SW 1/4, Sec. 27, or SE 1/4, Sec. 28, T. 18 N., R. 6 E.) in front of a farm house almost on a section line. It shows light-gray iron-mottled clay below and whitish clayey sand above, under a thin loessial mantle.

In the northeastern corner of the county, in the south wall of the valley of a tributary of Sykes Creek, a roadcut (SE cor. Sec. 32, T. 21 N., R. 5 E.) and a gully expose a few feet of light tan and yellow sand banded with red, under red Winona sand. It is believed to be Tallahatta.

THE WINONA FORMATION

The Winona formation as a whole consists almost entirely of glauconitic and non-glauconitic or sparingly glauconitic sands, and irregular knobby concretionary sandstones. The greensands and glauconitic sands, where fresh, are light greenish-gray to dark green, but weather to a dark brick-red or "Indian red." Commonly the sands are coarse, and massive to poorly bedded. In places the Winona contains thin beds or lenses of carbonaceous shale. Locally the sands are calcareous and fossiliferous. Thin beds and concretionary masses of siderite are present, especially near the top of the formation[11]. The Winona rests conformably on the Tallahatta.

Priddy[13] identified three parts of the Winona formation (he ranks it a member of the Lisbon) in Montgomery County: (a) A basal non-glauconitic non-fossiliferous iron-stained quartz sand containing thin discontinuous clay lenses, 20 feet thick; (b) a middle, slightly glauconitic sparingly fossiliferous ferruginous quartz sand 30 to 40 feet thick; (c) an upper very glauconitic very ferruginous quartz sand containing casts of pelecypods, about 20 feet thick. Thomas's Neshoba member of the Tallahatta formation is included in Priddy's lower and middle parts of the Winona.

The Winona formation, as represented at the surface in Carroll County, consists of interbedded rather coarse glauconitic green sand

and very irregular, knotty or knobby concretionary sandstone. Commonly the exposed sand and sandstone are Indian red because of oxidation of the iron of the glauconite; but the fresh, unoxidized sand has a greenish-gray cast. Existence of the sandstone is due to the cementation of the sand by iron oxide precipitated from solution by percolating water. In the oxidized zone the glauconite which the sand contained before it became sandstone by cementation, has been destroyed. A feature of the sandstone is that it is knobby and knotty, as stated, the many projections resembling the knots of a gnarled old tree. A cross-section of one of these protuberances may show a concentric structure, possibly because of circular or at least curved lamination in the sand before cementation, or possibly because of cementation around hard centers. The green sand may show cross-lamination or current bedding. At least one horizon of the Winona contains macroscopic fossils, of which a small collection was made (SW 1/4, Sec. 8, T. 19 N., R. 5 E.), and the same bed was noted in another place (NW 1/4, same section). The fossils are chiefly of pelecypods.

In Carroll County are several good outcrops of the Winona beds. In the southeastern part of the county, east of the Illinois Central Railroad and U. S. Highway 51, the Winona crops out here and there along the local roads. As stated in the description of the Tallahatta outcrops, the Winona sand overlies them apparently conformably, but at these places the sandstone layers are absent, probably either broken down by weathering or never developed. Of the many exposures of the Winona red sand in this part of the county, two or three deserve mention. Along the southwest-northeast main gravel road through Section 7, Township 17 North, Range 6 East, the deep red sand is conspicuously shown by a series of cuts; the sandstone appears not at all, or very imperfectly. Perhaps the best of these cuts is in the extreme northeastern corner of Section 7, a little northeast of a negro school; this cut shows 20 feet of red sand. Thomas[11] would call this Neshoba sand.

In the southeast corner of the corporate area of Vaiden, on the east side of Highway 35, is an excellent section of some upper Winona and the overlying Zilpha (see description of section in text relating to the Zilpha formation). A 10-foot thickness of Winona rock, consisting of coarse glauconitic green or red-brown sand below and a top layer of knotty sandstone, is exposed here.

A Highway 35 cut (NE 1/4, Sec. 25, T. 17 N., R. 5 E.) in the west wall of the valley of Big Black River, shows a considerable thickness of the Winona red sand. Road cuts in the two southeasternmost sections of the county (Secs. 33 and 34, T. 17 N., R. 6 E.) are walled with the same deep red sand, associated in places with concretionary nodules of ironstone, limonite slabs, ferruginous sandstone, and a little quartzite.

One of the best Winona sections of the county is brought to view by the Illinois Central Railroad cut (SE 1/4, Sec. 35, T. 17 N., R. 5 E.) about 2.8 miles south from Vaiden, on the east side of U. S. Highway 51.

SECTION OF THE EAST WALL OF ILLINOIS CENTRAL R.R. CUT 2.8 MILES SOUTH OF VAIDEN, ON THE EAST SIDE OF U. S. HIGHWAY 51, ABOUT MIDWAY OF THE LENGTH OF THE CUT (LONE OAK TREE AT TOP OF SECTION)

Description of Interval	Feet
Recent formation	
Soil, subsoil, loessial	1.0
Unconformity	
Zilpha formation	
Mostly covered, but presumably Zilpha	10.0
Zilpha gray clay	5.0
Winona formation	
Sand, coarse green, gray, and red glauconitic, and beds of knotty red sandstone, to bottom of wall, a little below track level	12.3
Total section	28.3

The exact Winona-Zilpha contact is visible here. A large piece of silicified wood was found a little above the contact.

Along U. S. Highway 51 within a distance of 3.5 miles south from Vaiden are at least seven cuts which expose the Winona beds. The northernmost of these, a cut some 200 feet long 0.9-mile south from Vaiden, has uncovered a sharp Winona-Zilpha contact for several rods on the west side of the pavement slightly above pavement level. Other cuts, a mile to a mile and a half farther south, all have brought good sections of Winona sand into view. Thomas[11] mentions poorly preserved Winona fossils, some of which are beautifully opalized, from a cut on the west side of Highway 51 about 0.85 mile north of Beatty Station. The only exposure of Winona rock observed along

Highway 51 in Carroll County north of Vaiden is a doubtful one a little more than a mile south of the Montgomery County line.

Upper Winona strata appear at the surface in several places in eastern Carroll County north of U. S. Highway 82, the region of the headwaters of Big Sand Creek. A local road cut (NW 1/4, Sec. 17, T. 19 N., R. 5 E.) in the steep south wall of the valley of one of the many headwater branches of Big Sand Creek has been made in Winona red sandstone and glauconitic sand. A similar trench (SW 1/4, Sec. 8, T. 19 N., R. 5 E.) in the opposite wall of the same small valley, leading up the steep bluff from the Columbus & Greenville Railway, shows an excellent Winona section of green sand and rough-surfaced sandstone layers. Fossil pelecypods were collected here from a block of consolidated green sand. Numbers of concretions consisting of loose green sand or black sand inside shells of ferruginous sandstone are lying in the roadside ditches or are embedded in the sand walls. They may have been formed in the process of differential cementation by which the rough sandstone layers came into being.

No Zilpha is present at either of these valley wall locations. Kosciusko sand caps the bluff 0.3-mile farther northeast and north.

In the northwest wall of the valley of another of the small headwater branches of Big Sand Creek, less than half a mile north of the outcrop just described, Winona rock is at the surface at the roadside (near center, Sec. 8, T. 19 N., R. 5 E.). Greensand and greensand concretions and the fossiliferous rock feature this outcrop also.

The south wall of the valley of one of the main headwater branches of Big Sand Creek, half a mile south of McCarley, is in large part Winona strata, but little or no Zilpha. Where the road's direction changes sharply (NW 1/4, Sec. 13, T. 19 N., R. 4 E.), several feet of Winona red sand and sandstone crop out on the east side. A mile farther east, a road cut (western part, Sec. 18, T. 19 N., R. 5 E.) in the west wall of the valley of a northward-flowing headwater branch of Big Sand Creek exposes a good section of Winona beds, but no Winona shows in the opposite wall of the same valley, less than half a mile farther east, although a good section of the Zilpha is present.

A road cut (NW 1/4, Sec. 12, T. 19 N., R. 4 E.) about half a mile north of the railroad at McCarley, exposes a section of the north wall of the valley of the main south headwater branch of Big Sand Creek:

SECTION IN WEST WALL OF ROAD CUT HALF A MILE NORTH OF MCCARLEY

Description of Interval	Feet
Recent formation	
Soil and subsoil, loessial, sandy	1.0
Unconformity	
Kosciusko formation	
Sand, brown	10.0
Zilpha formation	
Limonite slabs and plates, and ferruginous sandstone, platy, 1.0 to	2.0
Clay, gray and brownish; reddish towards the base; grades downwards into green sand; thin lentils and stringers of green sand in the base of the clay	15.0
Winona formation	
Sand, glauconitic, green and grayish, and red sandstone, knotty, concretionary; sand and sandstone interbedded	13.5
Total Section	41.5

A long and deep road cut (SE 1/4, Sec. 31, T. 20 N., R. 5 E.) in the south wall of the valley of a small tributary of the middle large headwater branch of Big Sand Creek uncovers some 12 feet of Winona red and green sand and red sandstone (also some 10 feet of deep red sand farther down the slope may be Winona), 11 feet of Zilpha gray clay, capped by silty limonite slabs and ferruginous sandstone, and a very considerable thickness of Kosciusko red and brown sand, 30 to 40 feet at least, overlain by 8 to 10 feet of loess. A feature of this outcrop is the strong development of ferruginous sandstone in the lower part of the sand—large masses and extensive sheets, some of which are contorted into bizarre shapes.

A short length of old road (NW 1/4, Sec. 31, T. 20 N., R. 5 E.), now abandoned as a public road because of destruction of a bridge and of the road in places by water, is paved and walled by Winona and Zilpha rock in two places. The eastern of these is a low ridge of Winona rock; the western is a shallow cut which exposes some 12 feet of Winona and 10 to 12 feet of Zilpha. Here the slabs of silty limonite, or limonitic silt, at the top of the Zilpha clay are 5 to 6 inches thick, and very dense and heavy.

A quarter of a mile northeast of the place last mentioned, hard Winona beds form small ridges or shelves across the north-south road. Here (NW 1/4, Sec. 31, T. 20 N., R. 5 E.) a thickness of some 20 feet of Winona strata and 8 feet of Zilpha is exposed.

The three outcrops last mentioned are in the northwest valley wall of a small tributary of the main middle headwater branch of Big Sand Creek.

Winona strata are exposed also in the northeastern corner of the county. At a bend in a local road (SE 1/4, Sec. 32, T. 21 N., R. 5 E.) on the divide between two headwater branches of Sykes Creek, and in the south wall of the valley of the northern one, the typical red sandstone and green sand crop out on the west side of the road, almost uninterruptedly for 0.2 mile. A thickness of 3 feet shows on the divide, and a greater thickness in the valley wall, where the red sand is underlain by a light tan and yellow red-streaked sand which possibly could belong to the contact zone between the Basic City and the Winona. Also in the opposite wall of the same valley the Winona red sand and some sandstone appear; but they were not seen elsewhere in the northeastern part of the county.

THE ZILPHA FORMATION

The Zilpha formation is chiefly black, gray-white and chocolate-brown carbonaceous clay and shale. According to Thomas,[11] the lower part of the section is typically a nearly pure blocky clay, the upper part more silty and shaly; plant fragments are present throughout, but are more abundant in the upper shaly facies; the lowermost few feet of the formation are glauconitic and sandy, and glauconite is present in small lenses and pockets all the way to the top; concretions of limonitic claystone or siltstone are more or less numerous, and a bed of hard, dense limonitic siltstone serves as a good marker for the top of the formation (Figure 14). The Zilpha is conformable on the Winona, the contact being sharply defined. The average thickness of the Zilpha is about 40 feet, although the section at Bucksnort Hill, Attala County, which Thomas designates the type section, is 54 feet thick.

Priddy[18] found the Zilpha in Montgomery County to consist of two units, a thin marine facies below and the continental Zilpha above. The marine Zilpha he determined to be present only locally, and in the west tier of townships, where it has a maximum thickness of 1.7 feet; but in a test-hole in Carroll County, 5 miles west of Winona, he found a thickness of 2.4 feet. It is greenish-buff fairly glauconitic blocky clay shale, which weathers brick red. The Zilpha proper is tan to chocolate-brown carbonaceous slightly silty clay shale which characteristically weathers gray-white. It is jointed, well bedded, contains lenses of micaceous silt in places, and some plant impres-

sions. The clays develop a blocky to conchoidal fracture by weathering. Joints may be filled with selenite. The Zilpha formation is conformable on the Winona, but unconformable with the overlying Kosciusko.

The Zilpha formation of Carroll County is chiefly clay which lies, apparently comfortably, on the Winona. It crops out in numerous places within the limits of a belt 9 to 12 miles wide, although the greatest thickness of the formation found was around 40 feet. By a test-hole (NE 1/4, NW 1/4, NW 1/4, Sec. 30, T. 19 N., R. 5 E.) some 2 miles west of the Montgomery County-Carroll County line, on the south side of U. S. Highway 82, Priddy[13] found 40.2 feet of Zilpha, and another test-hole (SW 1/4, SE 1/4, SE 1/4, Sec. 24, T. 19 N., R. 4 E.) on the south side of the highway half a mile farther west, was drilled through 45.2 feet of Zilpha.

Some of the best outcrops are in the vicinity of Vaiden. A section (SE cor., Sec. 10, T. 17 N., R. 5 E.) some three quarters of a mile north from the corporate limits of Vaiden, on the southwest side of U. S. Highway 51, was measured carefully:

SECTION ON THE SOUTHWEST SIDE OF U. S. HIGHWAY 51,
THREE-FOURTHS MILE NORTH FROM VAIDEN

Description of Interval	Feet
Kosciusko formation	
Sand, coarse, dull white and brown to red-brown, and a little ferruginous sandstone; contact at top of yellow and gray mottled clay. Northern of the two exposures combined for the section	11.0
Zilpha formation	
Clay, clay shale, and sand: the clay shale is light lignite-brown or olive-drab, tan, or light-gray, dense, and lumpy and blocky in the weathered zone; the sand is fine, tan or olive-drab, current-bedded. The clay is mottled dull white and yellow in the uppermost 2.4 feet, and capped by a thin crust of ferruginous sandstone. Clay shale and sand are interlaminated, interbedded, interlensed or interlentiled, and rust stained in places. Lignitic clay and sand thin layers are conspicuous, especially in the middle of the section. The interval, measured at the northern of the two outcrops, includes about 5 feet covered subjacent to the 2.4 feet of yellowish clay at the top	22.4
Clay, clay shale, and sand, as in interval above, but measured at outcrop 250 feet south of the other. Lighter of color, in general	17.7
Covered, to water in ditch; some glauconitic green sand, possibly marine Zilpha. Also some pieces of concretionary ferruginous sandstone	2.3
Total section	53.4

This section of Zilpha contains more black or dark sandy shale and sand than any other observed in the county.

As already mentioned, an excellent Winona-Zilpha section has been exposed by head erosion by a small tributary of Hays Creek at

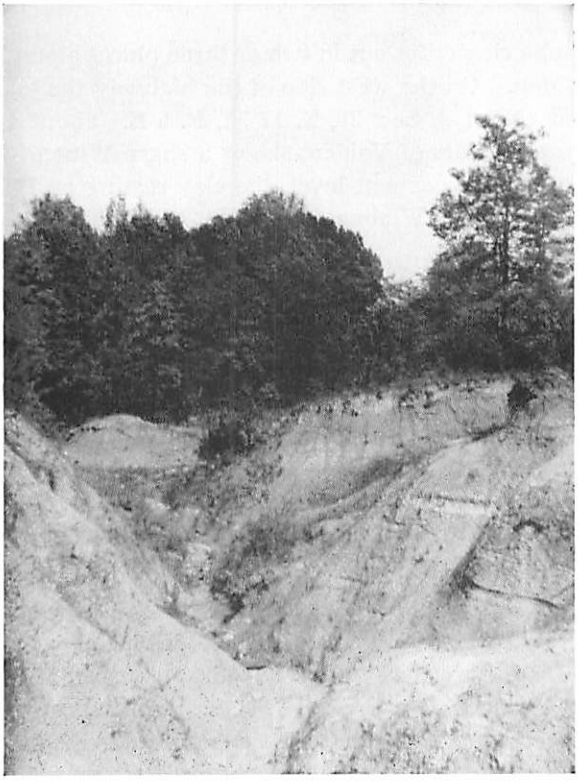

Figure 6.—Erosion in Zilpha clay. East side of Highway 35, southeast corner of Vaiden corporate area (NE ¼ of NE¼, Sec. 24, T. 17 N., R. 5 E.)

a place (NE 1/4, Sec. 23, T. 17 N., R. 5 E.) in the southeast corner of the Vaiden corporate area, on the east side of Highway 35.

SECTION ON THE EAST SIDE OF MISSISSIPPI HIGHWAY 35 IN THE SOUTHEAST CORNER OF THE CORPORATE AREA OF VAIDEN

Description of Interval	Feet
Zilpha formation	
Clay, gray, with some lentils of light-colored sand, to top of hill near house south of outcrop (Figure 6)	25.0

Winona formation

Sand and sandstone: coarse glauconitic green and red-brown sand, and a top layer of concretionary sandstone, to floor of ravine below the exposure 10.0

The position of the Winona-Zilpha contact here can be determined within a foot. Apparently the clay rests directly on the sandstone.

The Zilpha clay crops out in two or three places along Highway 51 south of Vaiden. On the west side of the highway the wall of a 200-feet long cut (NE 1/4, Sec. 26, T. 17 N., R. 5 E.) about a mile south of the corporate limits of Vaiden, shows a sharp Winona-Zilpha contact slightly above pavement level, the clay resting on Winona sandstone. Some 3 feet of Winona and 10 feet of Zilpha are exposed.

Some 2.8 miles south from Vaiden an Illinois Central Railroad cut (SE 1/4, Sec. 35, T. 17 N., R. 5 E.) on the east side of the highway, is walled with Winona and Zilpha strata (see description of section in the Winona part of the report).

In Holmes County about 1.3 miles south of Carroll County, and a little north of West, the Zilpha clay crops out in another Illinois Central cut, and also in the west wall of the Highway 51 cut just above the railroad, where it is overlain by Kosciusko sand. The Zilpha-Kosciusko contact here is featured by abundant quartzite. About 15 feet of Zilpha clay are visible.

In the extreme southeastern corner of the most eastern block of Carroll County, east of Big Black River, Zilpha clay has been laid bare in two or three places on local roads, at or near two road junctions (NE 1/4 and SE 1/4, Sec. 34, T. 17 N., R. 6 E.). A farmer whose home is near the farthest north of the clay outcrops stated that his well was dug through 13 feet of this clay before hard red rock (obviously Winona) was encountered. Winona beds crop out in several places in the vicinity. Some red sand overlies the clay, and ferruginous sandstone and quartzite are abundant in the vicinity. The clay in this section, then, its slight thickness, its geographical position, and its elevation, being considered, seems to be a Zilpha outlier near the eastern edge of the outcrop belt. No other Zilpha outcrop was found east of Vaiden; but the type section of the Zilpha, at Bucksnort Hill,[11] in northwestern Attala County, is only a few miles southwest of the Carroll County locality just mentioned.

In Vaiden west of Highway 51, and along the many roads west and southwest of the town, Zilpha outcrops may be observed. A few

of the number noted should be given a little more space than mere mention requires.

On the north side of the Vaiden-Black Hawk road, three quarters of a mile or more northwest of the corporate limits of Vaiden, several feet of the upper Zilpha are exposed almost in front of a farmhouse (Sec. 15 or 16—very near the section line—T. 17 N., R. 5 E.). The gray clay shale, which shows well-defined bedding, is overlain by dull white sand along a regular contact featured by masses of extremely dense light-brown quartzite. The peculiar surface protuberances of the quartzite (mammillary quartzite) suggest a correlation with rock of identical character in other places—Lafayette County, for example, where the Zilpha-Kosciusko contact has not been recognized as such. It is possible that in western Mississippi the odd surface feature is restricted to the Zilpha-Kosciusko contact; if it is, its value as a key to stratigraphy and structure in the chaotic terrane of northern Mississippi is obvious. It seems pertinent to note in this connection that the same kind of rock is present at the Zilpha-Kosciusko contact at the Highway 51 outcrop a little north of West, Holmes County, referred to in a preceding paragraph.

Another good Zilpha outcrop is created by a road cut and gullies (western part, Sec. 30, T. 17 N., R. 4 E.) in front of a cabin. The south wall of the cut exposes some 15 feet of gray clay, very plastic when wet. About the same thickness shows at another cut (eastern part, Sec. 25, T. 17 N., R. 4 E.), 0.3-mile farther west. In both places the clay is overlain by red-brown sand, and a thin ferruginous sandstone marks the contact.

Zilpha clay crops out here and there along the road to Wiltshire and southwest to the Holmes County line. At old Wiltshire (on line between Secs. 26 and 27, T. 17 N., R. 4 E.) Zilpha-Kosciusko contact features are conspicuous—silty limonite slabs and ferruginous sandstone. Light-gray to white, pink-mottled clay at the bottom of the exposure here appears to have been a pocket or lens in the sand—sand underlies it and loess is above, and it is bounded by ferruginous fracture fillings.

A little more than a mile farther west by south, a big ravine (about at the common corner, Secs. 27 and 28, T. 17 N., R. 4 E.), a quarter of a mile or less east of a road junction, has been cut in Kosciusko sand and Zilpha clay. A thickness of 15 to 20 feet of gray and chocolate-brown clay and some light colored sand is exposed down

slope from a road cut walled with brown and red-brown Kosciusko sand.

At a road junction (southern part, Sec. 5, T. 16 N., R. 4 E.) only about a quarter of a mile north of the Holmes County line, Zilpha chocolate shale crops out through a vertical interval of 20 to 25 feet, and above it, showing well in the walls of the road cut up slope, is a greater thickness of red-brown Kosciusko sand. The shale-sand

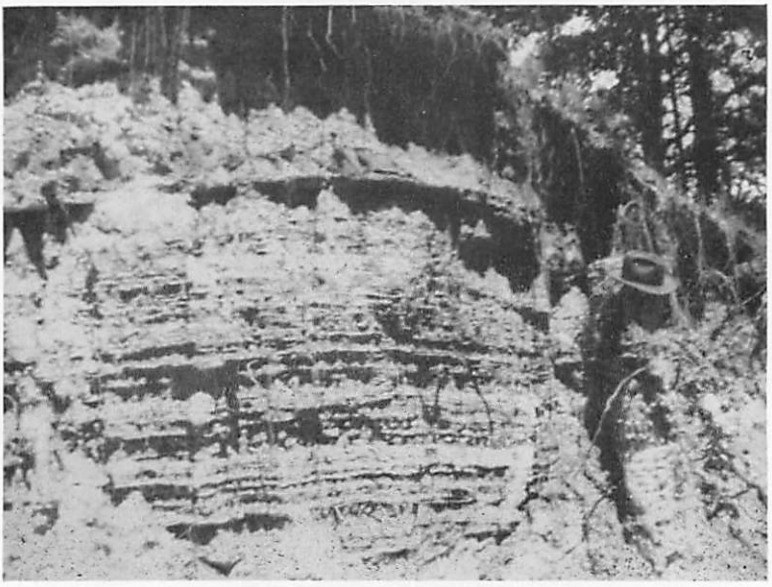

Figure 7.—Laminated top beds of Zilpha (SE ¼, Sec. 5, T. 16 N., R. 4 E.) almost on southern boundary of county. Resembles Basic City.

contact is featured by much ferruginous sandstone. About 0.3-mile farther southeast, the northeast wall of a road cut (SE cor. Sec. 5, T. 16 N., R. 4 E.) is a conspicuously bedded siltstone or claystone (Figure 7) which probably is uppermost Zilpha. It, too, is associated with much ferruginous sandstone.

Among the few other observed Zilpha outcrops in this part of the county, one (SW 1/4, Sec. 8, T. 16 N., R. 5 E.) includes a vertical interval of 15 feet or more. It is 0.3-mile southwest of a road junction.

Farther north the Zilpha shale and clay are exposed at a number of places by road cuts, ravines, and gullies. On the Vaiden-Black-

Hawk road are several such places. At a road junction (SW 1/4, Sec. 10, T. 17 N., R. 4 E.) the large masses and blocks of dense ferruginous sandstone at the top of the Zilpha are prominent (Figure 8). Loess lies on the clay here, no part of the red sand formation being present; but 200 yards or so farther southwest, at a lower elevation, a considerable thickness of sand shows under the loess. Possibly the clay

Figure 8.—Masses of ferruginous sandstone at Zilpha-Kosciusko contact (SW ¼, Sec. 10, T. 17 N., R. 4 E.) Vaiden-Black Hawk road.

which crops out at the road junction is only a lens in the sand—in fact, brown sand appears under it in the slope—or it may be at the top of a high place in the clay terrain, from which the sand was eroded before the deposition of the loess; or, a third alternative, the underlying sand could be a sand lens in the Zilpha formation.

Another cut (NE 1/4, Sec. 23, T. 17 N., R. 3 E.) on the same road, about 0.2-mile southwest of a road junction, has exposed 28 feet of the upper Zilpha, consisting of variegated thin strata of sand and clay, the weathered surface of which is mottled pink and white and reddish. About midway of the outcrop is a small fault on the west side of which the beds have been thrown down a few feet. The clay is overlain by loess only, which is involved in the fault. The Zilpha outcrop here is the westernmost seen on this road. It will be noted from

the map that although the greatest Zilpha thickness observed in Carroll County is little more than 40 feet, the outcrop belt between Vaiden and Black Hawk, almost down dip, is 12 miles wide.

The part of the county north of the Vaiden-Black Hawk road, east of the Carrollton-Black Hawk road, and south of Highway 82

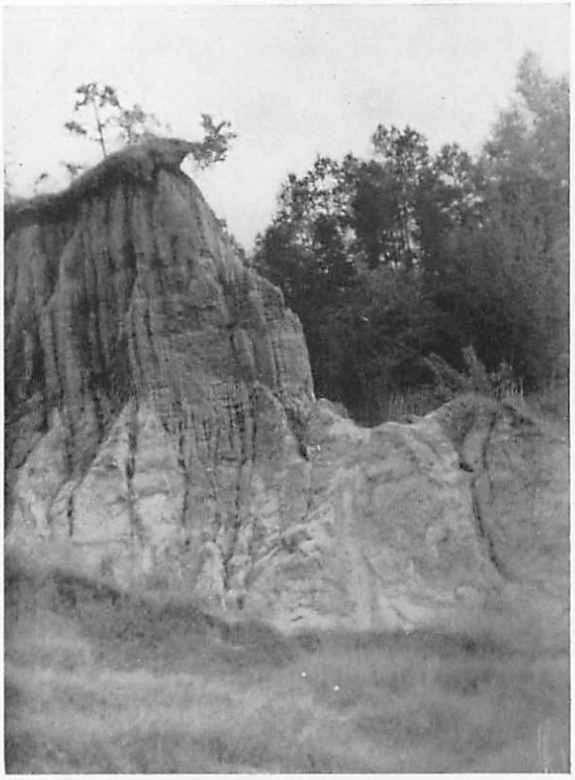

Figure 9.—"Island" remnant of sand, clay, and loess, erosion isolated, on south side of Highway 82 at local road crossing 1 mile east of Carrollton-Highway 82 road. (Sec. 19, T. 19 N., R. 4 E.)

was not traversed so thoroughly as were other parts of the county, but observations were made in this region along the main Vaiden-Carrollton road, and along a road leading northeast from it to Highway 51 in Montgomery County.

Zilpha clay shows well in the vicinity of a road junction and schoolhouse (common corner, Secs. 5, 6, 7, and 8, T. 17 N., R. 5 E.).

At the southeastern one of the outcrops (NW cor. Sec. 8, T. 17 N., R. 5 E.) the clay is well up on the low north wall of a small valley, and reaches almost to the top. The lower part of it is light gray, the upper part darker gray mottled with red, reddish tinted on the weathered surface, and checked. The northern one of the outcrops (SW cor. Sec. 5) at the school, shows gray clay.

Some six miles farther north along this road, a large ravine (NE 1/4, Sec. 14, T. 18 N., R. 4 E.) on the east side of the road has exposed 25 to 28 feet of gray clay below, and light-gray to white clayey sand, eroding into pinnacles, above.

Only two other Zilpha outcrops of consequence were observed on the Vaiden-Carrollton road. The southern of these (western part, Sec. 34, T. 19 N., R. 4 E.) is in roadside ditches half a mile south of a road junction. The clay, which is bluish gray, reddish at the top, and very plastic, is overlain by loess, the contact being marked by ferruginous sandstone and limonite slabs. The total thickness shown by the outcrop is 20 feet.

At the intersection of the Vaiden-Carrollton road and Highway 82 (eastern part, Sec. 19, T. 19 N., R. 4 E.) the clay-sand relationships are somewhat puzzling. Here a vertical-walled erosion remnant 20 to 25 feet high (Figure 9) of sand, clay, and loess stands between the present local road and the old local road (which is now a ravine), a few yards south of the highway. For a distance of about 40 yards from its north end, this remnant is composed of the red-brown sand below and loess above; but farther south than this it is cut into between the sand and the loess by a big wedge or lens of gray clay. The clay is separated from the sand by a thin layer of hard ferruginous rock. Still farther south the clay has been laid bare by erosion of loess and sand, leaving the sand-loess remnant as an "island". The entire clay exposure is 75 yards long. On the west side of the "island" a ravine, developed along the course of the old graveled road, has exposed the clay, the ferruginous seam underlying it and several feet of brown sand beneath (Figure 10). Thus at its north end the clay body is underlain by sand, and in the hill slope farther back it is overlain by sand. However, the sand above the clay is largely red-brown, apparently typical Kosciusko sand, but that below the clay is brown, of different appearance. Furthermore, on the northeast side of the graveled road north of the highway, at a lower elevation, sand only is exposed—gray, white, and brown; and

in the south wall of a Highway 82 cut about three quarters of a mile east of Carrollton and 0.6-mile west of the "island", at a greater elevation, gray lignitic-streaked clay below and white sandy clay above show through an interval of 10 to 12 feet above highway level. All

Figure 10—Contact of Zilpha clay (lens?) above and brown sand beneath (lens?). Ravine on south side of Highway 82 at local road crossing one mile east of Carrollton road and Highway. (SE ¼ of NE ¼ Sec. 19, T. 19 N., R. 4 E.) West side of "Island".

in all, the conclusion seems warranted by the field evidence that the Zilpha at this locality contains a sand unit, or sand units.

Zilpha clay is at the surface in a few places along a local road which joins the Vaiden-Carrollton road some 8.5 miles northwest from Highway 51 at Vaiden and connects with Highway 51 about the same distance north of Vaiden. At a road junction (SW 1/4, Sec. 8, T. 18 N., R. 5 E.) on this road, and southwest of the junction down the

slope for a considerable distance, Zilpha clay is exposed in the road and on both sides of it. The upper part of the clay is yellow and is overlain, as the Zilpha clay commonly is at its outcrops, by silty limonite and ferruginous sandstone. A sharp Zilpha-Kosciusko contact shows towards the top of the slope.

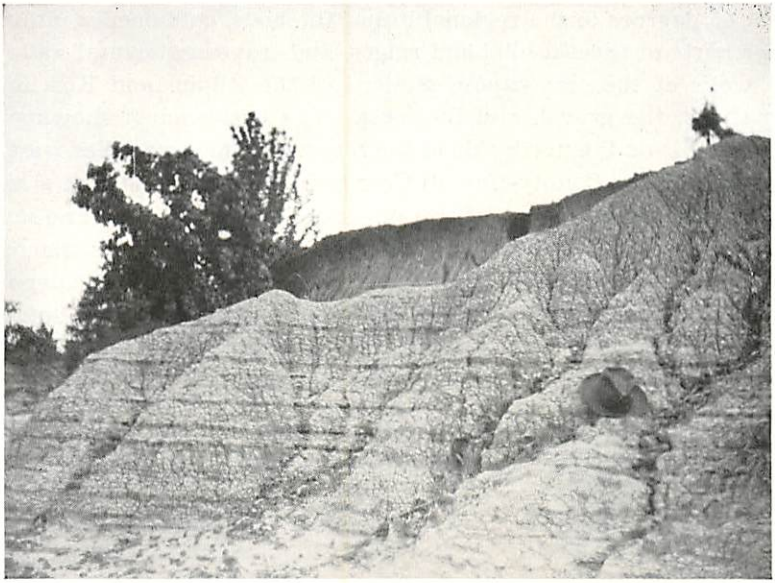

Figure 11.—Bedding near top of Zilpha—alternating sand and clay layers. (SE ¼, Sec. 24, T. 18 N., R. 4 E.)

At a curve (about on the line between Secs. 18 and 19, T. 18 N., R. 5 E.) of this local road, is an excellent Zilpha outcrop in the southwest wall of the valley of a tributary of Hays Creek: 15 to 20 feet of gray sandy clay, overlain by loess, are exposed by the road cut and by gullies.

A low ridge, crossed by the road at a place (SE cor. Sec. 24, T. 18 N., R. 4 E.) a quarter of a mile or so northeast of the Vaiden-Carrollton road, seems to be largely Zilpha clay. The gray clay, crusted with silty limonite, is exposed by the roadside ditches in the slopes almost to the top of the ridge, and is overlain by loessial material. The southwest end of the outcrop affords an excellent example of alternating thin clay and sand layers in the Zilpha (Figure 11).

North of U. S. Highway 82 the network of local roads and the intricate drainage system have created many excellent outcrops of sand and sandstone, clay, and loess. The larger and more prominent Zilpha exposures of the region will be described, in south-north and east-west order, insofar as is practicable.

The right-of-way of Highway 82 itself, extending at an angle of about 45 degrees to the regional dip of the beds, cuts deeply into the upper parts of several hills and ridges, and traverses several valleys. The walls of the cuts expose sections of the Zilpha and Kosciusko formations, the gravel, and the loess. The easternmost showing of the Zilpha is on the north side of the highway some two miles west of the Montgomery County-Carroll County line and a quarter of a mile east of a road intersection. Loess only overlies the clay here; no sand. Possibly the sand never was deposited at this place; or some may have been deposited, and later removed by erosion before the deposition of the loess. However, the clay-loess contact is not notably uneven.

At this place or very near it, Priddy[13] had his test-hole L-22 drilled.The log is given below:

LOWE WHITEHEAD PROPERTY

TEST HOLE RECORD L22

Location: T. 19 N., R. 5 E., Sec. 30, NE. 1/4, NW. 1/4, NW. 1/4 (Carroll County); beneath big pine above clay cut, south side of U. S. Highway 82 (Elevation: 361 feet)

No.	Depth	Thick	Description of strata and designations of samples
1	3.0	3.0	Soil—silt, clayey buff
			Upper (continental) Zilpha
2	5.4	2.4	Clay, silty, yellowish-gray weathered
3	10.1	4.7	Clay, fairly silty light-gray; P3
4	13.1	3.0	Clay, fairly silty light-gray; yellow limonitic stains along laminae
5	18.3	5.2	Silt, grayish-white
6	22.0	3.7	Silt, clayey gray-yellow stained; thin breaks of limonitic sandstone
7	22.8	0.8	Sand, fine-grained buff fairly micaceous
8	28.6	5.8	Clay, fairly silty light-gray yellow mottled
9	28.9	0.3	Silt, sandy grayish-white
10	30.9	2.0	Clay, fairly silty grayish-tan
11	36.6	5.7	Clay, fairly silty dark-gray; dries light-greenish-gray
			Lower (marine) Zilpha
12	39.0	2.4	Clay, fairly silty greenish-gray; contains large very glauconitic gray claystone nodules and glauconite as bedded sand
			Winona member
13	43.2	4.2	Silt, slightly clayey dark-grayish-green slightly glauconitic; large and small non-glauconitic claystones

A little north of its intersection with the highway, mentioned above, the local road is on an extensive Zilpha outcrop (SE 1/4, Sec. 24, T. 19 N., R. 4 E.) which is well represented on both sides of the road for 200 to 300 yards, both northwest and southeast of a junction with another local road, and is continuous almost to the highway.

Priddy's[13] test-hole L-25, located near the highway at the south end of this outcrop, was logged as follows:

T. F. McCormick Property

Test Hole Record L25

Location: T. 19, N., R. 4 E., Sec. 24, SW. 1/4, SE. 1/4, SE. 1/4, (Carroll County); beneath persimmon tree atop clay cut, 25 feet south of U. S. Highway 82 (Elevation: 372 feet)

No.	Depth	Thick	Description of strata and designations of samples
1	8.9	8.9	Soil—clay, silty; weathered Upper (Continental) Zilpha
2	12.0	3.1	Clay, slightly silty light-gray
3	24.8	12.8	Clay, fairly silty light-tannish-gray; P3
4	25.6	0.8	Clay, silty light-gray yellow stained; thin breaks of limonitic claystone
5	38.6	13.0	Clay, slightly silty grayish-tan; P5
6	42.7	4.1	Clay, slightly silty very dark-gray
7	42.9	0.2	Clay, silty yellow ochreous; thin breaks of yellowish-brown limonite along laminae
8	44.7	1.8	Clay, slightly silty dark-tannish-gray; pyritiferous
9	46.1	1.4	Clay, silty light-gray; laminae of fine-grained buff sand
10	48.3	2.2	Clay, fairly silty dark-gray; dries medium gray
11	54.1	5.8	Sand, slightly light-gray slightly micaceous

Along the highway west of the large outcrop, Zilpha clay appears again at 0.3-mile and at 1 mile from the intersection; but the next considerable exposure is in the walls of a large cut (SW 1/4, Sec. 22, T. 19 N., R. 4 E.) more than two miles farther west. About the middle of the south wall of this 25 to 30-foot deep cut, the section shows gray to red mottled clay below, grading upwards into brown and yellowish clayey sand. A little west of the middle the relationships of the units suggest a small fault or an erosion surface: The gray clay appears to be cut off sharply, and a mass of ferruginous sandstone occupies a position a little above the top of the clay and west of it; the light yellowish to whitish clayey sand east of the break is higher than the same sand west of it, which seems to be on the same level as the gray clay east of the break. Possibly the irregularity could be the result of erosion of the clay and subsequent filling of the erosion

depressions by sand; but the contacts appear to be too sharp to have been formed thus, and the beds appear to be definitely offset.

At the intersection of the highway and a local road (eastern part, Sec. 21, T. 19 N., R. 4 E.), less than half a mile west of the Zilpha outcrop described above, several feet of gray clay are exposed on the north side of the highway. The dry weathered surface is reddish towards the top of the interval, but the clay is mottled red and gray under the surface crust. A feature of this outcrop is a few concretionary masses of weathered limonite which were originally impure siderite, as attested by some small siderite cores remaining. Similar concretions were present sparingly at the faulted outcrop.

A quarter of a mile farther west, are a big highway cut and a ravine (near center, Sec. 21, T. 19 N., R. 4 E.), where the strata were carefully measured and described, as typical of the general character of the Zilpha:

SECTION OF SOUTH WALL OF U. S. HIGHWAY 82 CUT AND NORTH WALL OF RAVINE 2.4 MILES EAST OF CARROLLTON INTERSECTION

Description of intervals	Feet
Recent formation	
Soil and subsoil, loessial, brown, silty, sandy, and clayey; lower 2 feet darkened by moisture	3.0
Peorian formation (upper)	
Loessial material, weathered, with perhaps some subsoil: brown and mottled gray, spotted and streaked with plant-root tubes or insect burrowings; clayey, silty, sandy; soft and velvety to the touch	6.8
Unconformity	
Zilpha formation	
Clay, sandy and silty, ferruginous—clay-loess contact zone	1.6
Clay, light-gray to pale chocolate-brown, sandy and silty; top foot or so very rusty	8.7
Sand, fine, tan to light-gray, as 3d, 5th, and 7th intervals below	0.5
Sand and sandy clay, light chocolate-brown, blocky, leaf-bearing	1.2
Sand, fine, light-gray, as 3d and 5th intervals below	0.4
Sand, lignite-brown, silty and clayey, compact, blocky, leaf bearing; some of it nearer a sandy clay, as 4th interval	2.0
Sand, fine micaceous, light-gray; contains yellow rust pockets	0.8
Sand, fine, clayey and silty, light lignite-brown, blocky, leaf-bearing	1.5
Sand, fine light-gray to pale yellow; contains yellow rusty pockets	1.8
Covered, to pavement level, Highway 82	1.0
Clay, sandy, light-gray to dark-gray and a little chocolate-brown; small pieces of silicified wood (this interval is the ravine wall, 100 yards north of east of the highway cut section), to bottom of ravine	14.0
Total section	43.3

A quarter of a mile farther west gray clay and loess, but no sand, show in the walls of a shallow highway cut; and half a mile still farther west a large cut has exposed the yellowish sandy uppermost part of the clay formation, overlain by 18 feet of red and yellow sand and 10 feet of impure loess. The clay-sand contact is marked by silty limonite slabs and ferruginous sandstone.

Within half a mile east of the intersection of the Lexington-Carrollton road with Highway 82, Zilpha clay has been uncovered by highway cuts in at least two places. About half a mile east of the intersection is a shallow cut exposing clay and loess; and only about a tenth of a mile east of the same point, in a small valley, at least 10 to 15 feet of light-gray clay show on the south side of the highway. And half a mile west of this intersection, on the south side of the highway, is a face 20 feet high, measured from pavement level, made by the cutting of Zilpha beds near the bottom of a valley. The beds here are interbedded light chocolate-brown shale and fine gray sand.

This is the farthest west Zilpha outcrop along Highway 82; but road cuts and ravines a little south of the highway have exposed the clay in places for four miles farther west. About a mile and a quarter west of the Highway 82 outcrop just mentioned, a local road cut and nearby ravines (NE 1/4, Sec. 23, T. 19 N., R. 3 E.) have brought the clay to the surface 0.2-mile south of the highway and several feet below it.

The westernmost Zilpha outcrop observed in the county south of Highway 82 is along a small tributary of Palusha Creek, near its midlength (Sec. 20, T. 19 N., R. 3 E.) where the floor of the creek and the lower part of the channel walls are gray clay for a distance of more than half a mile. This is the longest Zilpha exposure in the county, so far as the present reconnaissance survey has determined. The eastern end of the outcrop is some 50-60 yards below the local road bridge, which is 0.4-mile from the highway via the local road. The greatest thickness of clay observed at any one place along the creek is about 10 feet. The right wall of the channel at a bend roughly 100 yards below the bridge shows a maximum of 8 feet of clay (Figure 12). Next to the channel the clay is overlain by a thin gravel interval and by loess; no sand. The clay along this stretch contains many marcasite concretions and fragments of lignitized wood; pieces of silicified wood, abundant in the float, may have belonged at one time to silicified tree parts embedded in the clay. Evidences of structural changes along the creek channel suggest that the notable

extent of the Zilpha outcrop here may be due, at least in part, to such disturbances. The matter is treated further in the section on Structure.

A silicified log (SE cor. Sec. 15, T. 19 N., R. 4 E.) embedded in yellow clay, is a feature of a Zilpha outcrop on a local road leading east from Carrollton almost parallel with Highway 82 half a mile north of it. The log is about three and a quarter miles east from

Figure 12.—Zilpha clay and basal part of loess, right wall of channel of tributary of Palusha Creek Sec. 20, T. 19 N., R. 3 E.) 100 yards below bridge. Hat marks top of clay and hammer an inclusion of lignitized wood.

Carrollton and 0.3-mile west from a road junction, on the south side of the road. A quarter of a mile farther west the same road extends down the east slope of the valley of a small tributary of Big Sand Creek through a cut walled with Zilpha gray clay. A thickness of 28 feet continuous exposure was measured from the valley flat, and the yellow clay top of the Zilpha beds at the petrified log is several feet higher; thus this section may include 40 feet or more of the formation. It is one of the largest in the county.

Another considerable clay section (SE 1/4, Sec. 17, T. 19 N., R. 4 E.) is in the east wall of the valley of another small tributary of

Big Sand Creek, about a mile and a half east of Carrollton, on the same local road as referred to above.

Along a bad country road through the southern part of Section 33, Township 20 North, Range 4 East are several good Zilpha outcrops, the largest of which, and also one of the best in the county, being in the southwest quarter of the section, at a place where the west wall

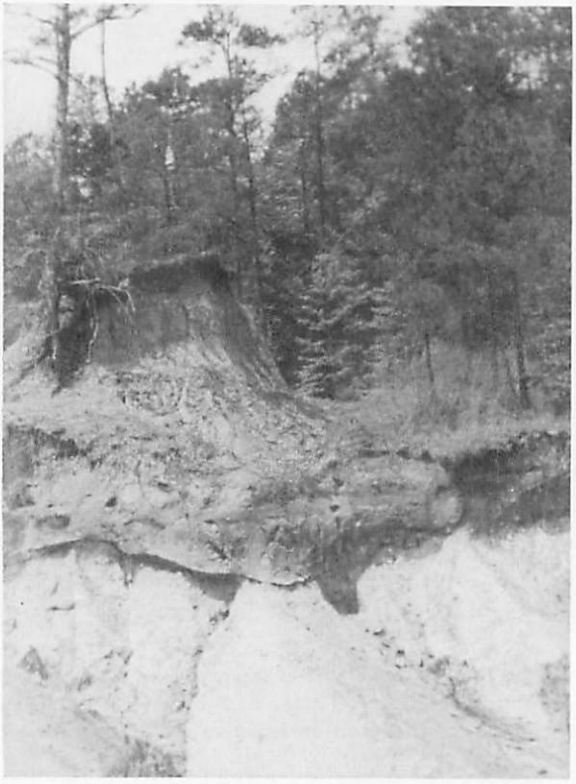

Figure. 13.—Erosion—Zilpha-Kosciusko contact? (SW ¼, Sec. 19, T. 20 N., R. 5 E.)

of a small valley is badly eroded. This outcrop is more than 250 yards long and includes a 30-foot vertical section of light-gray clay, with loess above. The local road that crosses this outcrop has been reached and cut into to some degree by erosion on both sides; obviously it will have to be abandoned soon.

Zilpha clay shows also in a road cut (SW 1/4, Sec. 28, T. 20 N., R. 4 E.) three quarters of a mile, more or less, north of the section de-

scribed in the preceding paragraph; and a mile farther north by the local road, finely laminated sand, silt, and clay which are white, pink, brown, and other colors, conspicuous in a big ravine (SW 1/4, Sec. 21, T. 20 N., R. 4 E.) east of the road, probably are upper Zilpha. The material is overlain by loess.

Four miles east of the place just mentioned, a large ravine (SW 1/4, Sec. 19, T. 20 N., R. 5 E.) west of the road has exposed a thickness of 20 feet or more of bedded white and pink sand and clay below and brown sand above a sharp contact (Figure 13). Closer examination of the material below the contact found it to be composed of thin layers of clayey and silty sand of various colors—white, light-brown, pale blue or green, and chocolate brown. At the top, in the road right-of-way, is checked gray clay, brown to red tinted on the surface, such as has been observed at the top of the Zilpha in many places. Probably the entire section of light-colored beds can properly be included in the Zilpha.

An extensive eroded area (NE 1/4, Sec. 35, T. 20 N., R. 4 E.) a little north of a road junction, shows rock material very similar in appearance to that just described. The presumption is strong that it is Zilpha, in part at least. A conspicuous feature of this outcrop is the quantity of ferruginous sandstone float, much of which may have been originally at the Zilpha-Kosciusko or Zilpha-loess contact.

At a road junction (eastern part, Sec. 14, T. 20 N., R. 4 E.) and a little north of it, a road cut and gullies have uncovered light-gray to white sandy clay and sand within a small area. Ferruginous sandstone lies on the clay. A mile or so farther north by west, a section of Zilpha terrain is well exposed on the west side of the same road by a large ravine (southern part, Sec. 11, T. 20 N., R. 4 E.). The section is about 150 yards long and includes 27 feet of light-gray to dark-gray sandy clay, interbedded with or containing lenses and lentils of light-gray or olive-drab fine sand, also oxidized concretions which were originally impure siderite. The clay is overlain by 4 to 5 feet of sandy and clayey loess. The gray clay crops out also some 0.3-mile farther north at a bend of the road.

Zilpha outcrops are not many in the northeastern corner of the county. One was observed near the center of Section 7, Township 20 North, Range 5 East, in the Sykes Creek drainage area, and another in the southern part of Section 32, Township 21 North, Range 5 East, where it is capped by heavy ferruginous sandstone, near the top of

the upland and is 0.4 mile west of a Winona outcrop. However, farther west in the northern part of the county are several excellent Zilpha exposures.

In the southwest wall of the valley of one of the headwater tributaries of a branch of Petacowa Creek, on the northwest side of a local road, at a place (SW 1/4, Sec. 16, T. 20 N., R. 4 E.) half a mile northeast of a road junction, Zilpha gray and yellow clay, capped by a bed of silty limonite, crops out in the road. It is overlain by loess. Some 2.5 miles northeast from here the clay shows in a road cut (southern part, Sec. 3, T. 20 N., R. 4 E.) in the northeast wall of another Petacowa tributary, although the southwest wall shows sand and loess only. The clay at the outcrop is overlain by Kosciusko sand.

A section from the bridge (NW 1/4, Sec. 2, T. 20 N., R. 4 E.) over the southern of the two main headwater branches of Petacowa Creek, to the top of the south valley wall, is described below:

SECTION OF THE SOUTH WALL OF THE VALLEY OF THE SOUTH MAIN HEADWATER BRANCH OF PETACOWA CREEK

Description of Interval	Feet
Recent and Peorian? formations	
Soil, subsoil, and weathered Peorian (?) loess, to the top of the valley wall	10.0
Unconformity	
Kosciusko formation	
Sand, red-brown to dull white ,containing some re-worked sandy clay towards the base, and some ferruginous sandstone	28.0
Sandstone, ferruginous, and slabs and flattish masses of dense limonitic siltstone	4.5
Unconformity	
Zilpha formation	
Clay, light chocolate-brown and light-gray; upper part stained with yellow iron rust; mostly sandy—to bridge level	3.3
Total section	45.8

One of the very best sections exposed in the county is along the local road leading east from Jefferson. A cut (SW cor. Sec. 34, T. 21 N., R. 4 E.) for this road in the east wall of the valley of a small tributary of Petacowa has revealed the section described below:

Figure 14.—Zilpha-Kosciusko contact 1.3 miles east of Jefferson (Extreme SW Cor. Sec. 34, T. 21 N., R. 4 E.)

SECTION OF EAST WALL OF VALLEY OF TRIBUTARY OF PETACOWA CREEK 1.4 MILES EAST OF JEFFERSON

Description of interval	Feet
Recent formation	
Soil and subsoil, loessial, est.	1.5
Unconformity	
Peorian formation	
Loess, gray and brown silt; sandy, est. 10.0 to	15.0
Unconformity	
Kosciusko formation	
Sand, coarse to medium, red brown to dull white; some ferruginous sandstone est. 30.0 to	40.0
Unconformity	
Zilpha formation	
Siliceous limonite, slabs—up to	0.5
Shale, chocolate-brown, and black; sandy, and some sand streaks, to level of valley flat (Figure 14)	24.0
Total section	81.0

At the road intersection (NE cor. Sec. 5, T. 20 N., R. 4 E.) in the village of Jefferson, a thickness of 15 to 20 feet of Zilpha gray clay

crops out under red-brown sand and loess. Gullies have been cut in the clay on both sides of the north-south road. Also, Zilpha clay is exposed in several places along the roads west of Jefferson, at least three of them within 0.7-mile west of the village. In the east wall of the valley of a small tributary of Petacowa Creek an eroded gray clay terrain (SW 1/4, Sec. 31, T. 21 N., R. 4 E.) has a thickness of 15 to 20 feet. The clay back from the outcrop is overlain by loess. Some 0.4-mile farther west, at a road intersection (SE cor. Sec. 36, T. 21 N., R. 3 E.) is another Zilpha exposure, and a mile west of it a thick section of clay (SW 1/4, Sec. 36, T. 21 N., R. 3 E.) shows in the east wall of another Petacowa Creek tributary. The last-named clay outcrop is almost as far west as any seen east of the Delta bluff and north of Highway 82.

Two or three Zilpha outcrops were noted in the extreme northern part of the county. The best of these is at a road junction (western part, Sec. 24, T. 21 N., R. 3 E.) where some 15 feet of gray clay are exposed, overlain by 7 to 8 feet of loessial material.

The westernmost showing of Zilpha clay observed in Carroll County is in the east wall of Teoc Creek Valley at a road crossing (SE 1/4, NW 1/4, Sec. 19, T. 20 N., R. 3 E.) or a little below it. At this point, which is some 2 miles east up the creek valley, from the village of Teoc, which in turn is at the eastern edge of the "Delta", the vertical face of the east wall of the channel shows clay, sand, gravel, and loess. The clay zone section is described below:

SECTION OF CLAY ZONE OF EAST WALL OF CHANNEL OF TEOC CREEK TWO AND A QUARTER MILES ABOVE TEOC (FIGURE 15)

Description of interval	Feet
Zilpha formation	
Clay, dark gray, stiff, plastic when wet, blocky when dry; sand inclusions; yellowish at top	8.0
Lignite seam, 1 inch	0.1
Clay and sand: Lower part consolidated dull white to light-gray rust-streaked sandy clay and sand; grades upwards into blocky dark-gray to very light lignite-brown sandy clay, darker at top	4.0
Sand, dull white, yellow laminated at top	3.7
Covered with talus to level of Teoc Creek	16.5
Total section	32.3

An estimated 30-foot thickness of gravelly sand and loess overlies the clay zone. The operators of a gravel washing plant here in-

formed the writer that the clay underlies the creek channel at a slight depth—3 to 4 feet.

A sand and loess belt, chiefly loess, 4 to 5 miles wide, intervenes between this Teoc Creek outcrop and the nearest exposed Zilpha clay east of it north of Highway 82. So far as was observed by the reconnaissance survey described in this report, the Zilpha formation does not show in the "Delta" bluff south of Highway 82, unless the sandy shale herein classified as Wautubbee should prove to be Zilpha.

Figure 15.—Bluff, left wall of Teoc Creek, western Carroll County, showing gray to white clay below, sand, gravel and loess above. At site of gravelplant (SE ¼ of NW¼, Sec. 19, T. 20 N., R. 3 E.)

THE KOSCIUSKO FORMATION

The Kosciusko formation was first named by Cooke, who described it as "ledges of saccharoidal to quartzitic sandstone exposed in the vicinity of Kosciusko, the county seat of Attala County, Mississippi, and . . unconsolidated sands of the same age in Mississippi." Thomas[11] includes in the Kosciusko all strata above the Zilpha shale and below the Wautubbee formation, and describes it as " a heterogeneous highly lenticular non-marine section in which sands and shales are the dominant facies." He states that an interval from the

base of the formation upwards, varying in thickness from 50 feet to 200 feet, is "typically composed of massive to highly cross-bedded sands which are colored red, brown, yellow, purple, pink, violet, gray, and white on the outcrop," but are invariably light of color where fresh; furthermore, that the sands are predominantly fine-grained and fairly well sorted. The shales, he says, "increase in abundance above the basal sand until they usually predominate over the sand in the upper part of the section." The shales may be light gray to mottled purple and gray silty clay, black to chocolate-brown carbonaceous, or dark gray to greenish gray (fresh) to light gray or brownish gray (weathered) lignitic silty shale. Plant fragments are abundant, and weathered remains of siderite concretions are common. "These shales are particularly abundant in the Kosciusko in Carroll County and are well-exposed along the highway between Winona and Carrollton." The ledges of quartzitic sandstone, which, according to Thomas, "are light-gray siliceous coarse siltstones which form by surface induration from light-gray compact argillaceous silt lenses in the massive Kosciusko sands," are best developed in Attala and Holmes Counties, but are present locally in Carroll. Limonitic sandstone, siltstone, and claystone are the common concretionary materials in the formation; petrified wood and lignite are rare, and in few places are the sands micaceous.

Thomas declares that the Kosciusko formation is 400 feet thick in Carroll County and that its contact with the underlying Zilpha is conformable and gradational. These conclusions are not in agreement with the present writer's interpretation of the field evidence, nor with Priddy's[13] findings in Montgomery and Carroll Counties.

Priddy[13] states: "The Kosciusko consists essentially of fine-grained to medium-grained buff well-bedded quartz sands containing two well developed beds of silt or silty clay, 50 and 90 feet respectively above its base. Distributed throughout the entire sandy phase are numerous dark grains of an iron-bearing mineral whose weathering stains exposures brick-red or reddish-brown. These grains are not glauconitic, and, since no fossils have been found, at least in Montgomery County, the unit is considered non-marine . . . . . In fresh exposures the beds of silt or silty clay are grayish-white but are tinted red, orange, and purple hues where exposed to weathering."

Priddy[13] states further that at the Carroll line, along U. S. Highway 82, there is evidence of a thickness of 100 to 150 feet, and ex-

presses the opinion that six miles farther north at a road forks (SE 1/4, Sec. 21, T. 20 N., R. 5 E.) on the Eskridge-McCarley road, the thickness of the Kosciusko may be up to 200 feet.

Concerning the Zilpha-Kosciusko contact, the same geologist says, "Although the Zilpha rests with conformity on the upper Winona glauconitic sands and ledges of ferruginous sandstone, the contact with the overlying Kosciusko sand, as pointed out, is distinctly non-conformable . . . . . resulting in a great variation in thickness of the division." He adds, "The division [Zilpha] has been eroded in several widely separated areas . . . so that the basal beds of the Kosciusko member rest on upper beds of the Winona, though not on strata lower than the glauconitic ferruginous semi-indurated sand." He mentions several Montgomery County locations where the entire Zilpha is absent.

The writer of the present report observed several places in Carroll County where the conditions mentioned by Priddy exist. They are referred to in the appropriate connection.

The Kosciusko formation, as observed in Carroll County, is almost entirely sand. In a few places it contains a small percentage of clay, especially in the basal zone. The Kosciusko lies on the Zilpha, except where removed by erosion, over all the Zilpha outcrop area, and presumably in the territory west of the Zilpha exposures. Its maximum thickness in the county probably does not exceed 100 to 150 feet. The south wall of a Highway 82 cut (western part, Sec. 20, T. 19 N., R. 4 E.) shows 31 feet of red-brown, brown, light yellow, and white coarse to medium sand, but the bottom of the formation is not exposed. In western Montgomery County, the first ridge crossed in traveling Highway 82 west from the junction of Highways 51 and 82 at Winona, is almost all Kosciusko sand, at least along the highway. Measurements from a clay-sand contact south of the highway and about a quarter of a mile west of the junction, to the summit of the ridge, proved a total thickness of 90 feet, but some 15 feet of this are loess. The section is 2.5 miles east of the Montgomery County-Carroll County line.

Good exposures of the Kosciusko sand are many. A few of the largest and most prominent will receive more than passing mention, in south-north order.

The terrain immediately west, south, and southwest of Vaiden is sand to a considerable depth, red-brown at the surface, and intricate-

ly eroded. It is prominently exposed at a road intersection (NE 1/4, Sec. 22, T. 17 N., R. 5 E.) just outside the southwest corner of the Vaiden corporate area. The Zilpha clay crops out a short distance to the northeast, and the thick sand interval lies on it, to the summit of the hill at the road intersection, where the sand is coarse and strongly cross laminated and contains many stringers, small fragments, and irregular small aggregates of clay, probably swept up from the Zilpha clay (Figure 16). The sand thickness here may be 30 to 35 feet.

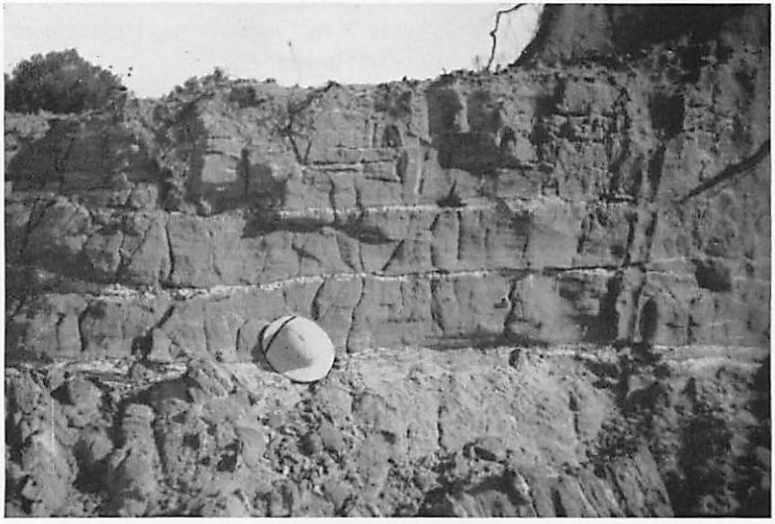

Figure 16.—Stringers of gray and purple sandy clay in irregularly bedded sand of the lower Kosciusko. Cut at five-way cross-roads about 1.0 mile southwest of Depot at Vaiden, Carroll County. E. P. Thomas, M.S.G.S., 48:12.

In the extreme southern part of the county, a big ravine or "cove" (SW 1/4, Sec. 4 or NW 1/4, Sec. 9, T. 16 N., R. 4 E.) has sand walls 30 to 40 feet high under some 10 feet of loess.

Along the Vaiden-Black Hawk road are two or three large showings of Kosciusko sand and many smaller ones. A conspicuous example of headward erosion in the sand (NE 1/4, Sec. 17, or NW 1/4, Sec. 16, T. 17 N., R. 4 E.) on the north side of the road, a quarter of a mile east of a road junction, has revealed a section which, together with the road cut, includes some 50 feet of sand (Figure 3). All along the main road in this vicinity, on both sides, are huge ravines in the red-brown sand, threatening to destroy the road. Three and a quar-

ter miles west by south from the big trench referred to above, on the north side of the road, a large exposure of eroded sand (SW 1/4, Sec. 13, or NW 1/4, Sec. 24, T. 17 N., R. 3 E.) is probably the best seen in the county for the display of points, peaks, fluted columns, and others of the great variety of erosion forms (Figure 2). At least part of the sand so conspicuous here may be Zilpha; much of it is clayey, and white or of some other light color.

The westernmost sand cut (NE 1/4, Sec. 20, T. 17 N., R. 3 E.) on this road east of Black Hawk shows a 30-foot section, including gravel in the upper part of the sand. This is the easternmost gravel outcrop observed on this road.

On the east side of the Lexington road, about 1.5 miles south of the road intersection at Black Hawk, big erosion trenches (SW 1/4, Sec. 29, T. 17 N., R. 3 E.) have been cut through 40 to 50 feet of sand and loess, but no gravel.

The Kosciusko red-brown sand is not conspicuous in the southwestern part of the county; apparently it is too far beneath the general surface level to be exposed by any except the deepest depressions. The region is a loess country in general, so far as surface material is concerned. However, at Adair a deep, vertical-walled ravine (SE 1/4, Sec. 21, T. 17 N., R. 2 E.) has bared a few feet of red-brown sand under 25-30 feet of loess. The road leading northwest from Black Hawk roughly parallel to Abiacha Creek half a mile to three-quarters of a mile farther south, traverses a region in which loess almost exclusively appears at the surface.

Along the Vaiden-Carrollton road the Kosciusko is well exposed in several places, in or near most of which the Zilpha clay shows, also. Among the Kosciusko outcrops may be mentioned specifically road cuts (northern part, Sec. 8, T. 17 N., R. 5 E.; NW 1/4, Sec. 31, T. 18 N., R. 5E.; eastern part, Sec. 25, T. 18 N., R. 4 E., at a road junction; and SW 1/4, Sec. 2, T. 18 N., R. 4 E., where pink and reddish sand is conspicuous). The most prominent sand walls of this road, however, are slightly north of a road junction (SE 1/4, Sec. 28, T. 19 N., R. 4 E.), on both sides of a cut 0.2-mile long in a slope. Features of the sand and the sand-loess contact here are the horizontal parallel small ridges or ripples (Figure 17) and the aggregate of ferruginous sandstone bowlders, blocks, and other pieces at the sand-loess contact (Figure 18). Just up slope from the road junction, in the east wall of the cut and in the west wall of a ravine on the west side of the

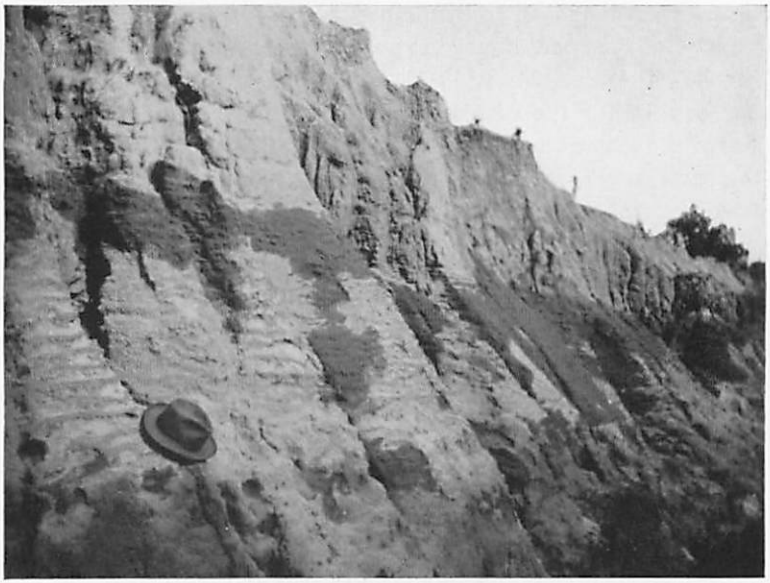

Figure 17.—Horizontal parallel small ridges in Kosciusko sand (SE cor. Sec. 28, T. 19 N., R. 4 E.)

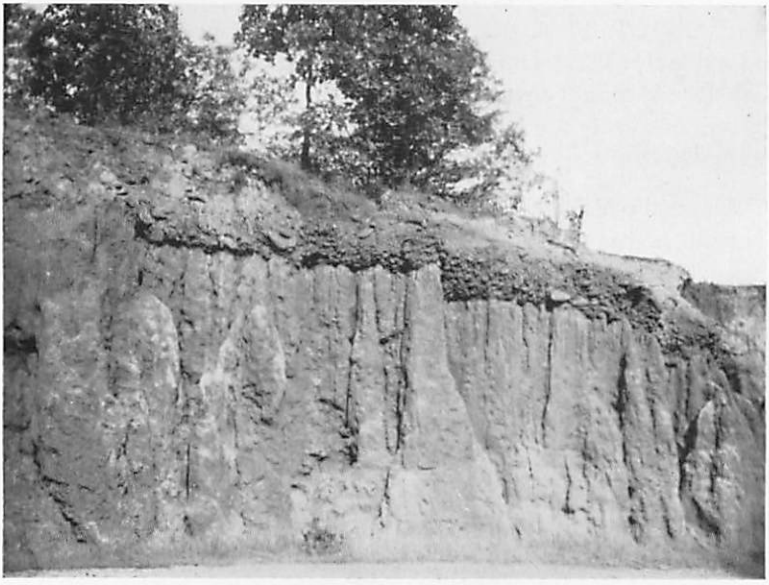

Figure 18.—Ferruginous sandstone aggregate—blocks, bowlders, and irregular pieces—at contact of Kosciusko sand and overlying loess (SE cor. Sec. 28, T. 19 N., R 4 E.)

road, variegated sand, much of it light of color and containing pink and white clay, is exposed to a height of 10 feet or so, suggesting the upper part of the Zilpha. This kind of material was observed grading downwards into the typical Zilpha clay in several localities.

Figure 19.—Sand in channel of Palusha creek; view from bridge, looking down stream (west). Sec. 35, T. 19 N. R. 3 E., near southern boundary.

Another large cut in the red-brown sand (SW 1/4, Sec. 20, T. 19 N., R. 4 E.) is about 0.6-mile southeast from Highway 82 and a few hundred feet northwest of a road junction.

The region north of the Vaiden-Black Hawk road and between the Vaiden-Carrollton road on the east and the Carrollton-Lexington highway on the west, was not explored in the present reconnaissance survey, because of lack of time, and because of uncertainty concerning the condition of the country roads and bridges; but the Carrollton-Lexington highway (unnumbered) was traveled two or three times

from Highway 82 to the southern boundary of Carroll County. It is a ridge road along the greater part of its length, but lies across the upper courses of the three largest streams of the southern half of the county —Palusha Creek, Coila Creek, and Abiacha Creek.

Half a mile south of Highway 82 the Carrollton-Lexington graveled highway is in a long cut (SW 1/4, Sec. 19, T. 19 N., R. 4 E.) on a slight rise. The walls of the cut are sand below and loess above, featured by large masses of ferruginous sandstone at the contact. Farther south big ravines in loess and sand on both sides threaten the road in places. Viewed from the Palusha Creek bridge (almost on the southern boundary of Sec. 35, T. 19 N., R. 3 E.) the wide sand-choked creek channel (Figure 19) gives more than a hint of the litho-logic character of the territory included in the stream's drainage basin, and also of what is happening to it. Road cuts in both valley walls expose thicknesses of red-brown sand.

The high point on this highway is about at two road junctions near each other (SW 1/4, Sec. 14, T. 18 N., R. 1 E.), from where the elevation gradually lessens southwards. The walls of the south head-water fork (SE 1/4, Sec. 5, and NE 1/4, Sec. 8, T. 17 N., R. 3 E.) of Coila Creek are strongly eroded Kosciusko sand.

Few outcrops of Kosciusko sand worthy of mention show west of the Carrollton-Lexington road. A long road cut (northern part, Sec. 17, and southern part, Sec. 8, T. 18 N., R. 3 E.) and the vertical walls of the creek channel at the bridge a little north of the cut, expose a con-siderable thickness of red sand. Some valley walls in the vicinity of Gravel Hill show sand outcrops, and the channel of Merrill Branch at the bridge (NW 1/4, Sec. 25, T. 18 N., R. 2 E.) is choked with sand.

The Delta bluff of Carroll County is chiefly sand, gravel, and loess, but just how much of the sand belongs to the Kosciusko forma-tion is a problem. The westernmost red-brown sand of the central belt of the county, except for alluvium, surely is Kosciusko, and presumably the greater part of the sand which appears in the bluff beneath the loess and gravel, north of Palusha Creek is Kosciusko, also, connected with the great body of the formation east of the belt of thick loess; but certainly most of the sand which underlies the loess in the Delta bluff south of Palusha Creek is not Kosciusko, but much younger.

In several places along Highway 82, on both sides, are outcrops of Kosciusko sand. From Highway 51 at Winona westward, Highway

82 lies in a series of small valleys of southern tributaries of Big Sand Creek, and a series of cuts through the upper parts of the ridges between these streams. The cuts along the three miles of pavement between Highway 51 at Winona and the Montgomery County-Carroll County line are through Kosciusko sand only. As already stated, a thickness of 75 feet or more of sand was measured in the first hill west of Winona. Highway cuts and ravines along the three miles in Montgomery County expose other considerable thicknesses of sand, most of it a deep red-brown or iron-red on the surface. As already stated, Priddy[13] found at the Montgomery County-Carroll County line evidence of a thickness of 100 to 150 feet of Kosciusko material. The easternmost highway cut (SE 1/4, Sec. 20, T. 19 N., R. 5 E.) in Carroll County likewise shows sand only, much of it light of color. Less than two miles farther west Zilpha clay appears under the sand, and crops out here and there westward for a distance of about 7 miles, in which distance the only cut which shows sand only is the one described at the beginning of the section of this paper dealing with the Kosciusko formation. Beyond the westernmost highway Zilpha exposure the Highway 82 cuts show sand and loess only except for a little gravel; the sand outcrops are at a progressively lower level and the loess thicker, until loess only is exposed. The sand reappears in the face of the "Delta" bluff.

North of Highway 82 the Kosciusko sand is conspicuous in many places, especially in the eastern half of the region, where the overlying loess is thinner than farther west. The larger streams, and a considerable number of the smaller, have cut through the loess and the Kosciusko and into the underlying Zilpha, exposing sections which include material of all three units; others, smaller or situated some distance southwest of the northeast edge of the sand formation, have not reached the clay. Being a relatively thin formation, in Carroll County, the Kosciusko has been cut into patches to such a degree that only a narrow ragged belt of it remains unbroken.

A few of the more prominent Kosciusko outcrops north of Highway 82 may be given special mention.

A complex of gullies (eastern part, Sec. 21, T. 19 N., R. 4 E.) has revealed red-brown, yellowish, and whitish sand under a small area of the west slope of a ridge not more than a quarter of a mile northeast of the measured Highway 82 Zilpha section and a lesser distance north of a Zilpha outcrop at the intersection of the highway and a

local road. Much of this deeply and irregularly eroded sand is at the same level as the gray clay of the highway outcrops, a condition which obviously suggests an interlensing or intertonguing of clay and sand, faulting, or a pronounced erosional unconformity. The sand may have filled a valley in the clay.

A mile or so east from Carrollton, on the south side of the local road which is sub-parallel to Highway 82, an old road cut (near middle of north boundary-line, Sec. 20, T. 19 N., R. 4 E.) in the west wall of the valley of a small tributary of Big Sand Creek, has been widened and deepened by erosion of loess and sand until it is a vertical-walled chasm some 75 feet deep and perhaps 200 feet wide. The walls show a sharp sand-loess contact.

The gravel highway extending east from North Carrollton a little north of the Columbus and Greenville Railway has no deep cuts, but at one place (NW 1/4, Sec. 10, T. 19 N., R. 4 E.) a short distance east of a road junction, the south wall of a cut is clay and cross-laminated sand, the clay appearing as stringers and irregular elongated sheets worked up into the red-brown sand. The two branches of Big Sand Creek crossed on this road are almost smothered in light-colored sand.

The red-brown sand and the ferruginous sandstone comprising the upper part of the large outcrop (NE 1/4, Sec. 35, T. 20 N., R. 4 E.) referred to in a preceding paragraph, probably is Kosciusko, much of the sandstone possibly having been originally at the Zilpha-Kosciusko contact. Also, at the ravine exposure previously mentioned (SW 1/4, Sec. 19, T. 20 N., R. 5 E.) the brown sand above the sharp contact is assigned to the Kosciusko formation (Figure 13). Some three-quarters of a mile northeast from this Section 19 outcrop, on the southeast side of the same road, is another large chasm cut through the loess and 20 to 25 feet into the red-brown sand.

The cuts at the road intersection (eastern part, Sec. 18, T. 20 N., R. 5 E.) are in loess and sand only, and westward from the intersection through Sections 18, Township 20 North, Range 5 East, and 13, Township 20 North, Range 4 East, a series of road cuts and nearby ravines and gullies has exposed considerable thicknesses of loess and Kosciusko sand. Perhaps the most prominent of these exposures (SW 1/4, Sec. 13, T. 20 N., R. 4 E.) is due to deep erosion on the south side of the road some 0.6-mile east of a road junction. Here the section of sand and loessial material probably is 50 feet, including a

considerable proportion of ferruginous sandstone. However, much of the sand is silty and clayey and variegated—white, pink, lilac, light purple, shades of brown, etc., and possibly should be assigned to the Zilpha, which crops out at the road junction a little farther west. Farther southwest along this same road (Duck Hill-North Carrollton) sand is very abundant, and Big Sand Creek channel and walls, as seen from the bridge between Carrollton and North Carrollton, are sand entirely.

Figure 20.—Sharp Kosciusko loess contact—Jefferson-Grenada road, (NW ¼, Sec. 21, T. 21 N., R. 4 E.)

In the northeastern corner of the county Kosciusko sand crops out at a road junction (SE cor. Sec. 31, T. 21 N., R. 5 E.) only a mile west of the Carroll County-Montgomery County line. Two and a half to three miles west of this outcrop, from a bridge over one of the headwater tributaries of Petacowa Creek up the south wall of

the creek valley, is the section (NW 1/4, Sec. 2, T. 20 N., R. 4 E.) described in the Zilpha part of the present report—a section which includes 32.5 feet of Kosciusko sand and sandstone. A mile west of this section, on the southwest side of a local road, a ravine (NW 1/4, Sec. 3, T. 20 N., R. 4 E.) cut into red-brown sand to a depth of 25 to 30 feet, threatens the road. Another big ravine (eastern part, Sec. 3) is cut in Kosciusko sand on the north side of a short east-west road three quarters of a mile southeast of the ravine in the northwest quarter of the same section, and a mile or so southwest of it is a long road cut (NW 1/4, Sec. 10, T. 20 N., R. 4 E.) exposing sand only, in the southwest wall of a small tributary of Petacowa Creek. A mile and a half south from this cut, at a road junction (NE 1/4, Sec. 16, T. 20 N., R. 4 E.) is another large sand outcrop where erosion has been active.

In the extreme northern part of the county, half a mile or less south of Grenada County, the east wall of a shallow road cut (NE 1/4, Sec. 21, T. 21 N., R. 4 E.) shows red sand below and loessial material above a sharp contact (Figure 20). The sand here contains masses of pink, purple, and white sandy clay, probably eroded from the Zilpha clay and rolled into the overlying sand.

About a mile and three quarters north of North Carrollton, and northeast of a road junction, huge ravines have been developed in the loess and sand almost all the way from the junction to the bridge over a branch of Big Sand Creek (NW 1/4, Sec. 6, T. 19 N., R. 4 E. and SW 1/4, Sec. 31, T. 20 N., R. 4 E.). The sand is red-brown above, white towards the bottom of the ravines. The Zilpha is not exposed in the deep valley, but at a curve in the road a little above the flat a large piece of silicified wood, embedded in the clayey sand, may be evidence that the place is not far above the Zilpha-Kosciusko contact. Two and a half miles north of this place, from a local road at the top of the west wall of another valley, an excellent view may be had of the intricately eroded loess and sand hills (SE 1/4, Sec. 24, T. 20 N., R. 3 E., and SW 1/4, Sec. 19, T. 20 N., R. 4 E.).

The channel of Petacowa Creek, as seen from the bridge a mile and a quarter north of Jefferson (SW 1/4, Sec. 28, T. 21 N., R. 4 E.) and the bridge site 4 miles farther west (SW 1/4, Sec. 26, T. 21 N., R. 3 E.), is a waste of whitish sand, over and through which, at times of low water, the creek winds its way. In places along this creek, as along the other main streams of the county, the water flows as two

or three or even more streams—that is, as distributaries (Figure 21). Most of the sand which clogs the channels of these creeks is from the Kosciusko formation.

The road intersection (SE 1/4, Sec. 3, T. 20 N., R. 3 E.) is in big cuts walled with red sand, and a mile and a half southwest of it

Figure 21.—View of Coila Creek, looking upstream from bridge (NE ¼, Sec. 4, T. 17 N., R. 2 E.)

similar cuts (northern part, Sec. 9, T. 20 N., R. 3 E.) for the Carrollton-Grenada County graveled highway in both walls of the valley of Thompson Branch expose sand, gravel, and loess. Also, sand, gravel, and loess are revealed by cuts for the same highway in the Teoc Creek Valley walls (NW 1/4, Sec. 21, T. 20 N., R. 3 E.) and in the walls of the valley of Little Teoc Creek (SE 1/4, Sec. 23, T. 20 N., R. 3 E.). Another cut exposing sand, gravel, and loess is at the road

intersection (near center, Sec. 35, T. 20 N., R. 3 E.), and other and smaller outcrops are farther south along the same highway.

Everywhere along the "Delta" bluff sand underlies the loess, and in most places gravel also is present. As already stated, north of Palusha Creek most of the bluff sand is Kosciusko.

A gravel pit (NE 1/4, Sec. 14, T. 19 N., R. 2 E.) in the face of the bluff a little less than half a mile north of U. S. Highway 82, exposes the section described below:

SECTION OF EAST BLUFF OF VALLEY OF THE MISSISSIPPI RIVER, 0.45-MILE NORTH OF U. S. HIGHWAY 82

Description of interval	Feet
Peorian formation	
Loess and loessial soil: loess, gray to light-brown slightly sandy silt 20 to	25.0
Unconformity	
Citronelle (?) formation	
Gravel and sand: brown coarse to fine sand, containing a large proportion of gravel, chiefly chert	18.0
Unconformity	
Kosciusko (and Zilpha?) formation	
Sand and clay: A large body of sand, brown, at least on and near the surface of the exposure; cross-bedded and otherwise current-bedded in places; includes irregular bodies and masses, large and small, of silty and clayey sand of several colors—white, pink, brown, yellow, red, purple, etc.—also some red, purple, pink mottled plastic clay. All the light-colored sand and clay has the appearance of having been re-worked into the dominantly brown sand body: rounded masses and angular fragments are conspicuous, embedded in sand, and the whole aggregate has a mixed up appearance. About	25.0
Covered: material washed down and slumped from above, to "Delta" plain, about	25.0
Total section	93

The terrain here is so churned up over a large area as a result of recent gravel digging operations and probably slides of an earlier date, that the stratigraphic succession and thicknesses of the geologic units are difficult to make out, and only rough measurements were possible.

North of Big Sand Creek the few bluff face exposures show the same succession of sand, gravel, and loess, with not more than a sug-

gestion of clay. In fact, the region is known as a "sand country", and most of the sand is, or was, part of the Kosciusko formation. The most prominent outcrops along the bluff northwards from Big Sand Creek for a distance of about three miles are afforded by the walls of the cut (NE 1/4, Sec. 2, T. 19 N., R. 2 E.) for a main graveled highway up the bluff. This road cut, some 0.7-mile long, shows only the upper few feet of the sand and gravel, because the loess, although it has a maximum thickness of only 25 feet, is present at all levels.

Large gravel pits (northern part, Sec. 35, T. 20 N., R. 2 E.) have exposed the loess, gravel, and some Kosciusko sand to a considerable depth, but no clay. Between the pits and Teoc Creek, some two miles farther north, the geological features are pretty well concealed. The left wall of the creek valley up stream two miles or more from the Delta shows a good section, already described in the part of the paper relating to the Zilpha formation. Reconnaissance along the bluff for almost two miles north of Teoc found no outcrop of consequence, but gravel pits (Secs. 25, 36, T. 21 N., R. 2 E.) bring into view the same materials observed farther south.

THE WAUTUBBEE FORMATION

The name "Wautubbee" was first used by Lowe,[6] who applied it to certain marls and sands of eastern Mississippi, which he included in the Lisbon formation. Thomas's[11] Wautubbee formation "includes all of the marine section above the Kosciusko and below the Cockfield in eastern and central Mississippi and its non-marine equivalent, the Shipps Creek shale, in western Mississippi". The same writer states further, "In western Holmes and Carroll Counties there is a thick tongue of carbonaceous shale lying at the stratigraphic horizon of the marine Wautubbee. It is named the Shipps Creek shale member in this report [Reference 11] and is considered to be the non-marine extension of the Wautubbee formation." The type locality is Shipps Creek, east-central Holmes County. The Shipps Creek member of the Wautubbee formation is composed of black to chocolate-brown to light-gray laminated carbonaceous shale, and gray to yellow to brown fine-grained loose sand. The shale contains irregular partings and interbeds of light-gray coarse silt, along which are flaky yellow-brown siltstone concretions; the whole is regularly bedded, but individual laminae are extremely irregular and lenticular; abundant plant fragments are in the shale; some of the fresh material is very lignitic. "The carbonaceous shales are interbedded and interlensed with silts and sands in an extremely complex man-

ner." The sand contains partings of gray shale, and many flaky siltstone concretions.

"The lower contact of the Shipps Creek is conformable and highly transitional," and the upper is conformable and varies from sharply defined to transitional. The thickness in the type area is about 65 feet, but the thickness along the "Delta" bluffs is about 200 feet.

The north wall of the channel of a small tributary of Abiacha Creek some 75 yards below the road bridge (SW 1/4, Sec. 16, T. 17 N., R. 2 E.) exposes the section described below:

SECTION OF NORTH WALL OF CHANNEL OF ABIACHA CREEK TRIBUTARY (FIGURE 22)

Description of interval	Feet
Peorian formation	
Brown and gray loess, slightly sandy	8.0
Disconformity	
Older Pleistocene terrace formation	
Sand, gray, and rusty light-brown, with much gravel; conglomerate at base	15.0
Unconformity	
Wautubbee formation, Shipps Creek shale	
Shale, very sandy, or shaly fine sand, dark-blue to purplish black, lignitic; laminated, fine white micaceous sand along laminae planes; leached to light color towards the top and fairly well consolidated in places	3.0
Total section	26.0

The dark shale is exposed along the base of the channel wall for about 200 feet.

The south wall of the creek valley, above the bridge is loess except for a little gravel towards the base. The north wall is loess and a little brown clay under it.

A stratigraphic section (NE 1/4, Sec. 13, T. 17 N., R. 1 E.) of the north wall of a road cut in the south wall of the valley of Abiacha Creek consists of some 15 feet of sandy gray clay becoming chocolate-brown towards the top. The clay is overlain by 3 to 4 feet of a very dark, soft earth, which is in turn overlain by 10 feet of gray and brownish loess. Farther down the slope sand and gravel, very similar to the sand and gravel of the Abiacha Creek tributary section, appear, apparently above the gray sandy clay, although their place in the

section is doubtful, inasmuch as at the place where the measurements were made no sand and gravel are present. The gray sandy clay, which is notably compact, and grades upward into light-brown material of the same character, is believed to belong to the Shipps Creek shale; the dark, soft interval may be Farmdale loess, or may be weathered Shipps Creek.

Figure 22.—Shipps Creek shale and overlying sand and gravel in north wall of tributary of Abiacha Creek, 75 yards west of bridge (SW ¼, Sec. 16, T. 17 N., R. 2 E.)

A short distance northwest of the place described above, the right (north) wall of the channel of Abiacha Creek at an old bridge pier (NE 1/4, Sec. 13, T. 17 N., R. 1 E.) a quarter of a mile or so above the present creek bridge, is a vertical cliff at the base of which, slightly above low water-level, the dark Shipps Creek shale is exposed (Figure 5).

Although no other outcrops of the Shipps Creek shale were observed during the present reconnaissance, the accuracy of Thomas's[11] statement, "Lithology typical of the Shipps Creek may be seen along practically every stream in the Loess Hills region of northwestern Holmes and southwestern Carroll Counties," is not herein questioned. Very probably the shale shows at the surface in several

other places in the rather large territory that might be included in southwestern Carroll County, but such places could not be searched out and studied in the time available for the present work. However, Thomas[11] mentions specifically 5 feet of black shaly lignite exposed at a spring (NW 1/4, NE 1/4, Sec. 1, T. 17 N., R. 1 E.) on the bluff about 2 miles north of Pine Pluff. He states also: "The black shales of the Shipps Creek are found along the bluffs bordering the alluvial valley of the Mississippi River for a distance of six miles north of the Carroll-Holmes County line and also along Abiacha and Coila Creeks and their tributaries."

THE CITRONELLE FORMATION

The name "Citronelle", originally applied by Matson[14] to a heterogeneous body of sands, gravels, and clays, widespread in southern Mississippi and contiguous states, has been used as a convenient designation for the same kinds of rock materials at the same general stratigraphic position far north of the type locality.

The Citronelle terrain in Carroll County is composed of sand and sandstone, gravel and conglomerate, silt and clay, and a few minor components. The proportion of chert in the gravel is so much greater than that of any other kind of rock that quantitatively the others are relatively insignificant. Crystalline quartz probably is the second most abundant component of the gravel; quartz pebbles are scattered through the chert, sparsely everywhere, but more numerous in some places than in others. Most of the quartz pebbles are small, well rounded, and colored. The chert gravel has a range of size from cobbles, even bowlders, to pea gravel; commonly it is dull white or gray or brown, but includes pieces of blue, red, yellow, black, or other colors. Most of the chert gravel is pretty well rounded.

The Citronelle, as decribed by Maston, is expressed topographically by a series of terraces of Pliocene age; but some later investigators have not only questioned the correctness of the age assignment, but have contended that the entire unit is of Pleistocene age. Indeed, doubt has been expressed that the so-called Citronelle is a unit. However that may be, and whether or not the formation of the type locality can be traced to all the places where it has been reported to be present, the fact remains that in Carroll County, as in all the counties which border the Mississippi alluvial plain, gravel, in a matrix of brown sand, immediately underlies the loess pretty generally in the face of the bluff and to several miles east from the bluff. It is not

a continuous bed of uniform thickness, nor does it wedge out uniformly towards the east; in fact, it is of very irregular thickness, and in some places is absent. The gravel zone ranges in thickness from a mere stringer to 30 feet or more; furthermore, thickness changes radically in short distances, so that large accumulations, or pockets, of gravel may be only a few rods distant from thin stringers of gravel or from barren sand. No sharp contact of gravel and underlying sand was observed. Where sparse gravel overlies Kosciusko sand, it seems to be in the upper part of the sand body, not lying on it as a separate unit above a definite contact. Of course such a relationship would almost necessarily come to be where gravel mixed with sand is deposited on a sand surface from over-loaded water which is incapable of degradational work: after deposition of the gravel, it would tend to sink into the underlying sand of its own weight, forcing the lighter sand and silt upwards relatively until the gravel is incorporated with the sand which originally underlay it, as well as with the sediments deposited with it. Furthermore, where the materials involved are exposed to the atmosphere, percolating rain water carries the finer particles downward, so that sediments younger than the gravel are mingled with it. In short, in many places a sharp contact between gravel and older sand probably never existed, or if it did exist it has been obliterated by weathering processes. Some gravel even appears to be in the basal zone of the loess, probably because of the settling of the silt or its downward transportation by ground water.

The so-called "Citronelle" gravel, sand, and clay lies on the Tertiary formations along most, if not the entire length of the bluff from Memphis to Vicksburg, and south of Vicksburg, and extends eastwards several miles under the loess. In Carroll County, it lies on the Kosciusko sand in the bluff at least as far south as Palusha Creek. In the southwestern part of the county gravel overlies the Wautubbee, but much of it, perhaps all, is Pleistocene.

The easternmost gravel bed observed in the southern part of the county is at a deep road cut (NE 1/4, Sec. 20, T. 17 N., R. 3 E.) half a mile east of Black Hawk. The gravel interval here is not thick, and no gravel was seen along the Carrollton-Lexington road south of Black Hawk, although deep ravines (SW 1/4, Sec. 29, T. 17 N., R. 3 E.) expose a thick loess and sand section. In fact, outcrops of gravel are few between the Mississippi River Valley bluff and the Carrollton-Lexington road. Some gravel shows in the vicinity of Gravel Hill (Secs. 24 and 25, T. 18 N., R. 2 E.), and at a place or two northeast

of there. However, the large gravel deposits are in the Delta bluff and in the walls of some of the creek valleys which open on the Delta. Probably the largest accumulations of gravel in the county are in the bluff in the vicinity of Wall's store, some 3 miles north of Seven Pines. A quarter of a mile or so northeast of the store huge pits (NW cor. Sec. 21, T. 18 N., R. 2 E.) have been opened in an area of several acres. The pit walls expose a section of 30 to 35 feet of gravel mixed with sand, and it was reported that a hole to a depth of 25 to 30 feet below the floor of the present pit found sand and gravel all the way down. The gravel, in stringers and irregular pockets or scattered thickly through the sand, is chiefly medium to small chert pebbles. The sand is brown and gray, the wall as a whole appearing brown. In a fresh face, both sand and gravel are seen to be notably cross-laminated in various directions. The pit floor is at an elevation of 20 to 25 feet above the Delta flat, and the top of the bluff probably is 150 feet above the flat.

A mile or less northeast of the big pits, a road cut (NE 1/4, Sec. 16, T. 18 N., R. 2 E.) in the bluff exposes sand, gravel, and loess, but no great thickness of gravel.

The north wall of the valley of Palusha Creek is sand, gravel, and loess at a place (NW 1/4, Sec. 28, T. 19 N., R. 3 E.) four miles east of the bluff. The gravel is exposed in the face of the valley wall and in a gravel pit. Also, a mile farther north, a 2-foot to a 3-foot bed of sand and gravel underlies the loess of the channel walls of a small tributary of Palusha Creek (Sec. 20, T. 19 N., R. 3 E.), and gravel is abundant in the channel.

The easternmost exposure of gravel along Highway 82 is at the intersection of the highway and a local road (NE 1/4, Sec. 23, T. 19 N., R. 3 E.) a mile and a half west from the intersection of the highway and the Carrollton road. Here scattered small pebbles are associated with ferruginous sandstone and clay lentils as contact features. From this point the gravel interval can be traced westwards in the walls of the highway cuts and in the eroded slopes on both sides of the highway. About 1.3 miles west from the easternmost of the gravel outcrops a pit (SE 1/4, Sec. 15, T. 19 N., R. 3 E.) on the north side of the highway has exposed a thickness of 15 to 20 feet of mixed sand and gravel below 15 to 18 feet of loess. The gravel is the usual Citronelle or "Lafayette-type", chiefly chert, but a small proportion of crystalline quartz.

The gravel can not be seen along the Highway far west of the gravel pit, because of the thickening of the loess as well as the irregularity of deposition of the gravel; but of course it appears in the face of the river bluff. The largest exposures in the bluff north of Highway 82, most of them created by gravel pits, have been described in the sections on the Zilpha and Kosciusko formations. The northernmost observed is some 3 miles east by south of Avalon, a little north of the place (near center, Sec. 36, T. 21 N., R. 2 E.) where a main graveled road reaches the Delta. East of the bluff and north of Highway 82 the gravel is at the surface in many places, all well west of Range 3 East. For example, as already mentioned, it can be observed in at least three places along the graveled highway leading northwest from Carrollton—specifically, a) in the walls of the valley of Thompson Branch; b) in the southeast wall of the valley of Teoc Creek; c) in the south wall of the valley of Little Teoc Creek. And within a mile north of Big Sand Creek are other outcrops: a) at Malmaison, in the walls of a deep road cut (NE 1/4, Sec. 7, T. 19 N., R. 3 E.) almost against the Columbus and Greenville Railway; b) gravel pits (SE cor. Sec. 5, and NE cor. Sec. 8, T. 19 N., R. 3 E.), on the railway; and c) gravel pit (NE cor. Sec. 3, T. 19 N., R. 3 E.).

Only a few places where deposits of gravel or gravelly sand may be observed have been mentioned. Without doubt many others could have been found, but it is believed that those referred to are typical.

OLDER PLEISTOCENE FORMATION

At places in the Delta bluffs intervals of lighter colored sand and gravel crop out immediately under the loess. Both gravel and sand are different from the typical Citronelle material—lighter of color, less compact, not so well cemented; furthermore, the proportion of quartz in the gravel is greater, and the ratio of gravel to sand is smaller. The gravel is distributed through the sand as stringers and lentils and thin lenses. This body of sand and gravel resembles the Natchez formation of Adams County, and at one time may have been connected with it, possibly as deposits of the same or a similar valley train. Its relationships with the Citronelle suggest that it may have accumulated in part in places whence the Citronelle and perhaps some Tertiary material had been removed by erosion, perhaps by Pleistocene waters. Leighton and Willman[16] noted in northwestern Mississippi, in the north bluff of the Coldwater River, on the east side of

U. S. Highway 51, under a loess exposure and above Lafayette-type sand and gravel, 1 to 3 feet (more than 10 feet in a small pit near by) of "sand, medium to fine, light gray with limonite-stained bands, loose." They considered the deposit "Older Pleistocene" (questionably). In Yazoo County they observed, a quarter of a mile south of the town named Valley, in a borrow pit in a bluff east of the railroad, 8 feet of "sand and silt, white and brown, cross-bedded, noncalcareous, basal concentration of pebbles." They did not assign an age to this material more definite than "Pre-Loveland". And in Warren County, at Redwood, in the borrow pit 100 yards east of Highway 61, the same kind of Pre-Loveland sand and silt was measured: "Sand, brown, contains lenses of fine angular chert gravel, 0-3 feet; silt, gray, mottled rusty, compact, crayfish borings, 4 feet." Some four miles farther south, sand of the same stratigraphic interval is classified as Natchez formation.

A few outcrops of sand, gravel, and silt very similar to those described in the foregoing show along the Mississippi River Valley bluff of Carroll County, and are thought to be correlative with them.

A promontory (NE cor, Sec. 22, T. 19 N., R. 2 E.) of the south wall of the valley of Palusha Creek between the old and the new bridge and about 0.2-mile above the new bridge, shows, under 20 feet or so of loess, some 25 feet of light-gray, white, and brownish sand containing here and there stringers of small, generally light colored gravel. The sand appears to be Pleistocene terrace sand and to underlie the beautiful little terrace a little below the top of the bluff which overlooks the abandoned Army Air Field. The whitish sand shows in the face of the terrace, along the road leading down the bluff to the landing field. The terrace sand of the Palusha Creek section probably is correlative with that of Abotcaputa Creek and the exposure southeast of Wall's store; possibly also with the sand and gravel interval which lies on the Shipps Creek shale outcrop north of Adair (Figure 21).

Half a mile or a little farther down stream from a road bridge, the left (south) wall of the channel of a small tributary of Palusha Creek is a 10-foot interval of silvery gray and white sand containing light-blue and white gravel, overlain by 10 to 15 feet of loess (SW 1/4, Sec. 20, T. 19 N., R. 3 E.). Presumably gravel shows here and there all along the walls of Palusha Creek Valley to the Delta bluff,

and the gray and white gravelly sand last mentioned may be correlative with the sand of the promontory near the debouchure.

At the foot of the descent through a long deep cut into the valley of Abotcaputa Creek and along the creek for nearly a mile below the bridge (Secs. 2 and 3, T. 18 N., R. 2 E.) gravel and sand are being dug from the creek channel, washed and screened, and piled on the creek flat, to be trucked away as sold. Great quantities of gravel have been and are being taken from the channel of this small stream, which has been cut into, perhaps entirely through in places, the body of sand and gravel which underlies the loess. The walls of the road cut show several feet of sand and gravel under the loess, in the form of interlocked lenses and lentils highly cross laminated and otherwise irregularly bedded. An interval of white sand containing aggregates of gravel overlies the main body of gravelly sand, which is gray and white and yellow; the gravel consists of small to large pebbles, and is in general light of color, not brown as is most of the Citronelle gravel. It seems probable that the sand and gravel here are Pleistocene terrace materials. The sand is very similar in appearance to that exposed by ravines and a road cut (NW 1/4, Sec. 21, T. 18 N., R. 2 E.) in the bluff at a road junction less than a quarter of a mile southeast of Wall's store, where the sand is fine, bedded, gray, tan, light-brown, light-yellow and dull white, is loose as a whole, and contains some more resistant laminae, and small clay fragments. At the Abotcaputa Creek outcrop the sand includes some lenses of clayey silt or dark-brown soft clayey earth, which may possibly have come from the Wautubbee beds or may have been derived from the decay of masses of clayey or silty organic matter buried in the sand and gravel. The same sand interval is exposed in a cliff (SW 1/4, Sec. 2, T. 18 N., R. 2 E.) which forms the left (south) wall of the creek channel a few rods east of the bridge; also at the road junction a quarter of a mile farther south.

THE LOESS, GENERAL

The loess of Carroll County is a segment of the great belt of loess which extends from north of the State of Mississippi through the entire state lengthwise as the uppermost part of the bluffs which bound the Mississippi River Valley on the east. This loess belt as a whole is thickest in the bluff escarpment and thinner eastwards from there, its thickness from west to east lessening at a roughly uniform rate as the distance from the escarpment increases. Some measure-

ments along Highway 82 made by a field party from Illinois[15] provide concrete evidence of this thinning of the loess eastwards and also information as to the rate of change:

Distance east from the top of the bluff escarpment	Thickness of loess, feet
1 mile	15 - 24
1.6 miles	15
3 miles	19
5 miles	16 - 19
6 miles	15
7 miles	13
9 miles	9
11 miles	8 - 10
13 miles	7 - 8
16 miles	7
17 miles	6
18 miles	5

In general, then, the loess formation as a whole is a long roughly wedge-shaped body lying with its length north-south, its thicker edge towards the west and its thin edge towards the east.

Loess is chiefly silt, commonly gray to light-brown, but in places darker brown to red-brown, tan or yellowish or bluish-gray. Mechanical analyses have shown, however, that not all of it is silt. One such analysis of weathered loess found that the sample analyzed contained 86.9 percent silt, 6.3 percent clay, and 5.6 percent very fine sand; materials of larger size negligible.[16] The individual particles are extremely fine: it was determined that 96 percent or more of some samples of fresh loess were composed of particles less than .0025 millimeter in diameter.[17] As a rule the particles of unweathered loess are sharply angular, a condition which is believed to be a factor contributing to the notable capacity of the loess to resist erosion and to stand with vertical-faced walls. Its high porosity no doubt permits rapid absorption of water, and thus helps to prevent washing, whereas interlocking of the angular particles may retard erosion. Yet, in spite of its capacity to withstand degradational agencies, loess may be easily crumbled in the hand.

Chemically, fresh loess of course is a composite of the chemical elements and compounds of which the minerals are composed. The analysis record of a loess sample from Adams County is as follows:[18]

Insoluble matter [largely silica and alumina]	67.377
Peroxide of iron } Alumina }	5.920
Potash	.139
Soda	.104
Lime	11.934
Magnesia	2.084
Brown Oxide of manganese	.171
Phosphoric acid	.138
Sulphuric acid	.002
Carbonic acid	8.976
Organic matter and water	3.087
Total	99.932

Beneath the subsoil and soil, which almost invariably are loessial in some degree at least, the uppermost formation over the whole of Carroll County is loess, which is present in greater or less thickness everywhere except where it has been removed by erosion. Numerous loess outcrops have been mentioned in the sections of this report which relate to older formations, and some thicknesses have been given. The greatest thicknesses are, as has been stated, in the bluffs which bound the Mississippi River Alluvial Plain on the east. The best exposure noted during the reconnaissance field work on which the present report is based, is in the south wall of the valley of Abotcaputa Creek at a road junction (NW 1/4, Sec. 10, T. 18 N., R. 2 E.) from which point a deep road cut extends southeast and south a quarter of a mile to the top of the bluff. The road from the south is between vertical loess walls from the surface of the upland to the floor of the creek valley except for a few feet of gray to light-brown gravelly sand which crop out under the loess at the junction of the roads. A 30-foot to a 40-foot thickness of loess is exposed here. The place is only a mile west of a similar loess and sand section (SW 1/4, Sec. 2, T. 18 N., R. 2 E.) referred to on a previous page.

THE LOESS FORMATIONS

Recent studies of the loess of the southern Mississippi Valley have discovered that it is not, as it has been considered to be by many writers of the past, physically a massive homogeneous unit, but consists of three distinct sheets. "The upper or surface sheet corresponds in position and appearance to the Peorian loess of Leighton and his coworkers, while the middle sheet corresponds to the Late Sangamon. The 'Third' or lower sheet is without correlation at this time but may correspond to the Loveland loess of the Missouri River Valley."[8] The

names "Peorian", "Late Sangamon", and "Loveland" are in general use in the Upper Mississippi Valley region to designate different loess deposits. Leighton proposed the term "Farmdale" as a substitute for "Late Sangamon", and the shorter and more distinctive name is used in this report. The writers quoted above continue, "Although the upper or Peorian seems to be represented in every observation where loess was present, the Late Sangamon (Farmdale) and 'Third' (Loveland?) loess could be present or absent as a result of variable erosion before the Peorian was laid down, variations in the wind during deposition, or distance from source. Where the total loessial material is less than six or eight feet thick or the Peorian loess less than four feet, the different sheets are not easily identified in the field."[8]

The Peorian loess is the "loess" of most writers. It makes up by far the greater part of the total loess interval almost everywhere. As appears from the few loess sections of Carroll County described herein, the Peorian loess comprises 80 percent more or less, of each section. It is the pale brown to yellowish-brown material which shows vertical faces of road cuts and gully walls, and in most places contains fossil snail shells and irregularly shaped lime concretions. The Peorian is the calcareous loess, although it includes a yellowish-brown non-calcareous silt-loam leached interval as its uppermost part —the "brown loam" of several writers. The Farmdale, subjacent to the Peorian, is non-calcareous in most localities, and more compact than the Peorian; morever, it is commonly a darker brown or redder brown than the overlying Peorian. The Farmdale is not separated from the Peorian by a sharp contact line, but grades gradually from it. The lowest, or "Third" or Loveland loess sheet can be distinguished from the others by a brownish-yellow fossil soil and a yellowish-brown red-mottled subsoil, grading downwards sharply into yellowish-brown to brownish-yellow non-calcareous silt loam, where the deposit is sufficiently thick; that is, the Loveland interval has a brownish-yellow or yellowish-brown color. It is much older than the other two loess sheets, and was much weathered before their deposition.

Mineralogically, the calcareous Peorian loess is chiefly orthoclase feldspar and quartz, but it contains also several other mineral species—mica, plagioclase feldspar, and heavy minerals, notably hornblende. The weight percentage of heavy minerals is high. The minerals of the Farmdale differ only slightly from those of the Peor-

ian—indeed, most of them are the same as those of the leached, non-calcareous zone of the Peorian. The Loveland, being more weathered than the Farmdale or the Peorian, contains only minor percentages of any minerals except the most resistant such as quartz. A rather high percentage of titanium minerals was found.

Descriptions of a few loess sections along Highway 82, by Leighton and Willman,[15] of the Illinois Geological Survey, are given below, with titles and some additions to the classification:

SECTION OF WALL OF HIGHWAY 82 CUT 0.9-MILE WEST OF CARROLLTON ROAD INTERSECTION (ELEV., 260' A.T.)

Description of interval	Feet
Pleistocene series	
Peorian formation	
Loess, lower 1 foot to 2 feet slightly calcareous	11.0
Farmdale formation	
Loess, darker than overlying loess	2.0
Unconformity	
Eocene series, Claiborne sub-series	
Kosciusko sand and micaceous silt	

SECTION OF WALL OF HIGHWAY 82 CUT 1.8 MILES WEST OF CARROLLTON ROAD INTERSECTION

Description of interval	Feet
Pleistocene series	
Peorian formation	
Loess	13
Farmdale formation	
Loess, sandy	2
Unconformity	
Eocene series, Claiborne sub-series	
Kosciusko formation	
Sands, red and purple	5

SECTION OF WALL OF GRAVEL PIT ON NORTH SIDE OF HIGHWAY 82, 2.8 MILES WEST OF CARROLLTON ROAD INTERSECTION (ELEV., 250' A.T.)

Description of interval	Feet
Pleistocene series	
Peorian formation	
Loess in part, colluvium in part	15
Farmdale formation	
Loess, 1 to	3
Unconformity	
Pliocene (?) series	
Citronelle, or Lafayette formation	
Gravel ("Lafayette-type") and sand	15

SECTION OF WALL OF HIGHWAY 82 CUT 5 MILES WEST OF CARROLLTON ROAD INTERSECTION

Description of interval	Feet
Pleistocene series	
Peorian formation	
Loess, lower 6 feet calcareous	15
Farmdale formation	
Loess	2
Loveland formation	
Loess	2

SECTION OF WALLS OF HIGHWAY 82 CUTS 6.8 MILES WEST OF CARROLLTON ROAD INTERSECTION

Description of interval	Feet
Pleistocene series	
Peorian formation	
Loess, 15 to	20
Farmdale formation	
Loess	4
Unconformity	
Pliocene (?) series	
Citronelle, or Lafayette formation	
Gravel ("Lafayette-type") and sand	4

The question of the origin and mode of accumulation of the loess has been answered in different ways, but none of the answers given seems to have satisfied all geologists. However, of late, general, although not complete, agreement has been reached among soil scientists and geologists that loess is a wind-deposited silt. The primary source of the loess of the southern Mississippi Valley was the flood-plain of the Mississippi River, and probably was limited to the meander belt of the river, the part of the flood-plain that received the coarser sediments.[8] It is believed that during the melting of the huge ice sheets in the glacial age, enormous volumes of water poured southward to the Gulf, carrying immense quantities of silt, much of which was spread on the river flood-plain at times of reduced volume of water, as during the intensely cold winters. At times of low water, then, wide, almost dry silt flats, bare of plants, were left exposed to sun and wind, and the winds, most of which were southwesterlies, sweeping the flats, lifted clouds of the dry silt onto the bluffs along the eastern side of the flood-plain, where it accumulated to considerable thicknesses close to the source of the silt (loess) and as a progressively thinner blanket towards the east.

THE RECENT FORMATION

In the broad sense, all rock material which has been changed from its condition (and this may include its stratigraphic and geographic position) at the close of the Pleistocene epoch, to its present condition, is part of the Recent formation. Of course such a "definition" does not sharply define, because the Pleistocene epoch did not close on any specific date, nor does a clear-cut contact exist everywhere between sediments which may be called Pleistocene and those which are correctly classed post-Pleistocene, or, for that matter, between post-Pleistocene materials and rock older than Pleistocene. In general, the Recent formation consists of the more or less unconsolidated rock debris classed as alluvium, colluvium, talus, and residual mantle rock: rock waste, residual or in transit, derived from older rock units through weathering and erosion processes.

By far the thickest part of the Recent formation of Carroll County is the narrow block of the great Mississippi River Alluvial Plain. Brown[7] states that the average thickness of this "river-dropped alluvium" for the plain as a whole is 140 feet, and inasmuch as the body of alluvium thickens southwards, in Carroll County it may have a greater thickness than the average. To say that the alluvium at a certain place is composed of all kinds of rock materials which the parts of the river system north and east of that point have reached, would hardly be an exaggeration; but except for a relatively small proportion, it consists of sand, silt, clay, and gravel. These kinds of sediments are intermingled to some extent, as clayey, silty, or gravelly sands, sandy or clayey silts, sandy or silty clay, and sandy gravel; but in general, and roughly, the material of each type is aggregated as units, commonly interlensed or interbedded with materials of the other types mentioned. From the river channel towards the bluffs an erratic gradation from coarser to finer sediments is the general order; it would seem, then, that the Carroll County part of the alluvium which underlies the plain of the Mississippi River should be largely silt and clay and fine sand, because the region is "backland", near the bluff. At greater depths, fine material may predominate; but at the surface and to some considerable depth sand is more abundant than any other kind of rock, due to the great quantities of sand brought to the river plain by numerous short streams from the east, which have built large alluvial fans at the foot of the bluff.[4] [5]

The logs of two Carroll County wells,[7] both at the foot of the bluff, show the sequence and character of the rock beds at the re-

spective locations. The John Long well (NW 1/4, SE 1/4, Sec. 23, T. 20 N., R. 2 E.) at Teoc was drilled through 20.4 feet of soil and clay, 21.7 feet of sand, 19.5 feet of sand and gravel, and 14.0 feet of gravel, a total thickness of 75.6 feet of alluvium, above the Zilpha clay. The Ralph Rivvett well (NE 1/4, NW 1/4, Sec. 30, T. 18 N., R. 2 E.) found 10.0 feet of "dirt" (soil, subsoil, clay), 23.2 feet of sand, 25.2 feet of gravel, 26.4 feet of sand, and 38.2 feet of gravel above the Kosciusko formation, a total of 123.0 feet of alluvium.

The alluvium of the valleys of the streams of Carroll County is dominantly sand, eroded from the Kosciusko formation (Figures 19, 21), although it contains a large proportion of silt from the loess and some considerable clay from the Zilpha formation and the shaly and clayey phases of the Kosciusko. Some of the valley flats are relatively wide, and the alluvium of their lower reaches may be 25 to 50 feet thick. Many tributaries of the larger streams have narrow floodplains underlain by alluvium which constitutes the only good farm land of the more rugged sections of the county. The soil may be sandy, but its loess admixture gives it a fertility greater than that of the soils farther east, beyond the boundary of the loess.

In all parts of Carroll County waste from its crumbling sand and clay foundation is falling or creeping down slope or being carried down by the life-giving but ruin-bringing water. It may be observed in all positions along the descending route, and in all stages of decomposition or disintegration. Much of it, to the county's great misfortune, is good soil and subsoil—mantle rock which had come into existence by the weathering of fresh rock materials, and had remained long enough at its birthplace to nourish many generations of plants and to receive vitality from them in return.

It has been said of the underlying country rock formations—the foundation and wall rock of the county—that they become thicker down dip. It can be said just as truly of the Recent formation—the roof rock—that it thickens down slope, the general direction of which in most of the area is west, at an angle of perhaps 40 degrees to the direction of dip. And the thickness of the Recent cover varies from a thin veneer to possibly 140 feet; but the roof is in need of repair—it has many holes in it.

STRUCTURE

The geologic units of Carroll County have certain structural features which are common to almost all sedimentary formations—

bedding of various types, lamination, dip and strike, unconformities and disconformities, contemporaneous erosion surfaces, joints, columnar structure and perhaps others of a minor rank.

The regional dip of the strata of this part of the state is southwest to a little north of southwest, and the degree of dip where it is uniform ranges from 25 to 35 feet to the mile.

The Ralph Rivvett well (NE 1/4, NW 1/4, Sec. 30, T. 18 N., R. 2 E.) at the foot of the bluff, passed through 105.1 feet of Zilpha clay, according to Brown's[7] interpretation of the log. The altitude of the surface at the mouth of this well is 125 feet, and the Winona sand was reached at a depth of 477.4 feet, or an altitude of 352.4 feet sub-sea. The altitude of the top of the Winona in Priddy's[13] test-hole L-22 (NE 1/4, NW 1/4, NW 1/4, Sec. 30, T. 19 N., R. 5 E.) on the south side of U. S. Highway 82 two miles west from the Montgomery County-Carroll County line, almost exactly up-dip from the Rivvett well, is 322 feet. The straight-line distance between the two holes is 19 miles, and the difference of elevation on the Winona-Zilpha contact is 674 feet; the average dip of this contact is, then, 35.5 feet to the mile. It may be noted here, too, that the Mrs. Riesie Gee No. 1 oil prospect well[19] (SE 1/4, Sec. 2, T. 17 N., R. 3 E.) some 4.5 miles northeast of Black Hawk encountered the top of the Winona at a depth of 360 feet. The elevation of the mouth of the well being around 450 feet, the elevation of the top of the Winona formation is about 90 feet above mean sea-level. Priddy's[13] Test hole L-22, on the south side of Highway 82, referred to on previous pages, found the Winona at a depth of 39 feet, or at an elevation of 322 feet, the elevation of the mouth of the hole being 361 feet. The distance between the well and the test hole is 11.25 miles in a direction northeast by north, and the difference in elevation of the top of the Winona is 232 feet—that is, in a southwest by south direction, the Winona beds dip 20.6 feet to the mile.

The distribution of outcrops, particularly of Zilpha outcrops, suggests that in parts of Carroll County the dip may be somewhat less than the degree mentioned above. The thickness of the Zilpha at the type section is only 54 feet, although the top is not exposed. Thomas[11] states that the maximum thickness (in Holmes County, just south of Carroll) is 75 feet. Priddy[13] found a maximum thickness of only about 33 feet in Montgomery County, and 45 feet or more on the south side of Highway 82, in Carroll County two and a half miles west of Mont-

gomery. The Montgomery County location is some seven miles east and two and a half miles south of the Carroll County location, which means that in a distance of seven and a half miles, roughly, in a west-northwest direction, which is somewhat south of the strike, the Zilpha formation apparently has increased in thickness by more than 12 feet. At the foot of the Delta bluff at Teoc, which is not far north of the projected line connecting the two test-holes just referred to, the log of the Long well, according to Brown's interpretation, shows 84.8 feet of "Zilpha clay and possibly Kosciusko sand." Of course this interval is under alluvium, and we can not know how much of it was eroded before the deposition of the alluvium. If all these figures are essentially accurate, the increase of thickness of the Zilpha in a distance of about 22 miles in a west-northwest direction is 52 feet. Yet, according to water well and oil test records, as noted by Priddy,[13] the Zilpha is 200 to 250 feet thick in parts of Tallahatchie County, perhaps 25 to 30 miles farther north.

If the above figures are to be accepted, the Zilpha of Carroll County has a thickness not greater than 75 feet—about the same as that of the Winona; and if the strata dip at the regional rate, they should have a relatively narrow belt of outcrop unless the surface relief is very considerable. Indeed, Thomas[11] states that "In northeastern Carroll, northern Montgomery, and Grenada Counties the outcrop is an irregular belt averaging about half a mile in width and having several topographic outliers and inliers." The present survey found Zilpha clay exposures in the southeastern corner of the county from the Winona-Zilpha contact at Vaiden (NE 1/4, Sec. 23, T. 17 N., R. 5 E.) along roads toward the southwest (down dip) to near the Holmes County line at a road junction (southern part, Sec. 5, T. 16 N., R. 4 E.), a distance of about 11 miles by a straight line. At the announced regional dip, this should involve a difference of elevation of at least 330 feet, more probably 385 feet, for the lower Zilpha contact, but of course it is not exposed anywhere along the line except at Vaiden. If the Zilpha-Kosciusko contact were 75 feet above the Winona-Zilpha contact, the Zilpha could crop out at the southwestern end of the line if the relief is as much as 255 feet to 310 feet. However, the relief is not so much as that; besides, at the Holmes County line locality, 20 to 25 feet of chocolate-colored shale are exposed. Thickening of the shale, unless much greater than calculated, could not alone account for outcrops here and there through a distance of 11 miles down dip. Some sort of structural change is suggested.

A little farther north, Zilpha outcrops can be observed along a northeast-southwest line from a point on Highway 51 some 2.5 miles north from Vaiden to a place on the Vaiden-Black Hawk road about 3 miles east of Black Hawk—a distance of 11.5 miles. Along U. S. Highway 82, which trends almost west, about halfway between dip and strike, the Zilpha beds crop out here and there for a distance of 9.5 miles west from the eastern boundary of Carroll County, and a little south of the highway they show at a place 3 miles farther west. North of Highway 82, also, Zilpha clay and shale are exposed in places far to the west and southwest over a belt 9 to 10 miles wide.

All in all, the width of the belt within which Zilpha clay shows at the surface seems too great for a 40-foot, 60-foot, or even a 75-foot formation, dipping at the general regional rate, the relief being what it is in Carroll County. .

The structures which Priddy found in western Montgomery County probably affect the strata of eastern Carroll County. The axis of the Duck Hill nose at least enters Carroll County (Sec. 8, T. 20 N., R. 5 E.), and the west flank of the Sawyer nose may include some beds in eastern Carroll (Twps. 18 N. and 19 N.).

Other evidences of departures from the usual monoclinal regional structure are more direct. The channel of a small tributary of Palusha Creek below a road bridge (Sec. 20, T. 19 N., R. 3 E.) exposes a fault trace and steeply northeastward-dipping strata. The fault trace strikes north-northwest across the channel floor. Upstream from it the low channel walls are brown cross-laminated sand below, a 2-foot to a 3-foot gravel interval above the sand, and a loess interval overlying the gravel. The brown sand is cut by platy ferruginous sandstone of various shapes, some tubular. In two or three places the slabs and sheets of brown sand rock are in a line across the channel, and are tilted upstream at a relatively high angle. The fault trace itself, 50 to 60 yards downstream from the bridge, is marked by a belt of yellowish clay athwart the channel. Downstream from it the channel floor and the lower part of the channel walls are Zilpha clay for more than half a mile; loess only is above the clay, except for a thin interval of gravel and sand. About 100 yards below the bridge the right wall of the channel shows 8 feet of gray clay (Figure 12) containing much marcasite and several pieces of lignitized wood. About 100 yards below this point the clay beds of the left wall dip almost northeast at an angle estimated at 30 to 40 degrees, and show this same dip for some

distance down stream. The clay exposed reaches a thickness of 10 feet or more still farther along the channel, and some 400 feet above the lower end of the outcrop the beds in the right bank dip southwest at a high angle. Beyond the lower (southwestern) end of its outcrop in the creek channel, the clay is overlain by some 10 feet of silvery gray and white sand and light-blue and white gravel, above which are 10 to 15 feet of loess. The sand and gravel appear to be terrace material.

The course of this small stream is suggestive of structure. From its upper end it is north by west for three-quarters of a mile, thence west for about the same distance, thence a little north of southwest for some three miles, at the end of which stretch it bends to east of south at almost a right angle, and joins Palusha Creek at an angle of 45 degrees, the apex of the angle upstream with relation to the main stream. Thus the small stream roughly describes half of an ellipse. Furthermore, two small tributaries of Big Sand Creek directly north of the Palusha Creek tributary describe a north-south arc. It might be added, too, that Palusha Creek flows almost northwest, and at this place Big Sand swings northwards more than a mile from its general east-west course. In short, the fault, the steep dips, and the peculiar drainage pattern combine to suggest strongly that a dome-like structure is present here, possibly a salt dome.

A small fault (NE 1/4, Sec. 23, T. 17 N., R. 3 E.) has broken the beds exposed in the southeast wall of a road cut 4.3 miles east from Black Hawk. The fault trace is about midway of the exposure, which shows 28 feet of variegated thin layers of sand and clay—mottled red and white and pink on the surface, and overlain by loess. The contact between the sandy clay and the loess is several feet lower on the southwest side of the fault trace than on the northeast side. It is noticeable that the strike of this fault is not far from coincident with that of the Palusha Creek tributary 12 miles north of it, but connection between the two is improbable.

The only unconformity within the Tertiary strata of Carroll County is between the Zilpha and Kosciusko formations. In many places the Zilpha was deeply eroded before the deposition of the Kosciusko; in fact, here and there the Zilpha is absent, as pointed out in the text, and the Kosciusko sand may rest directly on the Winona; in other places, where all three formations are represented, only a small part of the total thickness of the Zilpha is present. The un-

conformable contact probably accounts in part for the variable thickness of the Kosciusko and for the assignment to the Kosciusko of some silty clays which may be properly assigned to the Zilpha, and vice versa. The absence of the Zilpha may not be due everywhere to erosion; Zilpha materials were not deposited everywhere within the Zilpha area of deposition.

GEOLOGIC HISTORY

The history of the little part of the earth now known as Carroll County, from the time of the deposition of the oldest rock which now is at the surface in the county, to the present time, is a chronicle of slow change in land-sea relationships in the early ages and in land forms and land conditions in the later ages; also a record of the *modus operandi* of the tireless, unresting agents of change. At the beginning of this interval of time, which was very near the close of the Tallahatta age, the whole area was occupied by a shallow sea, on the floor of which silt and clay and fine sand were accumulating, brought from the low lands on the northeast by low-gradient streams and worked over and distributed by weak tides and waves and gentle currents.[11] The historical record was being written quietly along a low, marshy shore, and to some extent in the coastal marshes. The Tallahatta age drifted into the Winona as marine conditions spread; streams on the nearby lands became more active, possibly because of increase of volume, and marine shore currents were more vigorous. In early Winona [Neshoba] time, conditions probably were not favorable for marine life, or were unfavorable for the preservation of the evidence;[11] but later in the Winona age sea life seems to have flourished in the shallow water near shore. The shoreline slowly retreated southwards and westwards and left the Carroll County area a very low land surface. Sedimentation was constant, of course, during this slow withdrawal of the sea, and the waves, dragging the bottom in the shallow water, mixed the clayey sediments with the older greensand of the Winona.[11] Aggradation went on, along with slight erosion of the new land; silty clays, silts, and fine sands were deposited on tidal flat and coastal marsh as a record of the Zilpha age. Bottoms of lakes and bays were built up, also, where waves and currents sorted and distributed the fine material after various patterns.[11]

Erosion of the new clay and silt beds became increasingly effective during the Zilpha age, removing them entirely locally, and cutting into the underlying Winona sediments.[13] After a long period of such conditions, a slowly subsiding coast line and lengthening streams

brought about more rapid erosion, as well as transportation of sand, which was dropped on the coastal plain, along with silts and clays, recording the Kosciusko age.[11] The lowering of the land on the north and northeast and a renewed advance of the sea initiated the Wautubbee age in much of the territory which is now Mississippi, but a continuation of the monotonous history of a deltaic plain or coastal plain must be set down for the Carroll County area.[11] In fact, marine waters never returned to this little corner of the Mississippi Embayment; it has been land from the close of the Winona age—through the remainder of the Eocene epoch, the whole of the Oligocene, Miocene and Pliocene epochs, and through as much as has elapsed of the Pleistocene epoch. Millions of years have gone by since the Gulf strand line lay across the region which is now Carroll County, and during that long time the area has been under ceaseless attack by the atmosphere and by running water, both working toward one ultimate objective—the reduction of the land to or near the level of the sea. Probably the climate through the Tertiary period, at least up to the Pliocene epoch, was much like the climate of the same region is today—humid sub-tropical, which means abundant rainfall and moist atmosphere, conditions that favor weathering and erosion, but also favor a profuse plant growth that tends to retard the degradational processes.

Furthermore, although the land was lowered greatly during the Tertiary period, some of the loss was compensated by aggradation during the Pliocene epoch of the Tertiary and the Pleistocene epoch of the Quaternary period. In the Pliocene epoch a large, southward-flowing river, or perhaps more than one, spread sand and gravel and clay over the western half of the Carroll County territory, probably as flood-plain deposits which were ultimately left as terraces. It is reasonable to assume that during the Pliocene epoch the climate began to grow colder and erosion was less retarded by the plant cover. Then during the Pleistocene the southward-flowing waters, sometimes of enormous volume from the melting of heavy snows and the ice of the great glaciers far to the north, and gorged with sand and gravel and clay and silt, cut the huge Mississippi River trench and left a wide flood plain underlain by thick alluvium. Climate was very cold at this time, and probably the flow of the great river or rivers was so much reduced during the winter that the wide flats, left dry and bare of plants, were exposed to strong winds which surely were blowing almost constantly as the air masses shifted about in the disturbed

atmosphere. The history of the blustery Pleistocene epoch in Mississippi is written chiefly in the loess, but partly in the sand and gravel terraces and in the alluvium of the Mississippi River.

The geologic history of the Carroll County terrain has seen a marine phase and a non-marine phase, and now and then an intensification of the forces behind them.

ECONOMIC GEOLOGY

SOILS

No special study of the soils of Carroll County has been made, so far as the writer is aware, but the results of soil surveys of Montgomery and Holmes Counties can be accepted in large part for what the results of a similar survey of Carroll would be, because the stratigraphy of the three is very much the same, at least above the Tallahatta formation. In Montgomery County the Winona, Zilpha, and Kosciusko formations are well represented, and in Carroll County the Zilpha and the Kosciusko are as prominent as in Montgomery. The Wautubbee formation is not represented at the surface in Montgomery County, and in Carroll its area of outcrop is so restricted that the effect of the Wautubbee (Shipps Creek shale) beds on the soils is local and very slight. The Pliocene and Pleistocene sands and gravels are spread pretty generally over Carroll County above the Eocene strata except in places where they were never deposited or were later eroded away, and are thicker in Carroll County than in Montgomery. The Loess is much thicker, in general, in Carroll County than in Montgomery. It is present almost everywhere in Carroll.

The soils developed from the Winona beds are sandy, but the glauconite of the fresh rock has added some small percentage of mineral plant food, especially potash, to them. Glauconite is an opaque mineral of rather complex composition, but is essentially a hydrous potassium-iron-aluminum silicate of dull olive-green, grayish-green, blackish or yellowish color. Commonly it is impure, and in the form of grains or small aggregates. Oxidation of the iron colors the rock deep brick-red or Indian red, a color which is imparted to the soils to some extent, in which it is darkened in places to almost black by mixture with organic matter. The unoxidized or only slightly oxidized greensand, mixed with loess and organic matter, becomes, under the action of the weather, a light-brown to grayish sandy loam up to 8 inches thick. The underlying subsoil may be 1.5 to 2.0 feet thick, a red or reddish-brown sandy clay which may con-

tain pieces of sandstone concretions.[11] Of course, soil derived exclusively from Winona rock exists in few and small areas, because of the presence, almost everywhere in the Winona outcrop belt of Carroll County, of rock waste from younger formations, especially loess and sand.

According to Thomas,[11] weathering of Zilpha clay produces a fine sandy loam soil up to 8 inches thick, commonly regarded as a poor soil. The subsoil is brown to red heavy plastic clay or silty clay, 14 to 20 inches thick, and is underlain by a mottled red and gray heavy plastic clay. In relatively small areas residual Zilpha soils may be free from admixture with materials from other rock units.

Soils derived from the Kosciusko formation are invariably sandy; they might be classed as fine sand soils, or fine sandy loam. Commonly they are light-gray or light brown, and may be as much as a foot thick. The subsoil, a reddish-brown or mottled sandy clay or clayey sand, may range up to 6 feet in thickness, but such an extreme thickness possibly includes a little of the underlying unaltered or only very slightly altered sand.

Geib[20] recognized two types of soil derived from the loess in Holmes County—the Memphis silt loam, which as a rule is developed from loess that is not so thick, and the Richland silt loam, from thicker loess. No doubt the same two types could be distinguished in Carroll County, where the loess ranges from a thin mantle to 40 feet in thickness. The Memphis silt loam of Montgomery County[3] is described as a light-brown to brown silt loam ranging in thickness from 6 to 12 inches. The subsoil, to a depth of 3 feet or more, is a light-brown to a chocolate-brown silt loam containing somewhat more clay than is present in the soil. A mechanical analysis of a typical sample of Memphis silt loam from Montgomery County showed, in percent:

Soil: Fine gravel, 0.0; coarse sand, 0.5; medium sand, 0.8; fine sand, 1.6; very fine sand, 12.0; silt, 61.9; clay, 23.7.

Subsoil: Fine gravel, 0.0; coarse sand, 0.2; medium sand, 0.3; fine sand, 0.6; very fine sand, 17.2; silt, 59.8; clay, 22.2.

Mechanical analyses of samples of the Memphis silt loam of Holmes County[20] gave results somewhat different from those of the same soil type from Montgomery County:

Soil: Fine gravel, 0.0; coarse sand, 0.4; medium sand, 0.7; fine sand, 3.0; very fine sand, 2.4; silt, 83.6; clay, 9.1.

Subsoil: Fine gravel, 0.0; coarse sand, 0.1; medium sand, 0.2; fine sand, 0.7; very fine sand, 5.0; silt, 70.9; clay, 22.3.

The area of the Memphis silt loam soil is almost 49 percent of the total soil area of Montgomery County[3] and 42 percent of the total soil area of Holmes County.[20] No figures are available for Carroll County, but in view of the fact that the loess is spread over almost the entire county, the part of the total soil area it makes up certainly is as great as in Holmes County.

The Memphis silt loam is in general more fertile than other soils of the county, except perhaps the Richland silt loam and the alluvial soils, because of the considerable number and variety of mineral plant foods the fresh loess contains (see chemical analysis). Also, it is easily cultivated and a very good soil for all sorts of crops grown in the region. Soil men have remarked on its rather peculiar field behavior: "Where deep cultivation is followed and there is a comparatively large percentage of organic matter present, the soil is friable and absorbs and retains moisture very well. If shallow cultivation is followed, as is most often the case, the soil packs and puddles during heavy rains and the water runs off instead of being taken up by the soil."[20]

The chief drawback to the cultivation of the loess upland soils, however, is the steepness of the slopes in most places. Not only do relatively steep slopes pose difficulties in the operation of agricultural machinery, but they are likely to erode badly, once the natural forest or grass cover is removed. The steeper slopes at least should be kept in forest.

The Richland silt loam,[20] to an average depth of a foot, is brown or light brown; the subsoil is a chocolate-brown silt loam more compact than the soil, and containing a higher percentage of clay. The Richland silt loam is thicker than the Memphis silt loam, contains more organic matter, and commonly is not so deeply eroded. The topography varies from almost level to gently rolling. Considerable areas of excellent farm land in western Carroll County where this type of topography prevails probably have the Richland silt loam soil. The mechanical analyses record is little different from that of the Memphis silt loam.

The soil which is formed by the weathering of the Kosciusko sands is known as the Orangeburg fine sandy loam.[3] It is described as a brownish-gray or gray to light-brown fine to medium sandy loam, averaging 8 inches to 10 inches thick, but where mixed with loess, as it is in many places in the loess belt, it has a heavier texture. In virgin fields, where the organic content is considerable, the Orangeburg soil is called "black sandy land."[20] The subsoil, to a depth of 3 feet or so, is a red sandy clay. Mechanical analyses of samples from Montgomery County showed, in percent:

Soil: Fine gravel, 0.2; coarse sand, 5.7; medium sand, 8.3; fine sand, 38.6; very fine sand, 9.7; silt, 30.8; clay, 6.6.

Subsoil: Fine gravel, 0.2; coarse sand, 5.3; medium sand, 9.3; fine sand, 31.2; very fine sand, 5.4; silt, 16.6; clay, 31.7.[3]

Samples from Holmes County were found by mechanical analysis to contain, in percent:

Soil: Fine gravel, 0.0; coarse sand, 0.4; medium sand, 4.6; fine sand, 54.2; very fine sand, 6.5; silt, 30.1; clay, 3.5.

Subsoil: Fine gravel, 0.0; coarse sand, 0.2; medium sand, 7.9; fine sand, 53.0; very fine sand, 6.0; silt, 7.9; clay, 25.5.[20]

It may be reasonably assumed that the same soil type in Carroll County consists of similar relative percentages of the materials named.

The Orangeburg fine sandy loam occupies 17.8 percent of the total soil area of Montgomery County[3] and probably not less than 25 percent of the total soil area of Carroll.

The Orangeburg fine sandy loam, the Memphis silt loam, and the Richland silt loam are upland soils. The best soils of all, under favorable weather conditions, are the floodplain or bottomland soils, along the streams. In Carroll County the bottomlands range in width from only a few rods to the county's part of the great Mississippi River Alluvial Plain—the so-called "Delta"—which is a mile to four miles in width. The alluvial soil along any stream is in a way developed from rock waste drawn from everywhere within that stream's drainage basin, and might be expected, therefore, to contain all the mineral plant food elements present in the region drained, except such as have been dissolved out; but it should be remembered also that overflow waters sort rock detritus in the direction of flow,

laterally and vertically, so that beds of relatively pure sand, and gravel, and clay, and silt, are deposited. The result is, that alluvial soils may be spotty.

The cultivated bottomland soils of Carroll County streams are a mixture of sand, gravel, silt, and clay, probably much like the Lintonia loam of Holmes County.[20] Mechanical analyses of the Lintonia soil show it to consist almost entirely of silt and clay—86.8 percent silt and 10.8 percent clay; the subsoil was found to contain 81.2 percent of silt, 12.0 percent of clay, and 6.0 percent of fine sand. The Carroll County part of the "Delta" is very similar to the Holmes County part nearer the bluff. Geib[20] recognized several types of the "Delta" soils of Holmes County, of which the Sharkey clay occupies a very large part of the area, the Yazoo loam almost a third as much, and the Wabash clay only a little less. These three types have a combined area of about 31 percent of the total soil area of the county.

The Sharkey clay is a stiff brown clay 6 inches thick which occupies interstream areas, deposited there from quiet water. The subsoil, down to 3 feet or more, is a stiff, waxy, drab or mottled clay. The Sharkey clay cracks badly where exposed to the sun, and because of the small masses formed, it is known as "buckshot land." The mechanical analyses show, in percent:

Soil: Coarse sand, 2.0; medium sand, 1.6; fine sand, 4.0; very fine sand, 5.9; silt, 44.2; clay, 42.3.

Subsoil: Fine gravel, 0.3; coarse sand, 0.8; medium sand, 0.5; fine sand, 1.6; very fine sand, 8.1; silt, 37.9; clay, 50.6.

The Sharkey clay soil is difficult to cultivate on account of its tightness and poor drainage, but will produce well where drained and properly cultivated.

The Yazoo type[20] is a fine, brown or almost black heavy loam 6 to 10 inches thick; the subsoil is a drab or mottled clay loam or clay which may extend to a depth of 3 feet or more. The Yazoo loam is developed along streams or old stream channels. It is generally considered the best all around soil of the Alluvial Plain. The record of mechanical analyses is, in percent:

Soil: Fine gravel, 2.1; coarse sand, 3.8; medium sand, 1.4; fine sand, 3.2; very fine sand, 9.7; silt, 56.9; clay, 23.1.

Subsoil: Fine gravel, 1.1; coarse sand, 3.9; medium sand, 1.3; fine sand, 2.7; very fine sand, 9.5; silt, 65.3; clay, 16.5.

The Wabash soil type[30] is a black or dark-brown heavy clay loam 6 to 8 inches thick, underlain by a drab or bluish waxy clay which may extend to a depth of more than 3 feet. On drying it forms the typical "buckshot land." The Wabash clay commonly borders the front lands, between the Yazoo loam and the Sharkey clay. Mechanical analyses showed, in percent:

Soil: Fine gravel, 0.7; coarse sand, 1.9; medium sand, 0.7; fine sand, 1.7; very fine sand, 8.9; silt, 66.4; clay, 19.4.

Subsoil: Fine gravel, 1.1; coarse sand, 3.6; medium sand, 1.3; fine sand, 3.0; very fine sand, 12.6; silt, 57.4; clay, 20.2.

From the foregoing data it would seem that the alluvial and loessial soils of Carroll County are most fertile, and the soils derived from the clays and sands are least fertile. However, some of the alluvial soils are hard to cultivate, because too heavy and poorly drained, and are uncertain at the best, because subject to floods; and large areas of loessial soils are unsuitable for general farming because of steep topography. The wide distribution of the loess is a fortunate condition for agriculture, because it results in an admixture of every type of soil with some loessial material. The considerable variety of soil types and also of topographic and weather conditions has created a problem of adaptation and adjustment for the farmer, much more difficult to solve than is the problem of the same general nature which confronts the farmer in a region of pretty much one type of topography and very similar kinds of soils, such as a prairie or a floodplain. Two or three overall guiding principles seem applicable—keep something growing in all the soil, all the time; conserve the humus and incorporate it in the soil; plow deeply. Broadly considered, the mineral content of any one soil is likely to be the same in kind as that of any other, however different it may be in the proportions of the constituents; the productiveness of the soil, then, may depend in very large measure on how the soil is handled, and on its humus content.

WATER

Carroll County is well supplied with water for any purpose that might demand it. The rainfall is adequate, and the underground water is abundant. Of the formations described in the text of this report, the Winona, under the Zilpha as a cover, is a good aquifer;

the Kosciusko (the Sparta of the oil men) is one of the great water reservoirs of the state where it has proper cover; and the Citronelle and Pleistocene sands have for a long time past supplied water through springs and to relatively shallow wells. In addition to the strata which crop out in the county, the basal Claiborne Meridian sand and the Upper Wilcox Holly Springs sand,[13] both prolific aquifers, can be reached by wells.

In the vicinity of Coila and in some other localities the chief water supply is from springs and shallow wells which have their source in the Citronelle gravel.[21] The few deeper wells may draw from the Kosciusko. At Black Hawk, water is obtained from wells 25 to 100 feet deep, most of them about 65 feet, sunk into Kosciusko white sand. At Vaiden a 230-foot flowing well, located in the lowland near Hays Creek, was reported many years ago to be drawing water from the Holly Springs formation, and another flowing well, some 2.5 miles south of Vaiden, was said to have its source in the Winona sand at a depth of 110 feet. Two flowing wells, 408 and 260 feet deep, at Carrollton, near the bridge over Big Sand Creek, were said to draw water from the Holly Springs sand. At McCarley, 5 miles east of Carrollton, two wells, 175 and 160 feet deep, were believed to obtain water from the Winona sand,[21] but probably the Tallahatta is the source, because the Winona crops out both north and south of McCarley, and calculations from outcrops in Carroll County and actual measurements in Montgomery County indicate that the thickness of the formation does not exceed 80 feet. A 200-foot well a quarter of a mile west of McCarley was likewise said to receive its flow from the Winona.[21]

Brown[7] has listed 53 wells in Carroll County, 41 of them in the "Delta," and the other 12 in Sections 7, 12, and 18, Township 19 North, Range 4 East. All except four of the "Delta" wells are north of Palusha Creek. All the wells considered, they range in depth from 54 feet to 1,400 feet, as follows: 50 to 100 feet, 6; 100 to 200 feet, 4; 200 to 300 feet, 10; 300 to 400 feet, 8; 400 to 500 feet, 5; 500 to 600 feet, 3; 600 to 700 feet, 4; 700 to 800 feet, 1; more than 800 feet, 1; no depth given, 11. These variable depths testify to the existence of several aquifers under the surface of the county. In fact, Brown names the Kosciusko, the Winona, the Basic City, the Meridian, and the Wilcox strata as sources of water, but only the 1,400-foot well reached the Wilcox (Holly Springs?) The flow ranged from 1 gallon per minute to 49 gallons per minute, but the well which yielded 49 gallons per minute (SW 1/4, SW 1/4, Sec. 26, T. 18 N., R. 1 E.) was the only one

which flowed more than 15 gallons per minute. One well (SE 1/4, SW 1/4, Sec. 7, T. 19 N., R. 4 E.), in North Carrollton, owned by the Columbus and Greenville Railway, was pumped at the rate of 75 gallons per minute. The temperature of the water from these flowing wells was in the 60's of degrees Fahrenheit, the lowest (63 degrees) being of water from a 185-foot well, and the highest (69.25 degrees) of water from a 470-foot well, in Carrollton.

The record of a chemical analysis of water from one of the Carrollton town wells is given below:[21]

Mineral analysis of water from town well 408 feet deep at Carrollton, Carroll County

(Margaret D. Foster, U. S. Geological Survey, Analyst)

	Parts per million
Silica (SiO_2)	36.00
Iron (Fe)	00.64
Calcium (Ca)	16.00
Magnesium (Mg)	6.50
Sodium and Potassium (Na plus K) (calculated)	33.00
Carbonate radicle (CO_3)	00.00
Bicarbonate radicle (HCO_3)	149.00
Sulphate radicle (SO_4)	10.00
Chloride radicle (Cl)	2.70
Nitrate radicle (NO_3)	2.80
Total dissolved solids at 180 degrees C	184.00
Total hardness as $CaCO_3$ (calculated)	67.00.

SAND AND GRAVEL

The Winona and the Kosciusko formations of Carroll County, being composed almost entirely of sand, the Citronelle and the Older Pleistocene chiefly of sand, and the other rock units in part of sand, no lack of sand exists in the county. As has been stated, most of this sand is iron oxide stained from the surface to varying depths, but the Kosciusko sand at least is white or almost white where it has not been exposed to the weather. Unfortunately, quite generally it contains silt and silty clay and in places lignitic material, impurities which make the whole mixture unfit for industrial uses. However, here and there in the county the Kosciusko sand at a considerable depth appears to be relatively free from stain and from clayey and organic substances; from such localities sand suitable for the commoner uses, such as building and paving, certainly could be obtained. In fact, not uncommonly specifications are written to fit supplies

available near the place where the sand is to be used. Sand for use on the roads has been dug along the right-of-way at several points. One pit, in the south wall of a cut (western part, Sec. 20, T. 19 N., R. 4 E.) for U. S. Highway 82, exposes several feet of white to dull white sand which probably is satisfactory structural sand. Such material might serve as molding sand, also, of the class which contains a natural bond.

Immense quantities of white sand, eroded from the sand formations, are lying along the stream channels (Figures 19, 21). Although this sand has been washed by the streams and much of it freed from the greater part of the clay and silt transported with it, nonetheless it would require further washing before being used. The white sand of the county should be satisfactory for use not only as a structural sand and a molding sand, but possibly also for the manufacture of green or amber glass.

Sand is being pumped, along with the gravel, on a fairly large scale from the channel of Abotcaputa Creek (Secs. 2 and 3, T. 18 N., R. 2 E.). Seen as heaps on the creek flat, awaiting removal, it is white to very light brown. Also, sand is being pumped in the same manner from the channel of Teoc Creek (NW 1/4, Sec. 19, T. 20 N., R. 3 E.) and screened out of the gravel; from the bluff south of Teoc—in fact, at most of the gravel pits.

Gravel is very abundant in Carroll County, in the Citronelle and Pleistocene formations in place, and in the stream flats and terraces where gravel, eroded from the formations named, has been deposited. The chief gravel outcrops have been described under "Stratigraphy." As stated, the largest workings are in the face of the bluff which bounds the Mississippi River Alluvial Plain on the east, in the southwestern part of the county. These gravel pits (NW 1/4, Sec. 21, T. 18 N., R. 2 E.) are of several acres area; the gravel interval which shows is 30 feet or more thick, and may extend downwards several feet below the floor of the present pit. The deposit is being worked by Leflore County for road metal. In May, 1950, about 25 trucks and a Mississippi wagon were hauling gravel to Greenwood and elsewhere. The gravel is scooped from the working face and loaded on the trucks by a power shovel (Figure 24). The pit where the work is going on at present is connected with abandoned pits (Figure 23) excavated far back into the bluff.

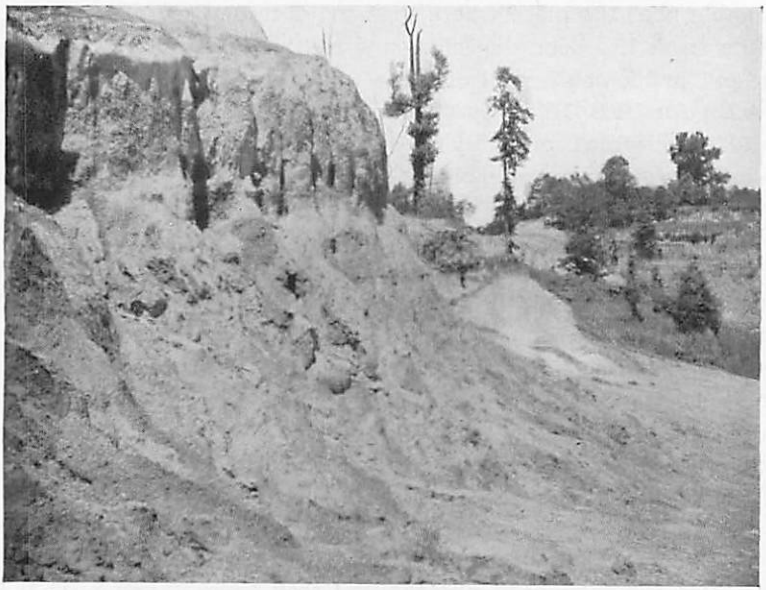

Figure 23.—View of abandoned gravel pit, near Leflore County workings, Mississippi River Valley bluff.

Figure 24.—Gravel pit operated by Leflore County. Mississippi River Valley bluff.

The Abotcaputa Creek gravel and sand washing plant (SW 1/4, Sec. 2, T. 18 N., R. 2 E.) is on the south side of the creek a few rods below the mouth of a small tributary from the northeast. Gravel and sand and water are pumped from the creek bed and to the top of the screen building or crib, from where they descend through the screens, which separate sand from gravel and sort the gravel. The original source of the gravel is the sand and gravel bed underlying the loess in the valley walls—a bed which in this paper is classified as Older Pleistocene terrace. The Abotcaputa Creek workings are fairly well situated as concerns transportation: a local road lies close to the creek on the north side for a mile or more and some two miles farther west connects with a main graveled road which joins Highway 82 six miles to the northwest, a little east of Greenwood.

Another large gravel pit (northern part, Sec. 35, T. 20 N., R. 2 E.) which has been mentioned, has been opened in the face of the bluff about two miles south of Teoc, where a small stream flows from the uplands onto the river plain. The operations here consist of digging the gravel and sand from the deposit (Citronelle) in the bluff, hauling it down slope to the washing and screening building, and trucking away the washed and sorted materials.

The small plant on Teoc Creek (NW 1/4, Sec. 19, T. 20 N., R. 3 E.) is very similar to that on Abotcaputa Creek. The sand and gravel are pumped from the creek channel, screened, and trucked away. The large operations east by southeast of Avalon (Secs. 25, 36, T. 21 N., R. 2 E.) in the face of the bluff, follow the same general methods.

A few abandoned pits tell something of the distribution of the gravel. The chief of these have been noted in the part of the paper which deals with stratigraphy. One of the largest (NE 1/4, Sec. 14, T. 19 N., R. 2 E.) is in the face of the bluff less than half a mile north of U. S. Highway 82.

Lowe[22] gives some data relating to two gravel deposits in the vicinity of Malmaison. One, owned by Dr. T. H. Somerville, of Oxford, is three miles northwest of the station at Malmaison, and four miles from the Southern (Columbus and Greenville) Railroad. The deposit extends for half a mile along the bluffs and is 25 to 30 feet thick; the loess which once overlay it has been eroded away. According to the information available, no operations had been carried forward here. The following report on a sample from the Somer-

ville deposit was made by the Bureau of Public Roads, U. S. Department of Agriculture, Washington, D. C.:[22]

REPORT ON SAMPLE NO. 7308 FROM CARROLL COUNTY, MISSISSIPPI

MATERIAL: SAND GRAVEL

	Percent
Retained on 3/4 inch sieve	1.2
Retained on 1/2 inch sieve	5.3
Retained on 1/4 inch sieve	9.0
Retained on 1/8 inch sieve	11.3
Total passed 1/8 inch sieve	88.7
Retained on No. 10 sieve	12.6
Retained on No. 20 sieve	31.3
Retained on No. 30 sieve	73.5
Retained on No. 40 sieve	85.4
Retained on No. 50 sieve	91.4
Retained on No. 80 sieve	94.0
Retained on No. 100 sieve	94.1
Retained on No. 200 sieve	94.5
Retained on No. 200 sieve:	
By analysis	0.2
By washing	5.3

Cementing value—

On material over 1/8 inch in size	Fair
On material under 1/8 inch in size	Excellent
On material as received	Excellent

Character—Sample consists essentially of large fragments of chert and quartz, with a large amount of quartz sand and some ferruginous clay.

Remarks—Material shows altogether too large a proportion of sand to be satisfactory in gravel road construction. The amount of sand should be reduced to about 30 percent of the whole for best results.

The other gravel deposit referred to by Lowe[22] was at Malmaison (Valley Hill P. O.) seven miles west of Carrollton, on a spur of the Southern (Columbus and Greenville) Railroad. This deposit, owned by Mrs. J. L. Leflore, of Malmaison, was being worked at the time of Lowe's report. The pit was several hundred feet long and a few feet to 40 to 60 feet deep. Overburden of the gravel was a few feet of loess. The output was 30 carloads a day. The report of the U. S. Department of Agriculture Bureau of Public Roads on a sample from the Leflore property pit, is copied below:[22]

REPORT ON SAMPLE NO. 7128 FROM CARROLL COUNTY, MISSISSIPPI
VALLEY HILL PROPERTY OF MRS. J. L. LEFLORE
MATERIAL: SAND GRAVEL

MECHANICAL ANALYSIS	Percent
Retained on 1 inch sieve	6.5
Retained on 3/4 inch sieve	13.3
Retained on 1/2 inch sieve	24.3
Retained on 1/4 inch sieve	37.0
Retained on 1/8 inch sieve	45.0
Total passing 1/8 inch sieve	55.0
Retained on No. 10 sieve	47.5
Retained on No. 20 sieve	56.0
Retained on No. 30 sieve	69.5
Retained on No. 40 sieve	80.4
Retained on No. 50 sieve	88.1
Retained on No. 80 sieve	89.8
Retained on No. 100 sieve	90.0
Retained on No. 200 sieve	90.4
Passing No. 200 sieve	9.6

Cementing value—

On material over 1/8 inch in size	Good
On material under 1/8 inch in size	Excellent
On material as received	Good

Character—Sample consists essentially of rounded fragments of quartz and chert, coarse sand and ferruginous clay.

Remarks—Material contains too much sand to be entirely satisfactory in gravel road construction. The amount of sand should be reduced to about 30 percent of the whole for the best results.

CERAMIC CLAY

The great body of the ceramic clay of Carroll County is in the Zilpha formation, the chief outcrops of which have been located and briefly described in the part of the report relating to the stratigraphy of the Zilpha. Zilpha clay commonly is very plastic, and contains sufficient sand to insure ease of working and at least relative freedom from cracking while drying. In fact, much of it is too sandy and silty for ceramic uses in its natural state.

Complete tests of three samples of Zilpha clay from Priddy's test holes L22 and L25 (see the logs in the text relating to Zilpha stratig-

raphy) were made in the Mississippi State Geological Survey ceramics laboratory. Sample P 3 was taken from a 4.7-foot bed of somewhat silty light-gray clay encountered 5.4 feet below the surface in test hole L22. Two samples were taken from test hole L25—the upper one, also designated Sample P 3, from a 12.8-foot bed of somewhat silty light-tannish-gray clay, reached at 12.0 feet; the lower, designated Sample P 5, from a 13.0-foot bed of slightly silty grayish-tan clay, reached at 25.6 feet. The record of the results of the tests follows:

TEST HOLE L 22, SAMPLE P 3

Physical properties in the unburned state
- Water of plasticity (percent) 33.50
- Drying shrinkage—
  - Volume (percent) 51.93
  - Linear (percent) 21.70
- Modulus of rupture (in pounds per square inch) 487
- Color ..... Light gray

Pyro-Physical properties—see table following Sample L 25, P 5

TEST HOLE L 25, SAMPLE P 3

Physical properties in the unburned state
- Water of plasticity (percent) 35.17
- Drying shrinkage—
  - Volume (percent) 53.91
  - Linear (percent) 22.81
- Modulus of rupture (in pounds per square inch) 628
- Color ..... Light gray

SCREEN ANALYSIS

Retained on screen	Percent	Character of residue
60	0.08	Abundance of gray clay nodules; small amounts of limonite and plant fragments
100	0.63	Abundance of clay nodules; small amounts of quartz and muscovite; trace of pyrite
250	8.10	Abundance of quartz; small amount of clay nodules
Cloth	91.19	Clay substance including residue from above.

CHEMICAL ANALYSIS (PERCENT)

Ignition loss	6.38
Silica, SiO_2	63.92
Alumina, Al_2O_3	16.43
Iron oxide, Fe_2O_3	3.53
Titania, TiO_2	1.20
Lime, CaO	1.08
Magnesia, MgO	1.32
Manganese, MnO_2	None
Alkalies, K_2O and Na_2O	0.82

Pyro-physical properties—see table following Sample L 25, P 5

TEST HOLE L 25, SAMPLE P 5

Physical properties in the unburned state

Water of plasticity (percent)	36.29
Drying shrinkage—	
Volume (percent)	54.13
Linear (percent)	22.92
Modulus of rupture (in pounds per square inch)	578
Color	Light gray

SCREEN ANALYSIS

Retained on screen	Percent	Character of residue
60	0.04	Abundance of gray silt nodules; small amounts of quartz and lignitic nodules
100	0.56	Abundance of gray silt nodules; considerable quantity of muscovite; small amount of quartz
250	6.83	Abundance of quartz; considerable quantity of clay nodules; small amount of muscovite
Cloth	92.57	Clay substance including residue from above.

CHEMICAL ANALYSIS (PERCENT)

Ignition loss	6.15
Silica, SiO_2	69.36
Alumina, Al_2O_3	16.88
Iron oxide, Fe_2O_3	3.50
Titania, TiO_2	1.04
Lime, CaO	0.76
Magnesia, MgO	1.34
Manganese, MnO_2	None
Alkalies, K_2O and Na_2O	0.77

PYRO-PHYSICAL PROPERTIES

TEST HOLES L 22, L 25

Hole No. Sample No.	At cone	Porosity in percent	Absorption in percent	Bulk specific gravity	Apparent specific gravity	Volume shrinkage in percent	Linear shrinkage in percent	Modulus of rupture in lb./sq. in.	Color and remarks	
	03	10.71	5.12	2.09	2.34	10.64	3.70	2840	Salmon buff	St.H.
	01	8.78	4.19	2.09	2.30	10.66	3.70	3270	Salmon buff	
	2	8.73	4.12	2.10	2.32	11.80	4.00	3846	Salmon buff	
L 22 3	4	7.94	4.08	2.09	2.32	12.00	4.45	3813	Salmon buff	
	6	4.32	2.01	2.17	2.27	13.95	4.90	3838	Reddish gray	
	8	3.70	1.74	2.12	2.20	12.41	4.35	3996	Gray	
	10	10.29	5.76	1.79	1.99	-3.54	-1.21	N.D.	Gray	Cr.,Bl.
	03	12.52	6.12	2.08	2.32	10.79	3.74	2784	Salmon buff	St.H.
	01	10.50	5.04	2.04	2.34	8.78	3.02	3130	Salmon buff	
	2	11.54	5.52	2.09	2.30	10.58	3.67	3481	Salmon buff	
L 25 3	4	9.31	4.48	2.09	2.36	10.85	3.77	3825	Salmon buff	
	6	5.80	2.79	2.10	2.23	11.14	3.88	4086	Reddish gray	
	8	5.55	2.61	2.13	2.25	12.71	4.46	2728	Reddish gray	
	10	6.92	3.49	1.99	2.13	5.49	1.87	N.D.	Gray	Cr.,Bl.
	03	13.48	6.57	2.05	2.38	9.47	3.27	2751	Salmon buff	St.H.
	01	11.67	5.79	2.01	2.28	9.29	3.20	3125	Salmon buff	
	2	11.53	5.59	2.06	2.28	9.17	3.17	3510	Salmon buff	
L 25 5	4	12.64	6.14	2.06	2.36	9.45	3.27	3537	Salmon buff	
	6	11.28	5.38	2.09	2.28	11.14	3.88	3957	Salmon buff	
	8	8.43	4.04	2.10	2.36	11.86	4.14	4899	Reddish gray	
	10	3.15	1.52	2.07	2.14	10.01	3.49	1243	Gray	Cr.

Mr. T. E. McCutcheon, the ceramic engineer who directed the tests, classified these clays as "Brick and Tile Clays—Clear," the word "clear" being used "to distinguish them from clays having generally similar properties but which are stained with calcium sulphate." Mr. McCutcheon summarizes their properties and the uses these clays might have: "The clays in this group burn to clear even shades of salmon buff, light-red, red, and gray . . . . . .The clays possess good plastic and drying properties although the drying shrinkage is rather high for certain samples. The dry strength of all samples is more than adequate for heavy clay products. On burning, porosity and absorption values decrease slightly with advancing temperatures. Linear shrinkage is low and increases only slightly within the firing range of 6 to 8 cones. The fired strength is higher than the average common clay. Modulus of rupture values are in the 2,500-3,500 pounds per square inch range at heavy clay products burning temperatures.

The clays are suitable for the manufacture of face brick and common brick, building block, facing tile, salt glaze silo tile, fire proofing tile, load bearing tile, roofing tile, and drain tile . . . ."

Logan[23] describes a clay outcrop "in a railroad cut on the Illinois Central, south of the station at Vaiden," and gives measurements and description of intervals of a section "in a small depression on the west side of the cut":

"SECTION NEAR VAIDEN

		Feet
5.	Soil	1
4.	Brown loam	8
3.	Reddish clay	10
2.	Red and white mottled clay	10
1.	Grayish clay	5"

He states also the results of tests of the exposed clays, and the records of chemical analyses:

"The clay from No. 1 requires 27 percent of water for plasticity. It has a total shrinkage of 15 percent. The raw clay brickettes have a tensile strength of 187 pounds per square inch. When burned, the tensile strength is 200 pounds per square inch. Absorption is 14.63 percent."

CHEMICAL ANALYSIS OF A SAMPLE FROM INTERVAL 1 GAVE THE RESULTS TABULATED BELOW:

	Percent
Moisture (H_2O)	10.06
Volatile matter (CO_2, etc.)	7.00
Silicon dioxide (SiO_2)	59.22
Iron Oxide (Fe_2O_3)	4.70
Aluminum oxide (Al_2O_3)	10.30
Calcium oxide (CaO)	1.68
Magnesium oxide (MgO)	1.18
Sulphur trioxide (SO_3)	0.23
Total	94.37

The rational analysis showed:

Clay substance	26.06
Free silica	15.76
Impurities	7.89

CHEMICAL ANALYSIS OF CLAY NO. 2 OF THE SECTION GAVE RESULTS AS TABULATED BELOW:

Moisture (H_2O)	6.77
Volatile matter (CO_2, etc.)	6.75
Silicon dioxide (SiO_2)	66.06
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	9.47
Calcium oxide (CaO)	1.95
Magnesium oxide (MgO)	0.72
Sulphur trioxide (SO_3)	0.10
Total	98.07

The rational analysis showed:

Clay substance	23.96
Free silica	51.58
Impurities	9.02

Logan comments on the clay of Interval 2, "This clay has too high a shrinkage to be utilized without the aid of non-plastic material. It would also require thorough crushing before it could be used, as it slakes slowly."

The Vaiden clays described and tested by Logan are no doubt Zilpha. The section described and figured in the present report (Figure 6) probably is near the place referred to by Logan.

In several localities red or reddish-brown or yellowish clay underlies the loess. It could be developed from the Loveland loess, or perhaps is part of the Citronelle or the older Pleistocene. One place where a considerable thickness of this clay exists is in the walls of the big gravel pits in the southwestern part of the county. Probably it would be suitable for the manufacture of brick.

LOESS

Loess, which is so abundant in Carroll County, has value other than as a source material for fertile soil. It has been used in asphalt mixtures for the manufacture of mattresses which in turn are used to protect the banks of the Mississippi River against washing. Also, it has been used to some extent as a filler in the building of concrete highways, U. S. Highway 84, and Mississippi Highway 8, for examples. Other uses are, as a component of building block material, and as a component in the making of brick. In brick manufacture, the fresh loess was mixed with the residual brown loam, or weathered loess, which is clayey in the lower part.

BUILDING STONE

Limonitic siltstone or silty limonite overlying the Zilpha clay has been described on foregoing pages as a feature of the Zilpha-Kosciusko contact (Figure 14). It is commonly very dense, fine-grained, brittle, brown to limonite-yellow rock, in the form of a bed of thickness ranging from only an inch or two to a foot or more; or, more than one bed may be present. Priddy[13] states that where there is but one ledge, the rock contains patches of fine-grained to medium-grained quartzite. In most places where the rock was observed in Carroll County, it was one bed only, a tabular bed of which the upper and lower surfaces were almost parallel. Crumbling and washing away of its clay support lead to breaking of the rock bed and scattering of fragments over the slope below the position of the bed. Some of the loosened slabs are of considerable size and are used locally for construction purposes. Priddy's[13] statement concerning this rock and its value as building material is about as concise a summary as could be written:

"In the west one-half of Montgomery County and in adjacent parts of Carroll County, the Zilpha-Kosciusko contact is marked by one to five beds of buff to light-brown well-indurated siltstone. Where there is but one ledge, or several ledges separated by shale breaks, slabs 3 to 18 inches in thickness and 3 to 4 feet in length and width may be pried from their position and dressed on the spot. The upper and lower surfaces are smooth, usually parallel, and free of contamination from the Zilpha clays below, the Kosciusko sands above, or from the interbedded silts. The slabs thus exposed are of uniform hardness, as hard in newly exposed faces as on the crop, and as hard in their centers as on their surfaces. But despite its hardness, the rock is sufficiently brittle to be easily squared by well directed blows of a heavy hammer. Nor is its brittleness increased by heat, for slabs used in chimney construction do not split or appear to weather."

He adds that the community house in Winona has been partly constructed of this rock, which also has been used locally for small buildings, for ornamental masonry, for chimneys, and for foundation stones.

It seems pertinent to note here that limonitic siltstone of identically the same character overlies the Ackerman clays in Choctaw County and elsewhere at the contact of the clay and the overlying

sand. It, too, is used locally as building stone—in the Lake Choctaw buildings, retaining walls, sidewalks, and outdoor stairways, for examples.

Kosciusko sandstone has been used here and there in Carroll County for foundation stones and in chimneys, but is of little value as a building material because of its great irregularity of shape, degree of cementation, and texture. It is said to be good road metal when crushed sufficiently and spread evenly over the road. Short stretches of road that have been all but impassable in wet weather have been made solid by the use of this natural rock.

The chief outcrops of the Zilpha-Kosciusko limonitic siltstone have been located in the part of this paper which relates to stratigraphy. East of Jefferson and north and northeast of McCarley the rock is prominent in places.

GLAUCONITIC SAND

Glauconitic sand which makes up a considerable part of the Winona formation, is of some value as a fertilizer, because of its potash content. Fresh green sand of this kind will improve the soil if applied directly to the fields.[13] However, chemical analyses of samples of glauconitic sand from Montgomery County showed that the sand samples were 80 to 83.5 percent silica, 5.7 to 7.8 percent alumina, and 5.7 to 7.00 percent iron oxide; only 1.3 to 2.18 percent was potash.[13] Grains of glauconite separated from the sand were found to contain 4.16 percent potash and 0.78 percent soda. The Montgomery County samples contained only 1.55, 2.35, and 2.68 percent combined alkalies, an alkali content which probably is approximately what samples from Carroll County would show. McCutcheon comments, "at best, the alkali content is too low to permit extensive use of the sand as a fertilizer. It seems plausible that the glauconite could be separated from the silica sand and be used as a commercial fertilizer or as the weighting element in mixed fertilizer. This possibility should be investigated by commercial interests."[13]

The chief outcrops of the Winona glauconitic sand of Carroll County are located and described in the "Stratigraphy" part of this bulletin. The best locations for mining the sand on an industrial scale are at Vaiden and southward along Highway 51 and the Illinois Central Railroad; the next best location would be McCarley, on the Columbus and Greenville Railway.

OIL AND GAS

Many years ago locations were made for oil prospect wells in Carroll County—in Section 27, Township 19 North, Range 2 East, and in Section 26, Township 17 North, Range 4 East, to name only two—but apparently no well was drilled at that time or shortly thereafter. In March, 1943, C. E. Walters's H. W. Flippin No. 1 (Sec. 22, T. 19 N., R. 4 E., 1180 feet north and 580 feet west of the SE corner of the section) was completed as a dry hole at a depth of 4,862 feet, and abandoned.[24] No shows were reported. The Texas Company's E. G. Whitehead et al No. 1 (Sec. 22, T. 18 N., R. 5 E., 660 feet north and west of the SE corner of the NE 1/4 of the section) was completed in January, 1948, as a dry hole, total depth 5,283 feet.[25] H. Barksdale Brown & Company's Mrs. Riesie Gee No. 1 (Sec. 2, T. 17 N., R. 3 E., 1946 feet north and 660 feet west of the southeast corner of the section) was completed in October, 1949, at a total depth of 3,580 feet, without production.[26]

The geological data which may have determined or influenced the location of the wells named have not been made public, but surface evidence of departure from the normal regional dip is lacking at the sites, except perhaps the asymmetrical valleys along U. S. Highway 51 in the vicinity of the Whitehead well. However, from the field study on which the present report is based, it would seem that a test-well location in the west-central part of the county, perhaps in the western part of Section 20, Township 19 North, Range 3 East, some five miles west by south of Carrollton, would have structural advantages over other parts of the county.

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GEOLOGIC MAP OF CARROLL COUNTY MISSISSIPPI

Franklin Earl Vestal

SCALE OF MILES
1 0 1 2 3

LEGEND

- R-Al — Recent alluvium and terrace material (possibly some Pleistocene) of stream valleys
- R-P-Al — Recent and Pleistocene alluvium of the Mississippi Alluvial Plain
- L — Loess, brown and gray silt
- O.P. — Older Pleistocene sand and gravel
- Cn — Citronelle formation, sand and gravel
- SC — Shipps Creek shale
- K — Kosciusko formation, sand and shale
- Z — Zilpha formation, shale, clay, and sand
- W — Winona formation, gray and green glauconitic sand and red sandstone
- BC — Basic City member of the Tallahatta formation
- X — Prominent outcrops and locations of photographs