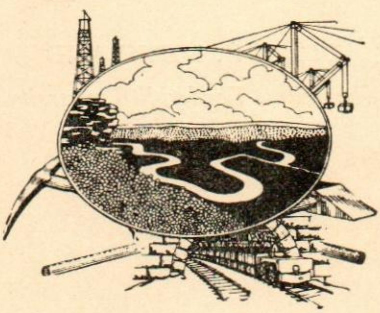
STATE OF TENNESSEE
DEPARTMENT OF EDUCATION
DIVISION OF GEOLOGY
Walter F. Pond, State Geologist

BULLETIN 37

GEOLOGY AND MINERAL RESOURCES
OF
HARDIN COUNTY TENNESSEE

BY W. B. JEWELL

Surveyed in cooperation with the Hardin County Court
L. L. Harbert, Judge



NASHVILLE, TENNESSEE
1931

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Air view of Savannah looking East. Note the flat flood plain in the foreground and the bluffs at Savannah as shown by the relative heights of the bridge approaches.

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FOREWORD

This report shows that there are minerals in Hardin county which have great possibilities while there are others which are in such small quantities or of such low grade that they may best be left alone. In general there does not seem to be much chance for the metals with the exception of iron of which several deposits seem to be worth prospecting provided the transportation and marketing problems can be solved. Of the non-metallics there are several of importance. Gravel and sand for road metal and construction work are practically unlimited in quantity and of wide extent. Limestone for structural uses and for concrete and road metal is present in great abundance over a large area in the eastern part of the county. Most of the limestones are suitable for burning to lime and practically all are high grade agricultural limestones. Some of them are capable of taking a good polish for marble and already such a deposit near Olive Hill is being prospected. The tripoli deposits of Wayne County, to the east, are being developed and some of those in Hardin County appear worthy of further prospecting. Other minerals are described which deserve attention.

It may seem to the average reader that too much space has been given to the description of the general geology. It must be understood, however, that this work lays the foundation for the later examination of mineral deposits, their correlation and judgment as to possible extensions since they are usually associated with some particular geologic formation or land form. The later geologist or engineer who examines the deposits will wish to know the evidence on which conclusions were drawn and for his own use in connection with further work.

This report was inspired by the desire of the citizens of Hardin County to know what mineral resources are present there. Correct and detailed information would then be available to any of its citizens as to the mineral possibilities on his own land and elsewhere in the county, and would be the basis for interesting local or outside capital. There was also the idea that this information would save money and effort from being invested in enterprises which had little chance of success. The failure of an enterprise leaves a feeling of doubt and discouragement which may later prevent the development of an industry of merit having a good chance of success if well managed.

A survey of the mineral resources of an adjoining area having been made previously by the Tennessee Geological Survey, it was not possible for that organization with its limited funds to do another detailed piece of work in the immediate region. The enthusiasm of the people of the county was such, however, that they offered to pay half the cost of the work and a "dollar for dollar" cooperative agreement between the Hardin County Court and the Tennessee Division of Geology was the basis on which the work was undertaken. This action may well be an example to other counties which desire detailed information on their natural resources but which are in localities where it will be years before the Division of Geology can do more than general work on the mineral resources.

If it were customary to dedicate the reports of this Division to persons, this one would be dedicated to Mr. E. K. Churchwell of Savannah, whose untiring enthusiasm secured the cooperation of the Division of Geology, attended the progress of the work and followed it through the various stages to completion, and whose expressed interest has been greater than that of any other citizen of the county.

WALTER F. POND, *State Geologist.*

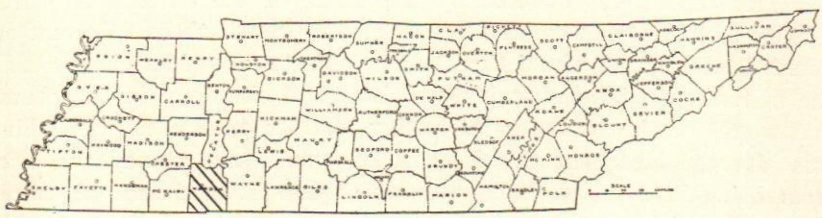


FIGURE 1—Index Map showing the location of Hardin County, Tennessee.

GEOLOGY AND MINERAL RESOURCES OF HARDIN COUNTY, TENNESSEE

By W. B. Jewell

INTRODUCTION

The field work for this report occupied three and one-half months of the summer of 1927, and was done for the Tennessee Division of Geology in cooperation with the Hardin County Court. The survey was conducted by the writer assisted by T. G. Andrews of Vanderbilt University to whom the writer is especially indebted for efficient assistance.

The writer acknowledges his indebtedness to Walter F. Pond, State Geologist of Tennessee, and to Dr. L. C. Glenn, chairman of the Department of Geology at Vanderbilt University, for valuable suggestions and help. He is also indebted to E. F. Burchard, geologist for the United States Geological Survey, for guidance, suggestions, and criticism in connection with the description of the brown iron ore showings.

The writer wishes to express his appreciation to the residents of Hardin County and especially to E. K. Churchwell and other members of the Civitan Club of Savannah, Tennessee, for their interest, help, and courtesy.

The chemical analyses unless otherwise noted were made by D. F. Farrar, chemist for the Tennessee Division of Geology. The writer has made free use of the published reports of Miser, Dunbar, Wade, and others who have done work in this and adjoining areas.

The purpose of the survey was twofold: (1) To determine the natural resources of the county; (2) To make a geologic map showing the distribution of the various kinds and ages of rock present, and in this way to indicate the more favorable areas for prospecting since many of the mineral deposits are closely associated with certain varieties of rock or with rocks of a certain age.

CHAPTER I

DEVELOPMENT AND GEOGRAPHY

LOCATION AND EXTENT

Hardin County has an area of approximately 560 square miles, and lies along both sides of Tennessee River, adjoining both Alabama and Mississippi to the south. The county is bounded on the west by McNairy and Chester counties, on the east by Wayne County, and on the north by Henderson and Decatur counties. The population of the county is 16,213 according to the latest revised 1930 figures.

TOWNS

Savannah, the county seat, with a population of 1,129, by the 1930 census, and the largest town in the county, is situated on the east bank of Tennessee River near the center of the county. It is the most important trading center and has good stores, banks, schools, churches, hotels, and homes, as well as saw mills, planing mills, cotton gins, ice plants, and other industries. The completion of the highway bridge across Tennessee River, now under construction at this point, will undoubtedly add much to the town's importance.

Saltillo, on the west bank of Tennessee river in the north section of the county, is second in size and although not so large as Savannah, is an important trading center for the northwest portion of the county.

In addition there are numerous villages, supporting one or two stores, such as Olive Hill, Gillis Mills, Walnut Grove, Lowreyville, Duncan's Landing, Cerro Gordo, Swift, Morris Chapel, Crump, Hamburg, Childers Hill, Counce, and others.

SHILOH NATIONAL MILITARY PARK

The famous Shiloh National Military Park, which has drawn so many interested visitors from all parts of the United States, lies entirely in Hardin County. It was established in 1895 to preserve the area over which the decisive Civil War battle of Shiloh was fought April 6, 7, 1862. The Park contains 3,547 acres and lies mostly on the high terrace overlooking Tennessee River between Snake and Lick creeks. It contains a splendidly kept cemetery, numerous and beautiful monuments and memorials, and is traversed in all directions by good roads. Numerous markers show the location of the various regiments, both Union and Confederate, during the battle. Much of the historic forest under which the battle was fought has been preserved. A charming rustic hotel lies just outside the southern boundary of the Park. A store and post office are situated within the Park boundaries.

RAILROADS AND ROADS

At the present time there is no railroad in Hardin County except a small logging railroad with gasoline locomotive and somewhat over a mile of track. Another small logging road operated in the southeast section of the county a few years ago but is now abandoned. It is reported that one of the prominent railroads is contemplating building, in the near future, a branch line from Jackson, Tennessee to Sheffield, Alabama. This road, if built, will presumably extend through part of Hardin County and will undoubtedly play a large part in its development.

The county has four good state highways which are excellently maintained. Highway 15 crosses the county from east to west, passing through Savannah. With the completion of the projects now under construction this becomes the direct route from Chattanooga to Memphis. Highway 17 connects number 15 with Henderson, Tennessee; Highway 69 connects number 17 with Decaturville, Tennessee, passing through Saltillo; and number 17 connects Savannah with Corinth, Mississippi.

On June 19, 1928 the Hardin County Court voted the bonds necessary for construction of a graded, surfaced road from Savannah to the Alabama line connecting with the road to Florence, Alabama. The exact proposed location of this road is not definitely known but it will open up a large tract of almost inaccessable land in the southeast corner of the county.

All other parts of the county are reached by dirt or gravel roads, most of which are in very poor condition. Where these dirt roads lie on natural road metal such as chert or gravel, they are frequently in fair shape even when practically no work is done on them. Unlimited quantities of good road metal occur in the county and the cost of construction for improved roads should be unusually low. On August 11, 1928, the Hardin County Court voted $300,000 in bonds to complete the improvement of roads in the county.

More and better roads, as well as much better care of the present ones, are necessary before the natural resources of the county can reach their fullest development. That good roads can be constructed in this section of Tennessee at a very nominal cost is shown by those in Shiloh Park which were built at an average cost of somewhat over $2,000 per mile, practically no grading being needed there.

CLIMATE

This section of Tennessee has a rather mild climate, though the summers are very warm, and temperatures below zero are occasionally experienced for short periods during the winter. The highest temperature recorded[1] is 105° F. and the lowest, 12° F.

[1]Nunn, Roscoe, The Climate of Tennessee, Resources of Tennessee, Volume VIII, No. 1, pp.7–45, 1918.

The average growing season is 205 days from the last frost in April to the first frost in October. The average annual temperature is about 60° and the average precipitation is 50 inches. The rainfall is rather evenly distributed in the different seasons though more rain falls in winter than in summer and more in spring than in autumn. The wettest months are December (5.22), February (4.89), and March (5.57), while the driest are September (3.30) and October (3.27).

Violent winds are rather rare. Gentle winds are nearly always present in the sections lying in the wide valley of Tennessee River.

TOPOGRAPHY

Hardin County contains parts of two physiographic divisions recognized in Tennessee; the Highland Rim, and the Slope of West Tennessee. Tennessee River is, in general, the boundary between them. Close to the river these provinces are not sharply separated, but farther away from the river the differences become more clearly recognized. The region along the McNairy County line is distinctly different, both in altitude and topographic outline, from the section adjoining Wayne County. Both the Highland Rim Plateau and the Slope of West Tennessee slope gently to the westward in this area. Along the east edge of Hardin County the hills and ridges attain altitudes of between 800 and 900 feet above sea level, while along the west edge altitudes of 500 to 600 feet are common. Separating the two divisions and flowing north in a valley several miles in width and 250 to 300 feet deep, is Tennessee River.

Drainage

Hardin County is drained by Tennessee River and its many tributaries. The Tennessee enters the County from Alabama and Mississippi where it forms the state boundary and flows in a northerly direction to the Decatur County line. A mile or two below Saltillo it swings to the east and continues in this direction to where it leaves Hardin County just above Clifton, Tennessee.

Several rather large creeks flow into the Tennessee in this area. Some of them have drainage basins of considerable extent. Many of the larger creeks are fed chiefly by springs and are usually clear except after heavy rains.

Horse Creek has a larger drainage area within the county than any other creek and drains much of the central and southeast portions of the county. Its source is in Wayne County a few miles south of Pinhook. In Hardin County, Horse Creek is joined by several tributaries of fair size. In the southeast part of the county, Germany Branch and Roger's Creek flow into it from the north and Holland's Creek and White's Creek with its two large branches, North and South Forks, join it from the south. Northeast of Savannah, Horse Creek is joined by Turkey Creek with its large tributaries English, Choate, Steel, and

Boone creeks. Horse Creek flows westerly from the Wayne County line for about 13 miles, then turns and flows northward, in general parallel to Tennessee River, for approximately 11 miles and flows into the Tennessee a mile above Cerro Gordo.

Indian and Hardin creeks, also rising in Wayne County, are important tributaries in the northeast corner of Hardin County. Indian Creek which empties into the Tennessee a few miles below Saltillo, has a general northwest course. Neighbor's Branch, Flat Gap Creek, Smith's Fork, and Poney Creek are tributaries.

Hardin Creek, though as large as Horse or Indian creeks, receives no major tributaries in Hardin County. It flows in general northwest, parallel to Indian Creek, across the extreme northwest corner of the county, joining the Tennessee about two miles below Grandview Landing.

In the western part of the county west of the Tennessee, the streams are in general more sluggish and have wider bottoms in comparison with their discharge than those east of the river. Many of them have been dredged into so-called "canals" to prevent excessive flooding during high water.

The chief streams west of the Tennessee in Hardin County are Yellow, Chambers, Lick, Snake, Beason, White Oak, and Doe Creeks.

Yellow Creek rises in Mississippi and flows only a short distance in Tennessee, discharging into Tennessee River just north of the state line.

Chambers Creek also rises in Mississippi and flows northeast across the southwest corner of the county, joining the Tennessee just below North Carolina Landing.

Lick Creek and Snake Creek with their large tributary, Owl Creek, are tributary to the Tennessee from the west in the vicinity of Shiloh Park.

Beason Creek flows into the river from the south and west a little above Coffee Landing while White Oak Creek with its major tributaries, Mud, Middleton, and Hurricane creeks, drains the entire northwest part of the county and flows into the Tennessee from the west about 1¼ miles above Saltillo.

Doe Creek runs into the river from the northwest about a mile below Saltillo and forms part of the boundary between Hardin and Decatur counties.

There appears to be no definite relation between the stream pattern present in the county or the courses of the present streams and the structures in the underlying bedrock though some of the smaller streams follow joint systems for short distances.

Miser [2] has noted a marked relation of drainage to structure in Wayne County to the east where the major streams appear to flow wholly or in part in synclines. Indian Creek, one of Miser's examples, flows through

[2]Miser, H. D., Mineral Resources of the Waynesboro Quadrangle, Tennessee. Bul. 26, Tenn. Geol. Survey, p. 41, 1921.

the syncline near Olive Hill but also across the marked upwarp near Russell.

The streams in Hardin County show in general, the normal dendritic or tree-like pattern so usually developed in horizontal or nearly horizontal rocks or in rocks of nearly equal resistance to erosion.

Bottoms

The "bottoms" or floodplains of the present streams are variable in width. Along the Tennessee the flood plain varies from less than a mile in width to nearly four miles though the average is not much over two miles. The average width of the flood plains of the larger creeks is less than a mile.

In places along the Tennessee and its major tributaries, bottoms are entirely absent on the outside of the stream curves. Such places are usually bordered by sharp slopes or bluffs. Pyburn's Bluff, Pittsburg Landing, Coffee Landing, Savannah, Cerro Gordo, Saltillo, and Grandview are cases in point. At Cerro Gordo, Pickwick Landing, and White's Landing the actual floodplain is somewhat less than a mile in width.

The width of the floodplain seems in many cases to be intimately related to the type of rock over or through which the stream in question flows. The relatively wide bottoms along the major streams west of the river are probably directly due to the fact that the creeks there flow in areas underlain by soft, unconsolidated, and hence easily eroded clays, sands, and gravels. East of the river the stream bottoms are relatively much narrower, and show marked constrictions where the resistant Mississippian shales and cherts outcrop at drainage level. This marked constriction is very well shown on both the North and South forks of White's Creek in the southeast corner of the county. On the South Fork there is considerable bottom both above and below the constriction where the floodplain is entirely cut out. At this point there is a 10 foot fall in the stream where it drops over ledges of the dark Ridgetop shale. Other less obvious narrow portions of floodplains may be explained in a similar fashion.

The material composing the floodplains along the creeks is generally sand, silt, and mud along the lower stretches and where streams flow through the soft limestones. These bottoms are generally damp and soggy and sometimes marshy. Along the headwaters of the creeks and particularly where the streams start in areas underlain by chert, the bottoms consist largely of coarse gravel. Many of the pebbles are of good size and often distinctly angular in shape.

Along the Tennessee River there are in some places more than one bottom or terrace. At Pickwick Landing there are three distinct bottoms or terraces, each successive one about 10 feet higher than the next lower. The upper and lower ones, i. e. the oldest and youngest, are comparatively narrow. At White's Landing two very distinct bottoms occur, the higher one being about 15 feet above the lower. On the west side of the river south of Hamburg there are two very distinct bottoms also. The lower one here is 15 to 20 feet below the upper. Elsewhere the bottoms are not distinct though suggestions of more than one are often present. The lowest and most recent floodplain of Tennessee River is generally 30 to 40 feet above low water level. The higher bottoms are terraces that represent former floodplains formed when there was a pause in the down-cutting of the river.

PLATEAUS

In the eastern part of the county the tops of the hills and ridges are at approximately the same altitude, and the skyline as seen from the top of one of them is remarkably flat. They represent remnants of what was once a continuous plain called the Highland Rim or Highland Plain. The surface of this plain slopes gently westward in Hardin County. Good sized fragments of this plateau are still present. They are flat or gently rolling on top and are known locally as "flatwoods".

Into this uplifted plain or plateau the various streams have cut and eaten their way so that now the "flatwoods" are but isolated remnants of a once continuous plain. In places this erosion by the streams has progressed further than in others so that the flattopped remnants have been cut back into flat ridges or even isolated hills. In some cases the altitude of some of the ridges does not vary more than 10 to 20 feet in several miles. In others the variations are more marked. The ridges often have deep saddles or notches cut in them by opposing streams. No clear case of actual stream piracy was observed but in a great number of cases such a change of drainage is imminent.

The streams flowing down the sides of these flat-topped areas are usually quite youthful, their valley walls in some cases having slopes up to 45 or 50 degrees. Falls up to 20 or 30 feet drop are not uncommon. In general the steepest slopes and most canyon-like valleys occur in the Mississippian cherts and shales. Often a stream starts leisurely on top of a flat ridge in the incoherent, red Cretaceous sand and, upon striking the underlying cherts and shales, suddenly develops a small gorge with box-like walls and numerous ledges and small falls.

In the east-central and southeast parts of the county the high flat-topped plateau areas are largely capped by red Cretaceous sand while in the northeast corner they are capped largely by Fort Payne chert. In this latter section the altitudes are lower and the flat areas are of smaller extent, suggesting that erosion has been more active here and has stripped off most of the Cretaceous rocks which were once present, leaving only small isolated patches of the Cretaceous here and there as evidence of its former wider extent.

On the west side of Tennessee River, Plateau remnants are also present. Here, however, they are distinctly lower in altitude and are capped by the red and variegated Cretaceous sands together with much younger terrace gravels. These flat remnants belong to a different physiographic province, the Slope of West Tennessee, and were developed during a later stage in the topographic history of the region. Though the remnants west of the river are for the most part lower in altitude than those east of it, and the stream fall consequently less, erosion has been perhaps more rapid here than on the Highland Rim because of the soft nature of the rocks west of the river. Many of the remnants of the old surface have been wholly or partly dissected and cut away by the streams. That erosion is progressing more rapidly at present, and presumably did so in the past, west of the river, than east of it, is evidenced by the very muddy character of the streams on the west in comparison with those that drain the hard rock area to the east.

Terraces

Scattered along both sides of the Tennessee throughout the length of the county are large and small patches of terrace gravels—deposits of gravel, sand, and clay that the river and its tributaries deposited thousands of years ago when the land was much lower than at present. Subsequent slight elevations have allowed the river to cut to lower stages. The river apparently flowed in much the same direction and place then as now, as shown by the close proximity of the terraces to the present channel.

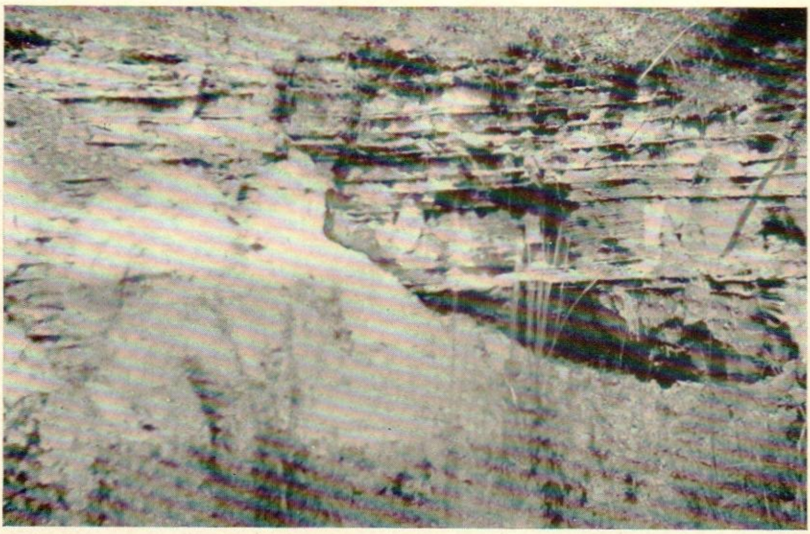
All of these gravel beds were not deposited at the same time, the river having left successive patches perched on the sides of the valley at lower and lower levels as the river cut slowly down to its present bed. The lower and younger of the gravel terraces are more extensive and better preserved than the higher and older ones because erosion had had a shorter time in which to tear them down. The upper and older ones are less and less distinct until the upper-most one becomes barely recognizable.

Wade[3] has recognized, and published an excellent description of the origin of as many as five separate and distinct terraces, all representing stages in flood plain deposition during the lowering of its bed by the Tennessee since this area began to rise in Tertiary times.

The high terrace remnants in southeastern Hardin County are of Pliocene age according to Wade. At best they are vague and not sharply defined. The pebbles are quite small and the gravel sheets very thin, occuring on top of the flats and ridges at altitudes of from 650 to 800 feet above sea level. The writer feels that the terrace origin of these highest gravels is questionable. Several instances were noted where the pebbles at present are being weathered out of the red sands of Cretaceous age. These red sands contain more or less gravel throughout their entire thickness and it is reasonable to suppose that much of the high gravel has been

[3]Wade, Bruce., The Gravels of West Tennessee Valley. Resources of Tennessee. Tenn., Geol. Survey. Vol. VII, No. 2, pp. 55-89, 1917.

(A) View down Tennessee River from Coffee Landing. The bluff on the left bank is composed of Coffee sand. The reef in the foreground is a huge block of cemented terrace gravels and has fallen from above.



(B) Cross-bedded Coffee sands and clays one-fourth mile south of Squire Newman's barn near Newman cemetery.

(A) View down White's Creek toward Horse Creek from the divide between the North and South forks of White's Creek. Notice the flat skyline.

(B) View south across Tennessee River from the top of the bluff at Pyburn Landing. Notice the flat skyline with the low swell in the middle background representing one of the gentle hills (Monadnocks) on the old peneplain.

derived in this way. The evidence is not conclusive to demonstrate definitely the true origin of the highest gravels.

In addition to the highest gravels of questionable terrace origin discussed in the preceding paragraph, the writer recognizes five lower and successively younger terraces which are probably of Pleistocene age.

1. Terrace about 600 feet in altitude but varying from 590 to 620 feet, typically exposed as small and thin patches west of Wynn's Landing.

2. Terrace about 550 feet in altitude but varying from 540 to 555 feet, developed west of Yellow Creek Landing and north of Red Sulphur Spring.

3. Terrace about 500 feet in altitude but varying from 500 to 525 feet, developed in Shiloh Park and northwest of Coffee Landing.

4. Terrace about 460 feet in altitude but varying from 455 to 475 feet developed west of Chambers Creek and west of Wolf Island.

5. Terrace about 420 feet in altitude but varying from 415 to 435 feet, developed at Savannah and at Saltillo.

Below these terraces occur the higher bottoms already referred to which are well developed at Hamburg, Pickwick Landing, and at White's Landing. The higher bottoms are of course true terraces but they more closely resemble the present floodplain both in position and in the character of the sediments composing them.

GLADES

Numerous small glades occur in the central and northeast sections of the county where the shaly Silurian limestones outcrop. The "glades" are barren rocky patches covered with limestone rubble and clay. Little grows on them except cedars and stunted forms of other vegetation. Some of them are thickly scattered over with silicified fossils while others are barren in this respect. The majority of the glades are developed on the Beech River shaly limestone. Many of the other Silurian limestones, however, form occasional glades.

CAVES AND UNDERGROUND DRAINAGE

Any region in a humid climate which is underlain by soluble calcareous rocks will generally contain numerous caves, caverns, sinks, and underground streams. In special cases where the limestones are pure enough and other factors are favorable, the bed rock is literally honeycombed by a network of underground channels. Such an area is said to possess *Karst* topography as for example, the area around Mammoth Cave in Kentucky.

The central and northeast sections of Hardin County which are underlain by limestone are no exception to the rule and although caves are not numerous, they are common. The caves are mostly small and do not appear to be confined to any particular formation. The surface streams often flow into these openings and many springs mark their reappearance at the surface. Small stalagmites and stalactites, or icicle-like forms of cave onyx, (calcium carbonate) occur on their floors and roofs.

Perhaps the most interesting of these caves is the one back of Mr. Quall's barn at Walnut Grove. The opening is small yet the underground channel must be of considerable extent. It is rumored that sightless fish as well as stalactites 3 feet long occur in the cave. Just below Dry Creek School, Dry Creek suddenly sinks into the stream bed and reappears a little less than a mile to the west as the large spring that feeds Spring Creek. The opening to the cave is approximately half way between the spring and the point where Dry Creek disappears. The flow of the spring is at least eight cubic feet per second (3,600 gallons per minute). The cave is developed in the Pyburn limestone.

Another underground opening known as the Blowing Spring occurs near the mouth of Haw Branch at Pyburn's Bluff. It is not really a spring but a sink hole. At certain times when the wind blows from the southwest, cold air currents issue from this opening. Presumably it is connected with openings in the bluff along the river. Other small caves occur in the Pyburn limestone along Pyburn's Bluff, some of which may connect with sink holes.

There is another small cave in the Dixon limestone about a quarter of a mile northeast of Paulk's Mill. A small stream flows into the cave on the east side of the ridge, passes through the ridge, and emerges on the west side as a spring. Quickfield cave on the Jones place on Turkey Creek is developed in the Decatur limestone. It is reported that one may go into the cave for 200 yards or more. Other small caves occur on Horse Creek at Rockhouse, on Ben Garrard's land on Indian Creek, on Hardin Creek near the Wayne County line, and elsewhere. Many of the springs in the limestones undoubtedly represent the reappearance at the surface of underground streams.

Topographic History

The hills and valleys of this section of Tennessee have not always existed as we find them today. There have been times in the remote past when the entire area was below sea level and the land covered by seas in which lived myriads of marine forms. At other times the land has been entirely above water and widespread erosion went on then as it is going on today. Such oscillation of the land took place many times but we are particularly concerned here with the changes that have taken place in rather recent geologic times.

Following the deposition of the gravels, sands, and clays during Upper Cretaceous time, the land was slightly elevated. Erosion went on slowly. To the northeast the land was being torn down more vigorously by the atmospheric agents and carried away by the streams draining to the west. Erosion in the area to the northeast where the Central Basin is now located, had begun previous to this and was probably going on more or less actively during the deposition of the Cretaceous sediments in West Tennessee. The latter area continued below sea level after Cretaceous time and received the load of sediment brought to it by streams from the east as shown by Tertiary deposits in the counties to the west.

There is no evidence to show that the area in Hardin County experienced any pronounced uplift until upper Tertiary time, although Central Tennessee began to rise slowly at the end of the Eocene. If this section along Tennessee river were elevated in the lower Tertiary, the uplift was of small amount and not sufficient to strip off the unconsolidated Cretaceous deposits.

During this long period the land which had never been greatly dissected, was beveled to a nearly flat plain and the streams draining it must have been slow and sluggish. In the late Tertiary, however, the land along Tennessee River in this area began to rise. That previous to this time vertical movements had been absent or negligible is evidenced by the altitude of the older terraces which in some cases are but slightly below the level of the Highland Rim Plateau. These higher terraces are probably no older than Pliocene and the Highland Rim must have been little above drainage level when they were formed. Most of the uplift in this section must therefore have taken place in late Tertiary and Pleistocene times.

This uplift once started, though perhaps not uniform, was rather steady as is testified by the numerous terrace stages preserved in the Tennessee valley, the various terraces not being separated by any great difference of elevation.

The rise of the land revived the sluggish streams and they began at once to scour their channels, cutting through their former floodplains and wearing away the rock below. This process is still going on and the deep valleys of the Tennessee and its tributaries are still getting deeper. During this downcutting by the streams the former plain was uplifted several hundred feet. In eastern Hardin County remnants of this old plain are now 800 feet or more above the level of the sea.

CHAPTER II

GEOLOGY

Former Work

Hardin County has been visited from time to time by numerous geologists and notes and descriptions of the rocks occurring there have been published in a number of places.

Among these descriptions may be mentioned those of Gerard Troost in his geological reports published in the 1830's; James M. Safford's "Geology of Tennessee," 1869; Killebrew and Safford's "Resources of Tennessee", 1874; August F. Foerste's "Silurian and Devonian limestones of Western Tennessee," Journal of Geology, Volume 11, 1903; L. C. Glenn, "Underground waters of Tennessee and Kentucky west of the Tennessee River, and of an adjacent area in Illinois", United States Geological Survey, Water Supply Paper No. 164, 1906; Pate and Bassler—"The late Niagaran Strata of West Tennessee", Proceedings of the U. S. National Musuem, Vol. 34, 1908; Bruce Wade—"Recent Studies of the Upper Cretaceous of Tennessee", Tenn. Geol. Survey, Bul. 23, 1920; Carl O. Dunbar—"Stratigraphy and Correlation of the Devonian of Western Tennessee", Tenn. Geol. Survey, Bul. 21, 1919; and H. D. Miser—"Mineral Resources of the Waynesboro Quadrangle, Tennessee", Tenn. Geol. Survey, Bul. 26, 1921.

Some of the descriptions are fragmentary, others are accurate and more or less complete.

General Features

The rocks exposed at the surface in Hardin County are entirely of sedimentary origin and include limestone, shale, chert, sandstone, sand, clay, and gravel. The rocks are of widely different ages and include beds deposited during Ordovician, Silurian, Devonian, Mississippian, Cretaceous, and Quaternary times.

The formations are in general rather thin, the total aggregate thickness being less than 2,000 feet. Unconformities are numerous, some representing short and others very long breaks in deposition. Notwithstanding the great age of some of the rocks they are not greatly deformed. Though faulted and folded to some extent, the throw of the faults seldom exceeds a few tens of feet and the dips are uniformly low. In fact in most places, the strata deviate but little from the horizontal.

The formations west of Tennessee river are all loose unconsolidated sediments of Cretaceous and Quaternary ages except where patches of hard rock come to the surface close to the river. East of the river consolidated limestones, cherts, shales, and sandstones are abundant and compose the floors of the valleys of all the major streams. This difference in the character of the bed rock in the two parts of the county is reflected in the rougher topography, sharper valleys, narrower floodplains, and general higher altitude in the east part of the county.

The rocks belong to 21 formations but only seven or eight are very widely distributed, the remainder having been partially lost through erosion during the time represented by the unconformities. Some of the formations were recognized at only one or two localities.

Because of the absence of any deep wells in the county direct knowledge is lacking as to the character of the rocks on which the Middle Ordovician Hermitage formation rests. It is probable, however, that the Hermitage lies on older Ordovician rocks—Carters limestone, etc.—which have been penetrated by deep wells at Iron City and at Collinwood in Wayne County.

The rocks exposed at the surface, together with their thicknesses and lithologic characters, are given in the generalized section below. Their distribution and areal extent are shown on the geologic map included in this report.

ORDOVICIAN SYSTEM

HERMITAGE LIMESTONE AND SHALE

The Hermitage formation is the oldest surface rock in the county and is exposed only in the central and north central parts. It comes to the surface again, however, just outside the county on the right bank of the Tennessee at Clifton and is said by Foerste [4] to outcrop on the left bank of the river at Swallow Bluff. The Hermitage limestone and shale is well exposed along Willoughby Creek about three miles east-southeast of Savannah. Borings in the bed of the river at Savannah for bridge foundations in 1927 brought up cores of Hermitage limestone from 30 feet below the river bed. It is also well exposed along Indian Creek near its mouth in the vicinity of Russell and in the valley of Poney Creek northeast of Swift. The Hermitage formation probably underlies the greater part of the county at no great depth. At no place in Hardin County is the base of the Hermitage shown. It is said by Miser [5] to be 126 feet thick in Wayne County. The greatest thickness exposed in Hardin County is 60 feet, a quarter of a mile southwest of Russell, but its entire thickness is probably much greater than this. The formation is unfossiliferous in the county so far as seen, and is composed of alternating beds of dense, tough, blue limestone and dark fissile shale. The beds vary from three to ten inches in thickness and are remarkably regular.

[4]Foeste, A. F., op. cit. p. 563.
[5]Miser, H. D., op. cit. p. 16.

Generalized Geologic Section of the Rocks in Hardin County, Tennessee.

System	Series	Formation	Member	Thickness in Feet	Lithologic Character
Quaternary	Recent	Alluvium		0–40	Sands, silts, clays, and gravels.
	Pleistocene	Terrace gravels	*Unconformity*	0–80	Chert gravels with sands and clays.
Cretaceous	Upper Cretaceous	Selma Clay		100±	Light gray to nearly white sandy, micaceous, calcareous clay with some greensand.
		Eutaw	Coffee sand and clay phase	300±	Micaceous, crossbedded, variegated sands and carbonaceous clays with some greensand.
			Tombigbee sand phase		Red and purplish, micaceous, crossbedded sands and light gray clays with some gravel lenses and variegated sands.
		Tuscaloosa gravel	*Unconformity*	100±	Chert gravel and sand with some clay.
Mississippian	Tennessean	Warsaw limestone		55±	Deeply weathered fosiliferous white chert, tripoli, and clay with some limonite.
	Waverlian	Ft. Payne chert		125±	Light gray slightly calcareous chert. Usually deeply weathered to white and yellowish porous chert, tripoli, and clay with some limonite.
		Ridgetop shale unconformity	*Unconformity*	110	Dark fissile shale and dense, tough, dark gray limestone, with black flint nodules.
		Chattanooga	Maury glauconitic member	0–6	Green phosphatic sandstone and shale.
			Black shale member	0–25	Black carbonaceous shale with some thin, dark, cross-bedded sandstone layers and lenses.
			Hardin sandstone member	0–16	Light to dark gray cross-bedded, marcasitic, phosphatic, fine-grained sandstone.
			Unconformity		

Devonian	Lower Devonian	Harriman chert		0–40	Thin bedded brittle, buff to gray chert.
			Unconformity		
		Quall limestone		0–10	Heavy bedded, dense cherty, gray limestone.
			Unconformity		
		Decaturville chert		0– 2	Porous, gray fossiliferous chert.
			Unconformity		
		Birdsong shale		0– 8	Deeply weathered light gray clay and thin cherty beds.
			Unconformity		
		Olive Hill	Flat Gap limestone	0–53	Massive, crystalline, stylolitic, light to pinkish gray limestone.
			Bear Branch limestone (and, or)	0–45	Massive, cross-bedded, ferruginous, reddish limestone.
			Pyburn limestone	0–40	Impure, cherty, massive to thin bedded, dark gray limestone, cross-bedded in places.
			Ross limestone	0–60	Dense, tough cherty, massive to thin-bedded, dark blue siliceous limestone.
		Rockhouse shale		0–26	Gray shale and shaly limestone.
			Unconformity		
Silurian	Middle Silurian	Decatur limestone		0–60	Massive to thin bedded, stylolitic, dense to crystalline, light gray to pinkish limestone.
		Brownsport	Lobelville limestone	0–40	Thin bedded, cherty, bronish to gray, dense lime stone, shaly or crystalline or pyritic in places.
			Bob limestone	0–20	Massive, crystaline stylolitic, light gray to white limestone. Rarely somewhat cherty.
			Beech River limestone	0–45	Thin bedded, brownish-gray shaly limestone and gray and greenish shales. Limestone occasionally glauconitic, pyritic or cherty.

GENERALIZED GEOLOGIC SECTION OF THE ROCKS IN HARDIN COUNTY, TENNESSEE. (*Con.*)

System	Series	Formation	Member	Thickness in Feet	Lithologic Character
Silurian	Middle Silurian	Wayne	Dixon limestone	0–40	Thin bedded, red, earthy limestone (frequently mottled and blotched with greenish limestone) and red and greenish shale.
			Lego limestone	0–36	Heavy bedded, stylolitic, dense, tough, light gray to pinkish-gray limestone. Occasionally pyritic.
			Unconformity (*a*) Waldron shale	0– 1½	Gray clay and shaly nodular limestone.
			Laurel limestone	0–35	Heavy bedded, stylolitic, dense, tough, light gray limestone.
			Osgood (?) limestone	0– 9	Pinkish limestone and gray shale.
	Lower Silurian	Brassfield limestone		0–25	Thin to heavy bedded, dense, greenish-gray, glauconitic limestone in upper part. Massive, glauconitic, ferruginous brown limestone in lower part.
			Unconformity		
		Fernvale (b) limestone		0–10	Thin bedded, crystalline, brownish gray limestone and gray shale.
			Unconformity		
Ordovician	Middle Ordovician	Hermitage limestone and shale		60±	Dense, tough, blue limestone and interbedded dark fissile shale.

(a) Unconformity local in the vicinity of Savannah where the Lego limestone rests unconformably on the Hermitage formation.
(b) The Fernvale is still considered by some to be of Upper Ordovician age.

Along Willoughby Creek the formation consists of about equal parts of shale and limestone, some of the limestone being quite siliceous. In the vicinity of Russell the Hermitage contains more shale than limestone. Along Poney Creek, north of Swift, the limestone layers up to eight to ten inches thick are separated by much thicker shale beds.

The base of the Hermitage is nowhere exposed in Hardin County and there are no well records which show the formations underlying the Hermitage in this area. In Hardin County the Hermitage is the only Ordovician formation exposed at the surface, being overlain unconformably by rocks of Silurian age or younger. In Wayne County the younger Ordovician formations, Bigby, Catheys, or Leipers, generally rest upon it. In Hardin County, so far as known, none of these are present. Along Willoughby Creek and near Russell the Hermitage is overlain unconformably by terrace gravels of Quaternary age. At Savannah, as shown by cores from the river bed and at the bluff on the right bank of Horse Creek, 1-¾ miles south of Willoughby school, the Hermitage is overlain unconformably by the Lego limestone. At the latter locality a small fold brings up 22 feet of Hermitage. Here the dense limestone beds are four to five inches thick, separated by fissile shale layers nearly twice as thick. The dense, greenish to purplish Silurian limestone with spots of pink calcite which overlies the Hermitage here may perhaps combine beds belonging to both the Laurel and Lego, but probably is composed entirely of the latter. These formations are practically inseparable lithologically. Directly above the unconformity there is developed in places a thin layer of chert up to one inch thick.

On the right bank of Indian Creek about half a mile above the bridge between Cerro Gordo and Swift there are exposed eight feet of Hermitage above low water level, which is overlain by the Brassfield limestone. The upper two and one-half feet of the Hermitage shows signs of erosion and consists of blocky and lenticular limestone fragments (Hermitage) embedded in fissile shale. The Hermitage had apparently been undergoing extensive erosion previous to the deposition of the Brassfield limestone, the limestone blocks having been ripped up and rolled about. The unconformity is slightly irregular, varying up to one foot. The shale beds in the upper Hermitage contain a few phosphate nodules. At the base of the Brassfield limestone at this point is a cross-bedded, conglomeratic sandstone containing rounded cobbles of chert up to six inches in diameter. This basal conglomerate varies in thickness up to ten inches.

In the valley of Poney Creek the Hermitage is overlain unconformably by a thin bedded, coarsely crystalline, brownish gray limestone which is referred to the Fernvale. The massive limestone beds in the Hermitage upon weathering in places develops a shaly parting so that the entire exposure looks like shale. Analyses of the Hermitage limestone are given as Nos. 1, 2, and 3, p. 68.

For some years the Hermitage formation was used for the manufacture of cement at Clifton, in Wayne County. Traces of oil and gas have also been found in the Hermitage in other parts of Tennessee.

SILURIAN SYSTEM

FERNVALE LIMESTONE

The Fernvale is not known to occur in the county except in the north-northeast section north of Swift. Here it is very thin (0 to 10 ft.) and consists of thin bedded, crystalline, brownish gray limestone and gray shale. The limestone weathers to a brownish sandy surface. It rests unconformably on the Hermitage and is overlain unconformably by the Brassfield limestone. It is probably entirely absent over practically the whole county except the northeast corner. The Fernvale is considered by some to be of Ordovician rather than Silurian age. An analysis of the Fernvale limestone is given as No. 4, p. 68.

BRASSFIELD LIMESTONE

The Brassfield limestone occurs at the surface, so far as known, only in the northern portion of the county along Indian Creek and its tributaries, though it probably underlies the younger Silurian rocks over much of the eastern part. As stated above, it is absent in the central part around Savannah. If present in the south and west parts of the county it is deeply buried. Its thickness is variable up to 25 feet. The thickest section of the Brassfield limestone measured is on the right bank of Indian Creek about half a mile above the bridge between Cerro Gordo and Swift. As a general rule it is probably much thinner than 25 feet. At the above locality the Brassfield consists of three distinct parts:

1. The lower ten inches consists of a conglomeratic sandstone, containing chert cobbles up to six inches in diameter. This basal conglomerate was not noted elsewhere.
2. The next seven feet above the basal conglomerate consists of ferruginous, brown limestone that is reddish where weathered at the surface. Small solution channels, containing small stalactites, are common in this member.
3. The ferruginous member is followed by 17½ feet of thin to heavy bedded, dense, gray, glauconitic limestone. The upper Brassfield is overlain conformably here by a pinkish limestone with some interbedded shale referred to the Osgood limestone. Nine feet of this are visible, but with the top not exposed.

The Brassfield at Iron City in Wayne County is reported[6] to contain 17 percent of metallic iron and has been mined and used as a flux with

[6]Miser, H. D., op. cit. p. 127.

brown iron ores. Analyses of the Brassfield limestone are given as Nos. 5 and 6, p. 68."

Wayne Formation

The Wayne formation is made up largely of limestone with some shale, but practically no chert. The formation consists of the following members, from bottom to top: Osgood limestone, Laurel limestone, Waldron shale Lego limestone, and Dixon limestone. The members are for the most part thin, as is the whole formation. For this reason this group of rocks could not be mapped separately in the short time available. The entire Silurian system has accordingly been mapped as a single unit. The Wayne Formation is widely exposed in the stream valleys in the northeast quarter of the county. If present elsewhere, it is covered by younger rocks. In the vicinity of Savannah the lower members are missing. The Lego or Laurel limestone, probably the former, rests unconformably upon the Hermitage limestone and shale of Ordovician age.

Osgood Limestone. The Osgood Limestone has not been certainly identified anywhere in the county. Along the lower course of Indian Creek, lying conformably upon the Brassfield limestone, there occur at least nine feet of pinkish to reddish limestone with some interbedded gray shale that is referred to the Osgood. The horizon elsewhere in the county is soil covered, buried, or absent through erosion.

Laurel Limestone. The Laurel and Lego Limestones are so similar lithologically that it is impossible to separate them except where they occur in the same exposure or where the Waldron shale is exposed. Foerste[7] long ago recognized this fact and proposed the term *Glenkirk* for the undifferentiated Laurel, Waldron and Lego beds. The lower part of the Glenkirk, or Laurel, is exposed at few places in the county, being largely confined to the outcrops along Tennessee River at Cerro Gordo and along the lower part of Indian Creek and its tributaries. Its thickness is rather uncertain, but it is probably not much over 35 feet. Three-fourths of a mile northeast of Swift, in the valley of Poney Creek, the terrace gravels lie on a dense, light gray to pinkish limestone which is referred to the Laurel. Twenty feet of this limestone is exposed but is separated from the underlying Brassfield limestone by a 40-foot covered interval. The Laurel probably occupies a good portion of this covered interval. In the bluff at Cerro Gordo Landing a few feet of Laurel are exposed at water level, overlain by 13 inches of Waldron shale. Here the Laurel does not appear to be quite so pinkish as the Lego limestone and it is less stylolitic, though the differences are so slight as to be easily overlooked. The Laurel is a heavy bedded stylolitic, dense, tough, light gray to pinkish gray limestone, and would probably make an admirable building stone. With the exception, however, of one or two places in the

[7]Foerste, A. F., op. cit. p 566.

vicinity of Swift, where the Laurel is exposed, it is buried too deeply to be of any importance.

Waldron Shale. The Waldron Shale was recognized at only a very few points in the north part of the county. It is uniformly thin, the thickest section noted being 18 inches. For this reason it might easily be overlooked and probably occurs more frequently than was observed. The Waldron consists of gray clay or shale and shaly nodular limestone separating the Lego limestone from the underlying Laurel. In the central part of the county the Waldron shale was not noted.

Lego Limestone. The Lego limestone, together with the overlying Dixon, is one of the most widely distributed Silurian limestones in Hardin County. The Lego is well exposed along Tennessee River at Savannah and again at Cerro Gordo. In addition, it forms extensive outcrops along Horse, Indian and Hardin creeks and their tributaries. It varies in thickness up to 36 feet and over much of the area where it comes to the surface is well over 25 feet thick.

The Lego limestone is remarkably uniform in character throughout the county. It is a heavy bedded, stylolitic, dense, tough, light gray to pinkish-gray limestone. In places it contains small crystals of pyrite; at others it has a slight lavender tinge, and elsewhere contains small grains and crystals of pink calcite. Where the pink grains are abundant they give a pinkish tinge to the rock. As a general rule the Lego is unfossiliferous, but occasionally orthoceratites or crinoid stems are present in addition to microscopic forms. The Lego is overlain conformably by the Dixon limestone. In the north and northeast portions it overlies confromably the Waldron shale, but in the vicinity of Savannah and along Horse Creek it rests unconformably upon the Hermitage limestone. The stratigraphic relations to the southeast, south and west are not known since it is buried by younger sediments in those areas.

The Lego limestone has been used as a foundation stone for several of the buildings in Savannah and has proved its value as a building stone. Its uniform character, resistence to weathering, and heavy bedded nature make it admirable for this purpose. In addition, the Lego is often the surface rock where little or no overburden is present and quarries might, therefore, be opened with a minimum of difficulty. An analysis of the Lego limestone exposed along Horse Creek, east of Scott's store, is given as No. 7, p. 68.

Dixon Limestone. The Dixon limestone is the most widely distributed surface limestone in Hardin County. It outcrops over much of the central and northeast portions, particularly along the stream valleys where it frequently forms ledges and bluffs. In the central and extreme northeast portions, where the Dixon is covered by younger sediments, it underlies much of the area at shallow depths. In a very few places the Dixon is absent where older rocks have been brought to the surface along the axes of folds. Single exposures showing the top and bottom of the

Dixon are infrequent, but show where present, a thickness of about 40 feet. In the east part of the county the Dixon is very slightly thicker, but it appears to be quite uniform in thickness in Hardin County.

In Wayne County, except in the northwest part, the Dixon is described as greenish-gray in color. In the vicinity of Clifton, however, it is red. In Hardin County a large part of the Dixon limestone is everywhere of a dark brick-red color. The dark red limestone is often blotched and mottled with patches of greenish limestone. The limestone beds are separated by beds of red to greenish-gray shale. The member is decidedly earthy throughout. As a general rule the limestone is redder than the shale. The whole of the Dixon is thin bedded and, except for a few orthoceratities and crinoid stems, fossils are rare.

The Dixon limestone lies conformably on the Lego limestone and is overlain conformably by the basal member of the Brownsport formation wherever its lower and upper boundaries are exposed. The Dixon weathers to a reddish or chocolate colored clayey soil which, on the basis of color, is often difficult to distinguish from the red Cretaceous sediments. The latter, however, always contain some sand and mica flakes which are not present in the residual soils from the Dixon. In the vicinity of Old Town this red clayey soil is 10 to 12 feet or more thick and is suitable for making a low grade paint. An analysis of the red Dixon limestone from Paulk's Mill, on the right bank of Horse Creek, 2½ miles northeast of Savannah is given as No. 8, p. 68.

Brownsport Formation

The Brownsport formation is not everywhere present in the county, being locally cut out by unconformities. It forms the surface rock in many places in the central, east, and northeast section. It consists entirely of limestones and shales with some chert, the limestones being predominant. It is divided into three members. The basal member is known as the Beech River limestone and shale, which is followed by the Bob limestone member and this by the Lobelville limestone member. The total aggregate thickness is only 105 feet and in most places is much less than this. The formation thickens and thins considerably. The Beech River member is the most persistent and has the greatest areal extent.

Beech River Limestone and Shale. The Beech River limestone and shale occurs at the surface at many places in the central, east, and northeast portions of the county. Its thickness is variable, ranging from nothing up to 45 feet. The member is thin bedded and consists of brownish-gray, shaly limestone and gray and greenish clays and shales. In many cases there is two or three times as much shale as limestone. Frequently the bulk of the shale occurs in the upper part of the member. The limestone is locally glauconitic, pyritic, or cherty. In places the Beech River limestone is dense and fine grained, at others slightly crystalline, and rarely coarsely crystalline. It is the most persistent glade-forming rock in the county and practically everywhere its outcrops are marked by barren patches of white or light gray clay and limestone rubble, upon which little grows except cedars, bushes, and weeds.

The glades are in some places covered with great quantities of excellently preserved fossils. The most abundant fossils are various kinds of brachiopods, trilobites, and gastropods. In most cases, however, the fossils, though abundant, are poorly preserved, while frequently the glades are practically barren of fossils.

To the north in Decatur and Perry counties, the glades formed by the Beech River are abundantly fossiliferous and in most cases the fossils are excellently preserved. The Beech River overlies the Dixon conformably and is in turn overlain conformably by the Bob limestone member. Rock from the Beech River member has been used to some extent for building chimneys for residences in the vicinity of Old Town and it is reported to be well suited for this purpose. Locally it is called "chimney rock".

Bob Limestone. The Bob limestone member of the Brownsport formation is less widely distributed than the underlying Beech River. It occurs in patches along the streams in the central, east, and northeast parts of the county. It is also probably present in other parts where it is covered by younger rocks. In thickness the member ranges from nothing to 20 feet, but appears to thin toward the east and northeast. In the vicinity of Burnt Church it is 20 feet thick and along the river below Grandview Landing it has decreased in thickness to 11 feet, while along Indian Creek close to the Wayne County line it is only 10 feet in thickness. In Wayne County it thickens to a maximum of 35 feet.

In Hardin County the Bob is a crystalline—almost sugary,—even bedded, light gray to white limestone. In places it is somewhat pinkish. At Grandview it is stylolitic and rather heavy bedded, beds occurring up to two feet thick, and contains a little brown chert. At Cerro Gordo the Bob is even-bedded in layers four to eight inches thick and is rather uniform in character. It overlies the Beech River limestone and shale conformably and is overlain conformably by the Lobelville limestone member. Where it occurs in rather thick beds it is probably suitable for building stone. It may also be suitable for making quicklime. An analysis of the Bob limestone from the bluff below Grandview Landing is given as No. 9, p. 68.

Lobelville Limestone. The Lobelville limestone is patchy and irregular in its distribution like the underlying Bob member and has in general the same areal distribution. The Lovelville varies greatly within a few miles—from nothing up to 40 feet in thickness. It is invariably thin bedded and cherty, the chert sometimes occurring in irregular beds up six or eight inches thick. The chert appears to be somewhat concentrated in the upper part of the members and is brown-black in color.

The limestone is generally brownish to gray in color but is in places blue. In some places it is somewhat shaly and occasionally contains small grains of pyrite. Locally, the Lobelville is packed with fossils, especially corals, the residual soils at such points containing beautifully preserved coral heads. The Lobelville limestone overlies the Bob conformably and is overlain conformably by the Decatur limestone.

Decatur Limestone

The Decatur limestone comes to the surface in many places along the streams in the eastern part of the county. In the southeast section along Horse Creek and its tributaries, it is only brought to the surface in small patches on the crests of folds. Due to its massive character its outcrops are often marked by bluffs. The formation varies in thickness from nothing up to 60 feet, being cut out in places by erosion subsequent to its deposition. The periods of erosion which this area underwent during Upper Silurian and later times and the numerous resulting unconformities are largely responsible for the extremely variable thickness of the various formations. The Decatur limestone is rather uniform in character throughout the entire county. It is dense, heavy bedded to massive, stylolitic, gray limestone, but varies somewhat from place to place. Occasionally it is slightly thin bedded or shaly, white to pinkish, crinoidal and crystalline, or slightly cherty.

The Decatur limestone overlies the Brownsport formation conformably but is marked at the top by a pronounced unconformity, the overlying rocks ranging from Devonian to Cretaceous in age. The purity of the Decatur would make it suitable for making quicklime, as a flux, or as a constituent for mixing with shales or clays in the manufacture of cement.

A chemical analysis of the Decatur limestone a tenth of a mile southeast of Burnt Church is given as No. 10, p. 68.

DEVONIAN SYSTEM

The rocks of Devonian age are not widespread in Hardin County but occur in small patches scattered along the streams in the eastern half of the county. They occur in nearly every case in structural basins or synclines where they have been preserved from subsequent erosion in these downwarps. The older formations and members are best preserved, and outcrop over a wider area than the younger ones.

Rockhouse Shale

The Rockhouse shale is the oldest Devonian formation present in Hardin County and so far as known outcrops only in the southern half of this county. It appears to thicken to the south but is below drainage south of Horse Creek. Exposures are therefore few, and because of the excellent and thick section exposed at the Rockhouse on Horse Creek, Dunbar[8] has named it the Rockhouse shale. It occurs also further down Horse Creek near the Chalybeate spring and again near Sulphur spring on the Ross farm. It also occurs in a small ravine by the roadside, half a mile south of the Sulphur spring. Here four feet of the shale are exposed below the base of the Ross limestone. Where exposed, the Rockhouse shale is greenish to gray, containing thin bands of shaly gray limestone, and is abundantly fossiliferous, containing, particularly, *Camarocrinus* bulbs. In thickness the Rockhouse shale varies from nothing to 26 feet. South of Horse Creek where it is covered it is probably thicker than this. It lies unconformably upon the Decatur limestone of Middle Silurian age, and is overlain conformably by the Ross limestone.

Olive Hill Formation

The Olive Hill formation is defined by Dunbar[9] as including the Ross limestone, Pyburn limestone, Bear Branch limestone, and Flat Gap limestone members. This group of limestones, excepting the Pyburn, is well exposed along Indian Creek in the vicinity of Olive Hill, in the northeast section of Hardin County. The formation consists entirely of limestone and is very patchy in its distribution because of the erosion it suffered in Upper Devonian time. The formation is fossiliferous throughout, brachiopods and trilobites being particularly numerous.

Ross Limestone. The Ross limestone, or lowest member of the Olive Hill formation, is also the most widely distributed. It is exposed particularly well on the Ross farm in the vicinity of the Chalybeate spring on Horse Creek. Good exposures also occur at Pyburn's Bluff on Tennessee River, along Horse Creek and its tributaries between Blount school and the mouth of Holland's Creek, along the headwaters of English and Choate creeks, along Indian Creek near Olive Hill, on both sides of the mouth of Smith's Fork, and in the bluffs below Grandview and Cerro Gordo. The thickest section measured occurs along Horse Creek in the vicinity of Chalybeate spring. The steep bluffs 30 to 40 feet high along the creek in this vicinity are formed by the Ross limestone, which here reaches a thickness of 60 feet. At many other places in the county the Ross shows a thickness of 40 to 50 feet.

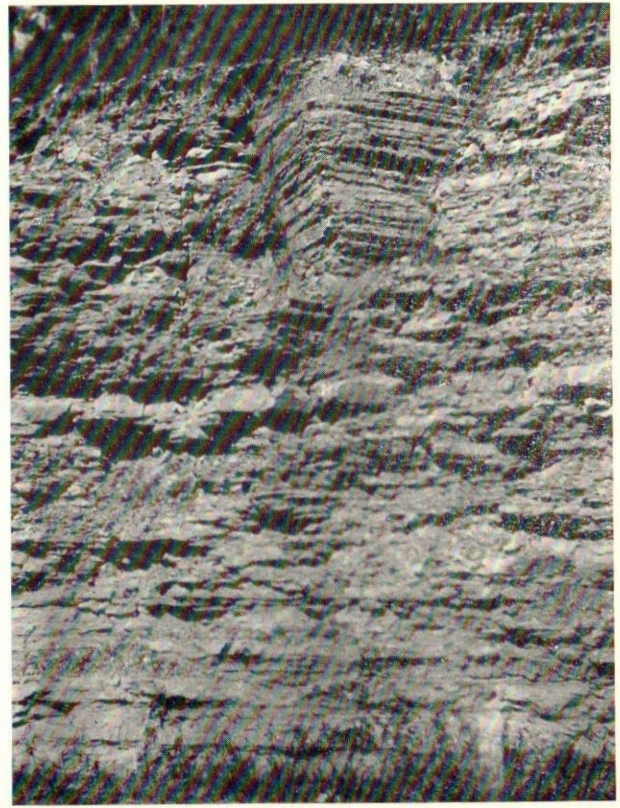
Lithologically the Ross is a dense, tough, cherty, massive to thin bedded, dark blue, siliceous limestone. Cores secured from borings on the Pickwick Landing dam site were dissolved in concentrated acid. The residue was a sandy aggregate of microscopic texture. The rock, however, looks and weathers like an impure limestone. At the type section at the Chalybeate spring there is very little chert present, as is also the case in the cut just east of Olive Hill, on highway 15. This fact prob-

[8]Dunbar, C. O. op. cit. p. 38.
[9]Dunbar, C. O., op. cit. p. 43.

(A) Flat 420 foot terrace north of Savannah.

(B) View west across the flat terrace, three-tenths of a mile northwest of Scott's store on the Florence road. Altitude is 435 feet.

(A) Typical exposure of the Beech River limestone and shale, $1\frac{3}{4}$ miles southeast of Grandview Landing. Notice the barren rocky soil and the cedar trees. It is on such glades as this that well preserved fossils in some places occur in abundance.



(B) Thin-bedded Ross limestone in first cut east of Olive Hill on State Highway 15. Approximately 25 feet of limestone are exposed.

ably led Dunbar to believe that the Ross contained very little chert. In the section exposed along the headwaters of English Creek particularly, but also in many other exposures, the Ross limestone is very cherty, containing solid beds and lenses of chert up to eight inches thick The absence of chert is rather unusual. The upper portion of the Ross at Chalybeate spring is slightly more than the middle and lower parts, but this was not noticed elsewhere. In the cut east of Olive Hill much of the Ross is crystalline and gray rather than dense and blue. The usual dense, blue character of the Ross is about identical in appearance with the much older Hermitage limestone. The Hermitage, however, contains abundant shale and no chert. In addition, the Ross contains many fossils, the most characteristic of which are *Camarocrinus* bulbs and fragments of huge trilobites a foot or more in length.

The Ross limestone overlies the Rockhouse shale conformably in the southern part of the county. Elsewhere it rests unconformably on the older Silurian rocks. It is overlain conformably by the Bear Branch and Pyburn limestones at Olive Hill and Pyburn's Bluff respectively, but at many places in the county the Ross is separated by an unconformity from the younger Devonian, Mississippian, or Cretaceous rocks which overlie it. The Ross limestone weathers into a friable, buff colored sand or rottenstone which in places is difficult to distinguish from the Hardin sandstone.

On the road between Counce and Pickwick the Ross has weathered into a rusty, crumbly sandstone which is crowded with fossils, trilobites of three or four kinds being the most conspicuous. This dense limestone would probably make a good building stone but it has not been used for this purpose so far as the writer knows.

Four analyses of the Ross limestone showing its impure and variable composition are given as Nos. 11 to 14, p. 68.

Pyburn and Bear Branch Limestones. At Pyburn's Bluff along Tennessee River in the south part of the county the Ross limestone is overlain conformably by the Pyburn limestone, while at Olive Hill the Bear Branch limestone overlies it. Dunbar[10] appreciated the possibilities of these two members representing the same horizon in spite of their distinct differences lithologically and stated, "It is supposed that if interformational erosion had not removed them from central Hardin County these layers (Bear Branch limestone) would become impure dirty limestone toward the south, grading into the Pyburn". The evidence collected by the writer is not sufficient to show definitely the exact equivalence of these two members but is strongly suggestive that the Bear Branch limestone at Olive Hill and the Pyburn limestone at Pyburn's Bluff are local phases of the same member.

In the section along the headwaters of Choate Creek the Hardin sandstone rests unconformably upon 18 feet of interbedded shale and

[10]Dunbar, C. O., op. cit. p. 50.

limestone that lie conformably on typical Ross limestone containing *Camarocrinus*. This 18 feet of limestone and shale is undoubtedly equivalent to the Pyburn and Bear Branch limestones and shows certain features common to both. It more closely resembles the Pyburn, as might be expected from the fact that it is much nearer to Pyburn's Bluff than it is to Olive Hill. The limestone on Choate Creek is light gray, crinoidal, and subcrystalline. It contains a small amount of hematite. The shale is greenish-gray. The gray color and shaly character is somewhat similar to the Pyburn limestone, while the crystallinity and hematite content are characters present in the Bear Branch. A close study of the faunas of the two members will be necessary to definitely prove their exact equivalence.

Pyburn Limestone. The Pyburn limestone is confined to the southern part of the county. It is well exposed along the bluff east of Pyburn on Tennessee River and along the tributary stream beds in this section. It is also well exposed along Dry Creek and its tributaries close to the Alabama state line. At these localities the Pyburn is an impure, cherty, massive to thin bedded, dark gray to brownish limestone. In places it is cross bedded as the Bear Branch member is, and locally the Pyburn is somewhat shaly. Again it is a dense blue limestone indistinguishable lithologically from the Ross. At Pyburn's Bluff it is very similar to the Ross in appearance. The transition from one into the other is extremely gradual though the *Camarocrinus* bulbs which are rather abundant in the Ross, stop abruptly at its top.

The Pyburn, as a whole, is more massive and less cherty and siliceous than the Ross limestone. The former is also apparently more soluble than the latter. No caves were observed in the Ross, but are common in the Pyburn in spite of its impure character. Along Haw and Bluff branches many small springs occur at the base of the Fort Payne chert where it rests on the impervious Ridgetop shale. The streams from these springs disappear as soon as they strike the Pyburn limestone, reappearing as springs again at the Pyburn-Ross contact. The Big cave at Walnut Grove on Mr. Quall's farm is also cut in the Pyburn limestone which is here very impure and cherty, the chert layers being occasionally three to four inches thick. In the bluff a quarter of a mile west of the mouth of Bluff Branch, galleries and solution channels have been dissolved along joint planes in the Pyburn and occur in sets at angles of from 80° to 85° to one another. At Pyburn's Bluff the Pyburn limestone varies from 40 feet in thickness to a feather edge. In the cave on the Quall place 35 feet of Pyburn are exposed without revealing the base. The thickness of the Pyburn is very variable. Wherever observed, the Pyburn rests conformably on and grades into the Ross limestone below. At Dry Creek school is it overlain by the Flat Gap limestone, thus occupying the same stratigraphic position as the Bear Branch limestone at Olive Hill. At many places the Pyburn is covered unconformably by younger rocks.

The chemical composition of a specimen of typical Pyburn limestone occuring along Haw Branch is given as No. 15, p. 68.

Bear Branch Limestone. The Bear Branch limestone, which is probably the equivalent of the Pyburn limestone, is best exposed along Indian Creek and its tributaries, in the vicinity of Olive Hill. Here a maximum thickness of about 45 feet is exposed. It thins rapidly to a feather edge in all directions. The exposure at the type locality along Bear Branch, a small tributary to Indian Creek, south-southeast of Olive Hill, shows a thickness of only 35 feet.

In the vicinity of Olive Hill the Bear Branch limestone is a massive, cross-bedded, finely crystalline, reddish, ferruginous limestone. The upper ten feet along Bear Branch are more distinctly bedded. The massive character is responsible for the steep bluffs which the member forms in this general area. The Bear Branch member is distinctly cross-bedded and contains a variable quantity of oolitic hematite. The iron content is very erratic, certain beds containing practically no hematite while others contain up to 45 percent of ferric oxide. A series of analyses showing this variation is given on page 59.

The ore at the old Sanders mine, 1½ miles south-southeast of Clifton, Tennessee, a short distance from Hardin County, is said by Dunbar[11] to be the result of the weathering of the Bear Branch limestone. At Olive Hill the Bear Branch member overlies the Ross and underlies the Flat Gap limestones. The iron content of the Bear Branch is too low to be utilized as an iron ore but it might be used under suitable conditions as a flux with the brown iron ore deposits that are widely scattered over this section of Tennessee.

Flat Gap Limestone. The Flat Gap limestone or upper member of the Olive Hill formation, is exposed, so far as known, in only three places in Hardin County. It is well exposed along Indian Creek and its tributaries at Olive Hill and takes its name from Flat Gap Creek which is tributary to Indian Creek just north of Olive Hill. It is also exposed at Dry Creek School on Dry Creek and along a small unnamed branch tributary to Hardin Creek a little over a mile east of Grandview Landing. Elsewhere it has been cut away by erosion that took place in later Devonian and subsequent time. Dunbar[12] gives a thickness of 53 feet for the Flat Gap at Olive Hill. No section measured by the writer was as thick as this though that is to be expected because of the erratic distribution of the Flat Gap. In the bluff adjacent to the floodplain of Indian Creek directly east of Olive Hill the member is approximately 40 feet thick at the north end of the bluff, yet pinches out entirely before reaching the

[11] Dunbar, C. O., op. cit. p. 45.
[12] Dunbar, C.O., op. cit. p. 120.

highway. East of Grandview the Flat Gap limestone is 20 feet thick with the base not exposed, while at Dry Creek School it is about 25 feet in thickness. Wherever exposed the Flat Gap is a massive, crystalline, stylolitic, light to pinkish-gray limestone and is remarkably uniform in character from top to bottom. It weathers to a light cream. It is sparingly fossiliferous. The Flat Gap overlies the Bear Branch and Pyburn limestones and is unconformably overlain by younger rocks. Because of the high content of calcium carbonate this limestone is suitable for the manufacture of lime. It would also make an admirable building stone, and because of its crystallinity and the good polish that it takes, would apparently be suitable for marble. An analysis of the Flat Gap limestone from Bear Branch, east-southeast of Olive Hill, is given as No. 16, p. 68.

Birdsong Shale

The Birdsong shale, so far as known, occurs at only one place in Hardin County. At the boat landing at Saltillo eight feet of deeply weathered light gray to white clay and thin chert beds rest unconformably on top of the Decatur limestone. These beds are overlain by the Decaturville and Harriman cherts in a small ravine nearby, but at the landing the Birdsong shale is overlain by river alluvium. The contact of the Birdsong and the Olive Hill formation is nowhere shown in Hardin County, but Dunbar thinks that the Birdsong shale is distinctly younger than the Flat Gap and separated from it by an erosional break.

Decaturville Chert

The Decaturville chert is not known to occur in the county except at Saltillo, Grandview, and along Dry Creek. At none of these points was it seen in place, but the presence of fragments of porous, gray, extremely fossiliferous chert suggests that a foot or two of the Decaturville is present. The contacts of the Decaturville chert are covered in Hardin County but in the exposures in the Tennessee River Valley to the north the Decaturville is separated by an erosional break from the underlying Birdsong shale. The fossils show that there is also an unconformity separating the Decaturville from the overlying Quall limestone of Oriskany age[13].

Quall Limestone

The Quall limestone apparently occurs in only two places in the county. Dunbar[14] reports four feet of this limestone at Grandview, but it was not seen there by the writer. Approximately 10 feet of it outcrops on the Quall place, along the lower course of Dry Creek east of Walnut Grove. Here it is a heavy bedded, dense, cherty, gray limestone which weathers to a porous mass of chert crammed with fossils. It

[13]Dunbar, C. O., op. cit. p. 27.
[14]Dunbar, C. O., op. cit. p. 116.

is overlain unconformably by the Hardin sandstone along the roadside in front of the Quall place. The Quall limestone along the road rests on top of the Pyburn, but at Dry Creek school less than a mile to the east, it is absent so that its exact relation to the Flat Gap limestone is not shown. Dunbar concludes that there it an unconformity between the Quall limestone and the Decaturville chert and also another break between the Quall limestone and the younger Harriman chert.

Harriman Chert

The Harriman chert is the youngest lower Devonian formation present in Hardin County. Approximately 40 feet of the formation is exposed in the bluff at Grandview and a thinner section in the ravine southwest of Saltillo Landing. Dunbar[15] reports its presence at Cerro Gordo, but if there the writer failed to find it. Where exposed at Saltillo and Grandview it is a thin bedded, brittle, buff to gray chert. At Saltillo the chert is badly fractured and crumpled. In places the fractured chert has been recemented, forming a breccia. Dunbar[16] describes the Harriman as a novaculite, implying that it is entirely crystalline. Microscopic examination of material from Saltillo failed to show this crystalline character except to a limited extent, and the Harriman formation in Hardin County at least, is a true chert. It is however, slightly more crystalline than the Fort Payne and other cherts and has a somewhat duller surface on fresh breaks. In Hardin County the Harriman chert is overlain unconformably by younger formations. Its lower contact is covered in the county so that its relation to older rocks is not shown. From a study of other localities in the Tennessee valley it is probable that there is an erosional break at the base of the Harriman chert. The cherts or novaculites of the Decaturville and Harriman formations are important road metals in other portions of Tennessee, but they are not present in sufficient quantities in Hardin County to be of any economic significance.

MISSISSIPPIAN SYSTEM

Chattanooga Formation

The age of the Chattanooga formation or "Black Shale" has long been in dispute. It was formerly considered of upper Devonian age but has since been placed in the Mississippian. By others it is considered to belong in part to both periods. The writer has no particularly convincing evidence to add to the existent mass of conflicting data. However, the Chattanooga formation in Hardin County, though often developed in three lithologic units, is distinctly related in its areal distri-

[15]Dunbar, C. O., op. cit. p. 74.
[16]Dunbar, C. O., op. cit., p. 71.

bution to the rocks of unquestioned Mississippian age and has therefore been mapped with them as a unit. However, one of the most pronounced unconformities in the entire section, frequently showing an angular discordance up to four degrees, occurs at the base of the Chattanooga formation. It is true that an unconformity also separates the Chattanooga formation from the overlying Ridgetop shale and this break between the Chattanooga, ("Whetstone Branch") and the overlying Mississippian rocks ("Carmack") in northeastern Mississippi has been used by Morse[17] to substantiate the Devonian age of the "Whetstone Branch" shale, which is apparently typical Chattanooga shale. In Hardin County, however, a few miles to the north an unconformity of almost equal significance occurs at the base of the Fort Payne formation, but this would not necessarily indicate a very great break in time between the Ridgetop and the Fort Payne. Also, the unconformity at the top of the Chattanooga formation in Hardin County is not nearly as profound as that below it. If sedimentary breaks have any true value in delimiting geological periods it follows that those in question indicate a Mississippian rather than a Devonian age for the Chattanooga formation in this section[18].

The Chattanooga formation is widely exposed in Hardin County and overlaps the older Silurian and Devonian rocks over much of the eastern half of the county. Though the proper horizon is in nearly all places deeply buried west of Tennessee River wherever the older rocks come to the surface, the Chattanooga is missing. It is present in northeastern Mississippi but is absent two miles north of the mouth of Yellow Creek. Foerste[19] reported it from a well north of the landing at Saltillo. This identification was probably erroneous for the Cretaceous gravels overlie the Devonian Harriman formation at Saltillo Landing and the Chattanooga shale is absent. In any case the Chattanooga horizon would be much above water level at the landing. The Chattanooga formation in Hardin County consists of the basal Hardin sandstone member, the black shale member, and the Maury glauconitic member. The black shale is often divided into an upper slabby part and a lower platy, extremely fissile portion. In places a sandstone bed separates the two. Evidence will be presented later to show that the Maury member, which is usually placed at the base of the Ridgetop, in reality belongs to the Chattanooga formation.

Hardin Sandstone The Hardin sandstone is well exposed along the streams in eastern Hardin County and is often present where the overlying black shale is absent Frequently the younger Mississippian rocks rest unconformably on beds older than the Chattanooga. The Hardin

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[17]Morse, W. C., "Paleozoic Rocks of Mississippi" Jour. of Geology Vol. XXXVI, p. 43, 1928.

[18]The work of E. R. Pohl in 1929 has shown that the Chattanooga shale in Middle Tennessee is entirely of Mississippian age. (Personal communication).

[19]Foerste, A. F., op. cit. p. 689.

sandstone is particularly well exposed along Indian Creek in the vicinity of Olive Hill where it has a maximum thickness of 16 feet. Thicknesses of from 12 to 15 feet are common along Indian Creek above Olive Hill to the Wayne County line. The Hardin sandstone thins to the west and south.

Near the union of the North and South forks of White's Creek the Hardin sandstone is 10 feet thick, At the head of Choate Creek it is but four feet thick and only 4-½ feet at Dry Creek School on Dry Creek. On Cain Creek, in the vicinity of Burnt Stand, it is reduced to from two to six inches. On the road 1-⅝ miles south of Scott's store it is only one foot thick, while in the vicinity of Pyburn's Bluff it is very thin or entirely missing.

In the vicinity of Olive Hill the Hardin is a ledge-forming, massive, fine grained, cross-bedded, marcasitic, phosphatic, gray sandstone. It weathers to a greenish-yellow. Iron stains are common from the decomposition of the marcasite. The weathered sandstone is in places full of nearly spherical cavities up to an inch or more in diameter, resulting from the disintegration of the marcasite nodules. Elsewhere in the county the sandstone is generally much darker in fresh exposures. In places it is nearly black. Along Cain Creek the base of the Hardin contains chert pebbles derived from the underlying cherty limestones. The darker colored sandstone generally contains more phosphate. Occasionally thin bands of black shale occur in the sandstone. The Hardin contains a variable quantity of phosphate throughout the county. Where the younger black shale is absent, due to post-Chattanooga erosion, the Hardin sandstone often shows in its upper portion, nodules of phosphate. It is doubtful if the Hardin sandstone will be of any economic significance in the near future. Analyses showing the phosphate content of the Hardin sandstone are given on page 72.

Everywhere in the county the Hardin rests unconformably on older rocks. This break is often of an angular character with a discordance of a few degrees. The maximum discordance of four degrees was noted along the headwaters of Bear Branch east-southeast of Olive Hill where the Hardin rests on the Decatur limestone.

Fish remains are reported to occur in the Hardin sandstone along Dry Creek, but no fossils of any kind were observed by the writer in the Hardin except small Lingula shells.

Black Shale. The black shale overlying the Hardin sandstone is not as widely distributed as the latter, though outcrops are common in the eastern part of the county. In places the change from sandstone to shale is sharp, but usually the sandstone grades into the overlying shale through a zone of sandstone and sandy shale beds. Sandstone beds and lenses a few inches thick are common throughout the shale. The sandstone beds and lenses in the shale are often very dark, but sometimes gray to yellowish, and are usually phosphatic. The shale is coal black and contains locally, abundant Lingula shells. It contains everywhere large quantities of carbonaceous matter. In places seams of coal a fraction of an inch thick are present. The shale will often burn when thrown on a fire. It is in no sense coal, however.

In August, 1915, after a perod of heavy rains, a large pile of rock that had been dredged from the river bottom south of Hamburg took fire and burned for two months. Bowers[20] has written a good description of this unusual occurrence. The rock pile was composed largely of Ross limestone with considerable quantities of black shale. Rapid oxidation of the iron sulphides in the rock raised the temperature sufficiently to ignite the oil and other organic matter in the shale. Large quantities of sulphur dioxide were given off and stripped the vegetation from the trees over a considerable area. Such spontaneous combustion is unusual in shales and points to the high carbonaceous content of the black shale.

The thickness of the black shale member is very variable in Hardin County. In the eastern part of the county east of Indian Creek it reaches a maximum thickness of 25 feet. In most places it is much thinner and is often entirely absent. The shale seems to be split into two distinct divisions at a number of places. The lower part is very platy and fissile, while the upper part breaks off in great slabs. East of Lowryville three-tenths of a mile, these two divisions are separated by a layer of sandstone.

Maury Glauconitic Member. At the top of the Chattanooga formation in a few places there is a thin greenish, phosphatic layer of sandstone and shale which is called the Maury glauconitic member. This member varies from nothing up to six feet in thickness. It is probably present at some places where the writer failed to find it because of its thinness. It is true, however, that the Maury member is entirely absent over much of the county. At numerous places the contact of the Chattanooga and Ridgetop formations is clearly exposed, and in all but four cases nothing comparable to the Maury glauconitic member is present. Along the headwaters of English Creek 18 inches of green, phosphatic, sandy shale, with a 10 to 12 inch bed of dark blue limestone at the base, occurs between the Chattanooga and Ridgetop shales. On Andrew Abel's place, on Still Creek, 6-½ miles northeast of Savannah, 12 to 14 inches of greenish to bluish, phosphatic sandstone separates the Chattanooga and Ridgetop shales. At the mouth of Holland's Creek a very interesting section is exposed. Overlying the black shale member there, which contains thin sandstone layers, occurs six feet of green to gray phosphatic sandstone and greenish shale. This is probably the equivalent of the Maury shale though at this locality it is largely sandstone. The six feet of greenish sandstone and shale are overlain disconformably by 20 inches

[20]Bowers, P. C., "An interesting case of spontaneous combustion," Tenn. Geol. Survey, Resources of Tennessee, Vol. VI, No. 1, pp. 37-40, 1916.

of glauconitic sandstone and phosphate nodules. This 20 inch sandstone bed, which in places is almost a conglomerate, is apparently overlain conformably by 35 feet of typical Ridgetop shale.

The Maury shale is generally considered to be the basal member of the Ridgetop formation, but in Hardin County the evidence seems to show that it belongs to the Chattanooga formation. There are several reasons for placing it there as has been suggested in the past by some geologists. Swartz[21] states in his discussion of the Chattanooga shale: "In western Tennessee the black shale has been entirely removed by post-Chattanooga erosion at many localities. The Maury shale, however, is invariably present, whether such erosion is complete or only partial", and uses this as proof that the Maury is the basal member of the Ridgetop shale. This is not true in Hardin County. As has already been stated, the Maury was observed at only four localities in the county though the contact between the Chattanooga and Ridgetop shales is clearly exposed at many places. At the mouth of Holland's Creek the basal member of the Ridgetop is a pebbly sandstone containing sandstone pebbles derived from the underlying Maury. In the Waynesboro quadrangle to the east, according to Miser[22], the Maury is usually but not always present. In this area, as in Hardin County, the Maury is very sandy. It would seem that if the Maury is the basal member of the Ridgetop it should be present everywhere at the base of the latter or at least it should be present in most cases. This is far from true in Hardin County where the Maury is not as widely distributed as the underlying black shale which in turn is not so widespread as the Hardin sandstone. If there were a distinct break between the Maury and Ridgetop as the section at the mouth of Holland's Creek indicates, the observed relations are as would be expected, but they are incompatible with the supposed Ridgetop age of the Maury.

The writer considers that the above evidence indicates that the Maury glauconitic member shows closer affinities with the Chattanooga than with the Ridgetop shales.

Analyses showing the phosphate content of the Maury member are given on page 72. The member is everywhere phosphatic. The phosphate content is variable and in general is disseminated through the shale and sandstone but also occurs in the form of nodules.

The Chattanooga shale, as well as the younger Ridgetop shale, is more resistant to erosion than the older limestones. The shales frequently cause sharp valleys and ravines where they outcrop. The Chattanooga formation contains large quantities of low grade phosphate rock and carbonaceous material, but it is extremely doubtful if these are of any economic importance under present conditions.

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[21]Swartz, J. H., "Age of the Chattanooga shale of Tennessee," American Jour. of Science, Vol. 7, p. 29 1924.

[22]Miser, H. D., op. cit. p. 24.

Ridgetop Shale

The Ridgetop shale is widely distributed in the county, occurring as narrow belts along the stream valleys in the east and south parts of the county. It is particularly well exposed along both sides of Tennessee River and its tributaries from Pyburn south to the Alabama and Mississippi state lines and along Horse, White's, Holland, Rogers, Turkey, and Indian creeks. The thickness of the Ridgetop shale is variable because of erosion which took place subsequent to its deposition and previous to Fort Payne time. It varies from a feather edge up to 110 feet in thickness. The thickest section measured was in the vicinity of Wynn Landing on the west side of Tennessee River about 2½ miles north of the Mississippi state line. At many other places however, thicknesses of 40, 50, 60 and even 70 feet are common. In the northwest part of the county at Craven's Landing and at Saltillo the Ridgetop is entirely absent. The Ridgetop formation consists principally of dark gray, fissile shale. At many places in the east part of the county the upper third of the Ridgetop contains beds of dense, tough, dark gray limestone which gives off a strong fetid odor when freshly broken. These tough limestone beds in some places contain layers and nodules of dark blue to black flint or chert. Some of the flint nodules are irregular in shape and contain, usually, abundant grains and small crystals of pyrite. The pyrite is in places segregated in the outer shells of the nodules. The limestone beds near the top in places contain small geodes lined with quartz crystals. Where the limestone has been exposed to weathering it is a light gray color. The shale weathers to a dirty gray or white clay which is sometimes sandy, greenish, or contains phosphate nodules.

The Ridgetop, like the Chattanooga, is practically barren of fossils, but in places, particularly along English and Rogers creeks, the limestone beds contain abundant fossils, chiefly brachiopods, the shells of which have been replaced by pyrite. The Ridgetop overlies the Chattanooga formation unconformably. It is overlain unconformably in Hardin County by the Fort Payne chert. This erosional interval between the Ridgetop and Fort Payne is not recognized by Miser[23] in the Waynesboro quadrangle, to the east, or by Wade[24] in Perry County to the north.

The "Carmack" limestone of Kinderhook age in northeast Mississippi, which is probably the equivalent of the Ridgetop formation, is said by Morse[25] to be "separated from the underlying formations by a pronounced unconformity. It is also separated from the overlying beds by a great unconformity."

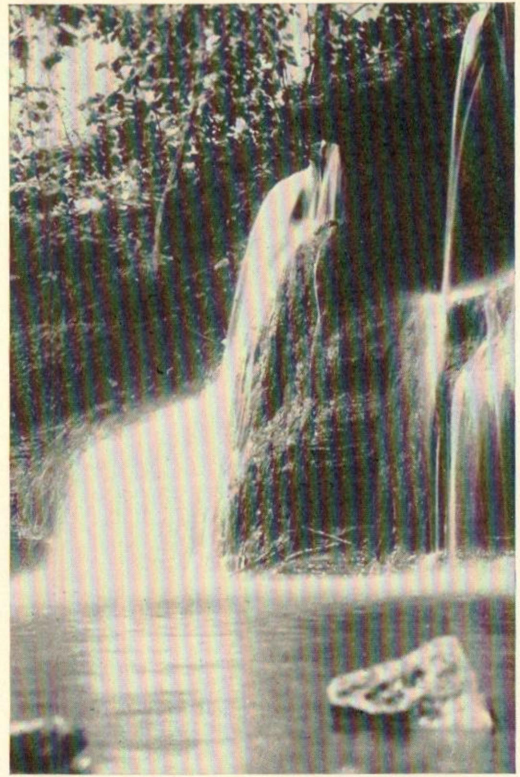
Physical evidences of a break between the Ridgetop and the Fort Payne in Hardin County are rather meager, but the upper part of the

[23] Miser, H. D., op. cit. p. 16.

[24] Wade, Bruce, "The Geology of Perry County and vicinity," Tenn. Geol. Survey, Resources of Tennessee, Vol. IV, No. 4, pp. 151–181, 1914.

[25] Morse, W. C. op. cit. p. 37.

(A) Deeply weathered Birdsong formation at Saltillo Landing. The exposure consists of clay and crumpled chert beds overlain by river alluvium.



(B) Chattanooga shale at falls on small creek three-tenths of a mile south of Lowryville. The Chattanooga shale forms the top of the falls, overlying 10 feed of Decatur limestone.

Ridgetop is sometimes leached to a dirty clay, while on the west side of Rogers Creek six to eight inches of glauconitic sandy clay containing brown phosphate nodules forms the uppermost bed of the Ridgetop shale.

The Fort Payne chert was seen to rest in many places on strata older than the Ridgetop. At various places the Fort Payne lies unconformably on the Hardin sandstone, the Harriman chert, Flat Gap limestone, Ross limestone, Decatur limestone, Dixon limestone, or the Beech River limestone.

The Ridgetop shale when freshly broken in places has a strong odor of petroleum, but the formation so frequently outcrops along the streams that much of the oil it once contained has long since escaped.

Analyses showing the composition of the Ridgetop shale are given as Nos. 17 and 18 p. 68.

Fort Payne Chert

The Fort Payne chert is widely exposed in the south and east parts of the county where it forms narrow belts along the stream valleys. It is particularly well exposed along Tennessee River and its tributaries in the south part of the county and along the upper reaches of Horse, Turkey, Indian and Hardin creeks and their tributaries. In the extreme northeast section of the county the Fort Payne chert caps the hills and ridges and is not covered by younger rocks in that section. This is particularly noticeable in the type of timber growth. On the siliceous soils residual from the Fort Payne in the vicinity of Bethlehem yellow pine is rare or absent, its place being taken by oak, hickory and other hardwoods. On the "Flatwoods" in the southeast part of the county, which are covered by Cretaceous sands and clays, the forests are made up essentially of pine.

In the central and western parts of the county the Fort Payne is extremely thin or entirely missing, having been cut away by erosion previous to the laying down of the Cretaceous deposits. In thickness the Fort Payne chert varies from nothing up to 125 feet or more. In most places it is less than 100 feet thick and does not average more than 50 to 60 feet. It appears to be thicker in the southeast part of the county and thins irregularly to the northwest. The greatest thickness measured was in a ravine one mile northwest of Wynn Landing. The Fort Payne chert is weathered to a considerable extent wherever it is exposed and at no place was the original unaltered rock observed. In the adjoining area to the east it is described by Miser[26] as a "dark gray calcareous chert - - - - composed in part of gray shale and compact, dark, bluish-gray flint." It is probable that the Fort Payne in Hardin County was originally similar to the above description, but due to the weathering and leaching to which it has been subjected, the calcareous material has been

[26]Miser, H. D., op. cit. p. 24.

dissolved away, leaving the porous chert behind. It is generally weathered into tripoli, clay, and white to yellowish, porous chert rubble. The tripoli and clay are frequently pure white, but usually are somewhat stained by iron oxides. The whole mass is very porous and springs are numerous at the Fort Payne-Ridgetop contact. This is particularly well shown by many springs along the east side of Holland's Creek.

The tripoli usually contains angular chert fragments of variable size but occasionally it is free from them and is nearly as fine as flour. The brecciated chert is usually pure white in color and unfossiliferous. In a small ravine tributary to Horse Creek about 1½ miles northeast of the mouth of White's Creek the Fort Payne chert was less weathered than anywhere else in the county. Here it was light gray rather than white and the ravine contained many blocks of massive chert three or four feet in diameter. Locally the fractured chert has been replaced by limonite and cemented into a breccia. Rarely, replacement of the chert has advanced to such a stage that little or no chert is visible in the limonite. The Fort Payne, so far as observed, is unfossiliferous in Hardin County, though the overlying Warsaw limestone is in places crowded with fossils. The Fort Payne rests unconformably upon the Ridgetop and older rocks. It is overlain unconformably by Cretaceous sediments and terrace gravels except in the southeast part of the county where the Warsaw limestone rests upon it. The Warsaw is, however, so deeply weathered that the two cannot be separated except by the most detailed work. For this reason they have not been differentiated on the geologic map. The stratigraphic relations of the Fort Payne and Warsaw formations are not definitely known for Hardin County. It is probable that they are conformable as Miser[27] reports them to be in the adjacent area to the east. The chert from the Fort Payne makes excellent road metal. The tripoli and limonite deposits associated with it may also be of some importance.

An analysis showing the composition of the slightly weathered massive white chert in the Fort Payne formation is given as No. 19, p. 69.

WARSAW LIMESTONE

The Warsaw[28] limestone is confined to the southeast portion of the county. It is best seen along the headwaters of Horse Creek and its tributaries. It is thin, however, being nowhere much over 50 feet in thickness. In Wayne County it is as much as 200 or more feet thick and is described by Miser[29] as a very cherty gray limestone. In Hardin County it thins rapidly to the northwest and pinches out in a short distance. Nowhere in the county was the unaltered limestone observed, but its presence is indicated by chert rubble, often containing abundant fossils. Chert cobbles up to four inches in diameter containing a wealth

27Miser, H. D., op. cit. p. 16.

28The cherty limestones above the Fort Payne chert in this area were formerly considered to be of St. Louis age. E. R. Pohl has since (1929) found them to be of Warsaw age. (Personal Communication).

29Miser, H. D. op. cit. p. 24.

of brachiopods and bryozoans occur in the terrace gravels. These have evidently been derived from the Warsaw and St. Louis limestones. In Hardin County the Warsaw, like the Fort Payne, is deeply weathered into tripoli, clay and chert rubble. It contains some limonite deposits.

The Warsaw is overlain unconformably by Cretaceous gravels and sands. The limonite and tripoli deposits together with the chert may be of economic importance.

CRETACEOUS SYSTEM

The greater part of the county is covered by rocks of Cretaceous age which are generally unconsolidated, though in places the sediments have been converted by the introduction of iron oxide cement into resistant sandstones and conglomerates. The rocks consist entirely of gravels, sands and clays, some of which are calcareous. They rest unconformably on the older Paleozoic cherts, limestones, and shales and are overlain in places by patches of much younger terrace gravels. The Cretaceous beds dip gently to the west about 20 to 25 feet per mile.

Tuscaloosa Gravel

The Tuscaloosa formation is largely confined to the southeast section of the county, although a few feet of it are sometimes present in the central and northern parts. In the southeast section, where the formation is best developed, it is not always present and when present is extremely variable in thickness. It has an average thickness of 25 to 30 feet in the southeast section of Hardin County though locally it may be 100 feet thick as it is in the vicinity of Second Creek. It appears to thin out to the west and north. The Tuscaloosa generally consists of coarse gravel with some sand and clay and is only slightly compacted and indurated. Locally it has been transformed into a tough conglomerate by the introduction of limonite cement which passes in places into low grade iron ore. No fossils of any kind were observed in the Tuscaloosa gravel. The pebbles do not average much over an inch in diameter and appear to be more distinctly spherical than those in the terrace gravels. Pebbles larger than one inch in diameter, are, however, very common in the Tuscaloosa, grading into cobbles up to six inches and more in diameter. The pebbles are composed of chert derived from the older Paleozoic rocks but chiefly from the Fort Payne, Warsaw, and St. Louis formations. In places pebbles of quartzite and glassy vein quartz are present. The origin of the latter is questionable. In general the lower portion of the Tuscaloosa gravel is coarser than the top. In places the transition from the Tuscaloosa into the overlying Eutaw sand is gradual, the upper part of the Tuscaloosa and the lower beds of the Eutaw consisting of fine gravel and sand.

The Tuscaloosa gravel would make a good road metal and may in places contain deposits of workable iron ore.

An analysis of a cemented bed in the Tuscaloosa on Turkey Creek is given as No. 20, p. 69.

EUTAW SAND

The Eutaw sand, consisting of the Tombigbee sand phase and the Coffee sand and clay phase, covers the higher hills and ridges in the eastern part of the county except a small patch in the extreme northeast corner where only a few isolated remnants remain. In the west third of the county the base of the Eutaw is largely at or below drainage level. There is no clear separation of the Coffee and Tombigbee sands in Hardin County. The type section of the Coffee sands at Coffee Landing five miles below Savannah, is notably different from equivalent beds in the southwest portion of the county which are indistinguishable lithologically from the Tombigbee sand. In Shiloh Park, though typical green sands and lignitic clays of the Coffee phase occur close to the river level, the upper portion contains little clay and is not different lithologically from the Tombigbee. In the vicinity of Counce the basal beds of the Tombigbee contain variegated sands and carbonaceous clays like the Coffee sand. The Coffee sand at Coffee Landing is over 200 feet thick. If it formed a distinct member of the Eutaw formation it should outcrop in a broad band along the west edge of Hardin County. This, however, is not the case. The Coffee phase, while typically developed in the northwest part, grades along the strike into ferruginous sands in the southwest part of the county, that are indistinguishable lithologically from the supposedly older Tombgibee sands.

Bruce Wade recognized the fact that the two phases were not sharply separated but believed nevertheless, that the Coffee member was younger. Wade[30] says, "This member (Tombigbee) is nowhere in Tennessee very sharply demarked from the overlying Coffee member and probably does not extend northward any farther than the northern part of Hardin County."

Stephenson recognized the equivalence of the Coffee sand in Tennessee and the Tombigbee sand in northern Mississippi. He says[31] "The beds (Coffee sand) are the Tennessee representative of the thickened portion of the Tombigbee sand member of northern Mississippi, which in turn represents the time equivalent of the basal portion of the Selma chalk." Yet in his Plate X he represents the Coffee member as younger and resting on the Tombigbee in northern Mississippi.

It seems probable to the writer that the Coffee sand is not a distinctly younger member of the Eutaw formation clearly separated from the Tombigbee sand, but simply phase of the latter deposited under slightly

[30] Wade, Bruce, op. ct. p. 56.

[31] Stephenson, L. W., Cretaceous Deposits of the Eastern Gulf Region. U. S. G. S. Prof. Paper 81, p. 21, 1914.

different conditions. The Eutaw sands vary in thickness from about 60 feet to approximately 300 feet in the southern part of the county close to the Mississippi state line. In the latter area none of the lignitic clays and green sands are present. At Coffee Bluff over 200 feet of variegated sands and lignitic clays are well exposed. If these two phases represented separate and distinct members the aggregate thickness for the Eutaw would exceed 500 feet. Stephenson[32] gives the total thickness of the Eutaw as 400 to 500 feet. Since the Cretaceous formations thicken to the south it is quite evident that the Eutaw could not be 500 feet thick in Hardin County. It therefore follows that the Coffee sands and clays are equivalent in part at least to the red Tombigbee sands in southern Hardin County and northern Mississippi.

Tombigbee Phase. The Tombigbee phase of the Eutaw sand consists for the most part of fine, unconsolidated, red and purplish sands containing seams and balls of gray clay. Gravel lenses with pebbles of well rounded chert and some quartz are locally present. The sands are cross-bedded throughout and are universally micaceous. Certain seams a fraction of an inch thick contain 25 per cent of more of muscovite flakes. The sands in the immediate vicinity of clay seams or balls are in some places cemented by iron oxide. Under the microscope the sands appear to be made up almost exclusively of flat muscovite flakes and angular to sub-angular quartz grains. A very few well rounded and frosted sand grains are present. The sand grains are coated with a film of red iron oxide, most of which can be removed by continued washing.

The only fossil remains seen were wood fragments, part of which are silicified. Marine fossils have been reported from these sands in a few scattered localities. Very rarely the Tombigbee phase is composed of red clay with some very fine sand.

An analysis of typical, red Eutaw sand from the vicinity of Mt. Hermon Chapel is given as No. 21, p. 69.

Coffee Phase. The Coffee phase of the Eutaw, so well developed in the northwest part of the county, consists of variegated sands and laminated carbonaceous clays. At Coffee Landing there is little red sand in the Coffee phase, but at many places west of Tennessee River both red and variegated sands occur with the dark clay. The sands are micaceous and cross-bedded. The Coffee phase contains, in addition to leaf and stem fragments, beds of lignitized wood impregnated with pyrite and marcasite. The Coffee sand also contains, locally, good sized silicified logs. Small pellets of amber are often associated with the lignite. Though the lignite will burn and has been used to some extent in local blacksmith shops, the iron sulphides give off offensive fumes. No beds of lignite of commercial importance are known in the county.

Some of the lighter colored sands from the Coffee phase could be used for building purposes and the greensands have some fertilizer value.

[32]Stephenson, L. W. op. cit. p. 20.

The red sands, with washing, might be utilized in making plaster, or stucco, and for other structural purposes. Limonite deposits of small extent may be opened up in the Eutaw sand. Where the Eutaw consists primarily of red clay it might be used in the manufacture of paints. Analyses of the greensands in the Coffee phase are given on page 92. An analysis of the orange colored micaceous sands interstratified with the black clays at Coffee Bluff, is given as No. 22, p. 69.

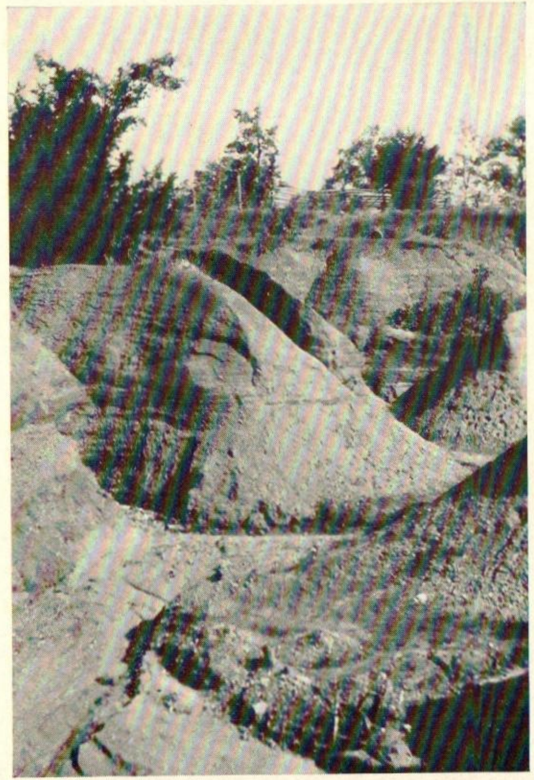
SELMA CLAY

The Selma formation in Mississippi and Alabama is distinctly chalky, containing an abundance of foraminifera. In Tennessee it is a non-chalky marine sediment best described as a sandy clay. In general where exposed in stream beds it consists of light gray to white, micaceous, sandy, calcareous, fossiliferous clay. In places it is bluish, especially when wet. The Selma weathers to a reddish-buff to brownish-gray, clayey loam often indistinguishable from the soils derived from the Eutaw sand or terrace gravels. In places marcasite nodules occur and greensand beds are locally present. The Selma clay is confined to the west and northwest parts of the county, where it overlies conformably the Eutaw sand. It is well exposed along Mud Creek in the vicinity of Morris Chapel, as well as on the south side of the creek close to the McNairy county line. Typical clay carrying an abundance of Selma fossils is taken from wells in the vicinity of Fellowship Church in the extreme northwest corner of the county. In western Alabama and eastern Mississippi the Selma is over 900 feet thick[33] but in Hardin County it is much thinner. It varies from nothing up to approximately 100 feet in thickness in the extreme northwest corner. In the vicinity of Fellowship Church, wells for water must be sunk 80 to 100 feet through the Selma clay, which contains marine fossils throughout. Water is reported to come from a red sand beneath the clay. This red sand is undoubtedly the upper portion of the Eutaw formation. Samples of the Selma clay that were analyzed for Mr. Mitchell, the county farm agent, are said by him to contain up to 35 percent calcium carbonate. The Selma is not everywhere fossiliferous. Marine fossils are locally very numerous, however. Thick shelled oyster-like forms are the most characteristic kind of fossil. Occasionally the ground is thickly scattered with the shells that have weathered out of the clay.

The soft Selma clay where the content of calcium carbonate is sufficiently great could be used to correct soil acidity. Considerable limonite float occurs in the Selma clay three miles south of Morris Chapel and it is possible that workable iron ore bodies in the Selma formation may eventually be opened up. An analysis of typical Selma clay from 2½ miles south of Morris Chapel is given as No. 23, p. 69.

[33]Stephenson, L. W., op. cit. p. 21.

(A) Terrace gravels 6½ feet thick, lying unconformably on the red Eutaw sands south of Pyburn on the road to Pyburn's Landing.



(B) Gullies washed in the terrace gravels one-fourth of a mile east of Paulk's Mill. Approximately 12 feet of gravel are exposed in the wash.

(A) Selma clay $2\frac{1}{2}$ miles south of Morris Chapel, showing the great number of fossil shells which in places occur in the clay.

(B) Rich bottom lands on east side of Horse Creek north of State Highway 15. These bottoms produce good crops year after year without the aid of fertilizers.

QUATERNARY SYSTEM

TERRACE GRAVELS

The terrace gravels, which are chiefly of Pleistocene age, though the highest ones may be of Pliocene age, are widely scattered in the vicinity of Tennessee River and its larger tributaries. In general these terrace gravels are confined to the west half of the county. Some of the higher hills and ridges east of the Tennessee are also capped by these gravels. Some of these patches have not been mapped because of their small size.

The terrace gravels are not all of the same age. There are at least five and perhaps six distinct terrace levels representing various stages in the carving of the present valley of Tennessee River. The gravels are of variable thickness, varying from nothing up to approximately 80 feet. They consist largely of chert gravels with a few quartz and quartzite pebbles and some sand and clay. Most of the chert pebbles are an inch or less in diameter though some cobbles up to six inches in diameter occur. Mechanical analyses showing the proportion of the various sizes of gravel making up the terrace deposits are given on page 88.

The bulk of the gravels were derived from the Tuscaloosa gravel and the Fort Payne and Warsaw formations. The origin of the quartz and quartzite pebbles is more questionable. The terrace gravels and sand are often cross-bedded and lenses of sand or gravel are common. Locally the gravels have been converted into resistant conglomerates by the introduction of iron oxide cement. Some completely cemented beds are 12 to 15 feet thick, though the pockets and beds of cemented gravel are generally much thinner than this. The cementation shows in many cases a marked relation to ground water circulation by occurring just above relatively impervious material.

The terrace gravels have been used extensively for road building and for making concrete. Because of the enormous quantity of gravel in the county, and because it is suitable for road metal, the terrace deposits form one of the most valuable natural assets of the county. When used for concrete in structural work the gravels require washing to remove the fine sand and clay. In the summer of 1927 gravel from this source was used with good results in concreting the basement of the new high school building at Savannah.

ALLUVIUM

All of the larger streams and many of the smaller ones in the county have relatively wide floodplains or "bottoms". These bottoms are composed of the sediment deposited by the present streams in recent times during periods of high water. They constitute the best agricultural land in the county. As mentioned in an earlier part of this report, there are occasionally evidences of at least two and sometimes three distinct bottoms. The alluvium along the streams varies from nothing to approximately 40 feet in thickness. It consists principally of sands, silts, and clays along the larger streams, but along the swift streams draining the hard rock area in the east part of the county, it is composed in many places of coarse gravel.

The bottoms are noticeably wider in comparison to the size of the streams in the west part of the county than in the east portion. This is due to the unconsolidated nature of the sediments west of Tennessee River which wash badly and hence cause overloading and muddiness of the streams. The bottoms along some of the larger creeks such as Horse, Turkey, Indian, etc., are extremely rich and produce good crops of corn year after year without the aid of fertilizer.

STRUCTURE

The rocks of Hardin County lie in essentially horizontal attitudes. They have, however, been warped into gentle but irregular synclines and anticlines. The structures have a general northeast-southwest strike in sympathy with the large structural rise to the northeast known as the Nashville dome. The younger Cretaceous sediments, which lie unconformably upon the older and more resistant Paleozoic rocks, dip gently to the west at from 20 to 30 feet per mile. Some of this dip, though how much is uncertain, is probably due to the slope of the sea floor on which the Cretaceous sediments accumulated.

Joints

The rocks of the county are practically free from faults though a few normal faults of small throw were observed. Most of the hard rocks are well jointed. The joints are particularly well developed in the Ridgetop shale, and occur in two main sets approximately at right angles to each other. The joints when well developed are remarkably uniform over the whole county. The two chief sets are vertical and strike respectively N. 50° W. and N. 37° E. on an average though they may vary a few degrees.

The joints in the Ordovician, Silurian, Devonian and Mississippian rocks are essentially parallel, and coincide with the two main sets of joints. The N. 37° E. set appears to be slightly more prominent. At Pyburn's Bluff a three foot vein of coarse calcite appears to follow a joint belonging to this set. The vein has a N. 35° E. strike and vertical dip.

Folds

Although the folds are gentle and irregular there are several distinct basins and domes, the limbs of which are always cross-folded to a certain degree. For this reason reversals of dip frequently occur within a few hundred yards. The dips are uniformly gentle and are usually less than five degrees. In many places the strata are so nearly horizontal that it is almost impossible to secure readings of any value with an ordinary clinometer.

Locally, the strata may dip as much as 15 or 20 degrees in the vicinity of marked basins or domes. There is a marked dome or upwarp in the strata in the vicinity of Russell in the central north part of the county. In the center of this dome older beds are exposed than in any other part of the county. The Ordovician Hermitage formation outcrops along the axis of the fold and is overlain by the Silurian on all sides.

Other distinct upwarps occur in the vicinity of Willoughby School, Pyburn's Bluff, Dry Creek, Lowryville, Rogers Creek, the junction of the North and South Forks of White's Creek, the junction of Horse Creek and Germany Branch, Neighbor's Branch, Burnt Church and Boggess Branch.

Several distinct basins or downwarps occur in the county. Some of them are marked by patches of Devonian rocks which have been preserved from erosion as a result of the folding. The most prominent of these basins is that in the vicinity of Olive Hill where the maximum thickness of Devonian strata occurs. The center of the basin is approximately at the intersection of highway 15 and Indian Creek just east of the town of Olive Hill. Here the Hardin sandstone of lower Mississippian age outcrops at water level. The beds rise in all directions away from this point.

Other distinct downwarps occur west of the mouth of Hardin Creek, at the mouth of Smith's Fork, along Horse Creek in the vicinity of Rockhouse, at the mouth of Pompey Branch, between Neighbor's and Germany branches, and between Rogers Creek and the head of Choate Creek. In addition to the above, many small local downwarps occur. Such small folds, both synclines and anticlines may be seen along Tennessee River north of Cerro Gordo, in the vicinity of Saltillo, east of Grandview Landing, at the head of Bear Branch, and along the river above Pyburn's Landing.

At a few places the Chattanooga black shale, being a weak bed structurally, is crumpled into small compact folds a few feet across, as along the head of English Creek and on a small tributary to Choate Creek on Tom Irwin's place.

Similar structures undoubtedly occur in the older rocks west of Tennessee River where they are covered by the unconsolidated Cretaceous deposits. Systematic core drilling will be necessary to locate structures in that part of the county.

Structure contours which show the altitude of a certain horizon or "key bed" are frequently used to show, the structure of an area. This method is impracticable, however, in Hardin County, because of the great number of unconformities present and because there is no bed which is widely enough exposed or persistent enough in its distribution to serve as an horizon marker.

Dip and strike symbols are also used to a limited extent to show structure. They are of little use except where the folds are fairly regular in outline. The broader structural features are brought out to some extent by the distribution of the formations on the accompanying geologic map.

FAULTS

There is a pronounced fault on the north side of Pompey Branch about one mile east of the Walnut Grove Road. The actual fault plane is soil covered so that the exact strike is uncertain. It appears to have a north-south trend. The fault is nearly vertical with the downthrow on the west, bringing the Fort Payne chert in contact with the Hardin sandstone. The throw is probably 75 to 100 feet. The Hardin sandstone is slightly crushed close to the fault and some limonite has been deposited in the fractures.

Dunbar[34] mentions a probable fault in his section at Pyburn's Bluff. The writer examined this section and Dunbar's explanation seems the most plausible. At the mouth of Bluff Branch the beds are dipping west at from 6 to 8 degrees. Below the mouth of Anderson Branch slightly more than half a mile to the west of Bluff Branch, the beds are still dipping west. The same beds are present at both places. Since there is no evidence of an east dip between the two creeks, a fault seems the only explanation. The east side of the fault is the downthrow side. The throw or vertical displacement required is 25 to 50 feet.

Six-tenths of a mile west of Baker's cemetery in the extreme northeast section of the county two small faults in the Hardin sandstone were observed. The faults have a north-south trend and throws of 18 and 22 inches. The east side is the downthrow side in both cases.

On the west bank of Still Creek about half a mile north of highway 15, typical Dixon limestone outcrops with a strike of N. 32° E., and a dip of 10° S. E. Two hundred yards up stream to the north the same beds outcrop dipping slightly to the southeast. As there are no evidences of a reverse dip between the two points a fault seems the best explanation. The southeast side is the downthrow side and the throw is 25 to 50 feet.

Foerste[35] reported the presence of the Chattanooga black shale in a well north of the landing at Saltillo. The youngest Paleozoic rocks exposed at the landing are the Oriskanian cherts which are overlain unconformably by Cretaceous sediments. If the report is correct, which seems doubtful, a fault is probably present here.

The generalized structure of the bed rock is shown in the diagrammatic section along an east-west line through Savannah, on the accompanying geologic map.

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[34]Dunbar, C. O., op. cit. p. 124.

[35]Foerste, A. F., op. cit. p. 689.

CHAPTER III

MINERAL RESOURCES

Although Hardin County contains a considerable variety of mineral resources, some of which are present in large quantities, they have not been developed in any sense. The reason for this is chiefly lack of transportation, but partly lack of interest on the part of the land holders. In very few cases have the deposits been prospected even in a superficial way. The poor condition of the rural roads, lack of railroad facilities, and the remoteness of many of the deposits from Tennessee River have discouraged any sort of development.

The deposits present in larger or smaller amounts include iron, manganese, limestone, chert, tripoli, phosphate rock, sand, gravel, clay, ochre, lignite, oil shale, lead, zinc and copper. Some of the first named above are present in large quantities and could be profitably developed if transportation, capital, and many other features which determine the value of such deposits were available. Some of the others have never been and never will be of any importance.

Outside of the sand and gravel which have been used to a limited extent for road building and structural purposes, the mineral deposits of the county have not been touched except in an extremely small and local way.

Vigorous and intelligent prospecting, adequate transportation, and sufficient capital are needed before the deposits will have any real value.

IRON ORE

General Features

There is no report of iron ore having ever been produced in the county. Furthermore, no deposit in the county has even been superficially prospected. Yet the eastern half of the county lies within the brown iron ore belt of the western Highland Rim and indications of deposits of varying sizes are present at a great number of places. Many of these are similar to deposits which have been of importance in adjacent counties to the east.

It is absolutely impossible to give even a vague estimate of the tonnage of iron ore in Hardin County until systematic and adequate prospecting has been completed. It is generally believed by the average layman that all that is necessary to interest mining companies in a property is to show them a good chunk of ore. Nothing could be further from the truth. Extensive prospecting is almost always necessary for proving up a certain quality and quantity of ore before a company can be interested.

The mining of iron ore has been dull in this section of Tennessee during recent years and this fact has undoubtedly been a blanket on the enthusiasm and hopes of interested parties. Eventually, however, if conditions are more favorable, the industry may be revived and deposits of little consequence at present prove profitable ventures.

The iron deposits in the county consist principally of "brown ore" or limonite. This type of ore occurs almost exclusively in the Mississippian cherts and cherty limestones and in the sediments of Cretaceous age. Prospecting therefore should be focused on these rocks. The bulk of the float and shot ore or other indications, occur in the Tuscaloosa gravel and Eutaw sand of Cretaceous age and in the weathered products of the Warsaw limestone and Fort Payne chert of Mississippian age. As a general rule the float is thicker near the base of these formations, which suggests that the bulk of the deposits is segregated there. The deposits are of secondary origin and are apt to be extremely variable both in shape and size.

Some primary deposits occur in the Devonian limestones but so far as known they are not rich enough to constitute ore. They might, however, be used advantageously as a flux with higher grade ore.

With the exception of a very little wad, an impure oxide of manganese, which occurs with the limonite at a few localities, no other associated minerals of importance occur. All the deposits tested contain some manganese.

Because of the lack of prospecting very little is known of the form of the deposits or the reserves available. As indicated by the distribution of the shot ore and float, the ore bodies may be expected to be extremely irregular both in form and extent. An estimate of the quantity of ore present would be simply a guess. The surface indications suggest that the total quantity of ore is large but whether it occurs in small pockets or in large continuous, though irregular bodies, is unknown. The probability is that, as a whole, it is rather pockety. Bodies of sufficient size for economic extraction would probably be uncovered by prospecting.

Origin

Although the limonite deposits occur chiefly on the tops of the hills and ridges or on their slopes, they are not necessarily confined to these places and may occur anywhere. Their location depends largely on the ground water circulation which depends on the character of the rock as much as on the surface irregularities. Impervious beds such as clay seams or beds of shale, particularly if they have the proper attitude, tend to check the downward flow of water and in some cases, may actually pond it above them. Since the bulk of the material would be precipitated out, other conditions being equal, where the solutions moved slowest, the most extensive deposits might be expected to occur at or near the bottom of the porous rocks. Field evidence seems to support this conclusion.

The limonite deposits occurring in the Cretaceous sands, the Tuscaloosa gravel, and those in the Warsaw limestone and Fort Payne chert are secondary deposits which have resulted from rain water carrying iron salts in solution. This water percolating through the porous rocks deposited the iron minerals in the pore spaces and, in the case of the brittle and fractured cherts, largely replaced the silica of the cherts.

Source of the Iron

The source of the original iron is unknown. Part of it composing the deposits in the Mississippian rocks may have been derived from the Warsaw limestone which probably covered the entire area at one time. It is now absent through erosion, except small remnants in the east and south parts of the county. Some of the iron was certainly derived from Cretaceous sediments, both from the Tuscaloosa gravel and the Eutaw sands, and perhaps from younger beds of which now there is no trace.

There is no fresh exposure of the Warsaw anywhere in the county so that its original nature is not definitely known. In Wayne County to the east, however, though even there the Warsaw limestone is almost universally deeply weathered, the fresh rock is described as a gray cherty limestone. It contains very few iron minerals where freshly exposed, yet the unaltered rock is so infrequently visible that this fact has little significance. The original limestone may very probably have contained considerable quantities of pyrite, marcasite, or other iron minerals.

The Eutaw sands contain abundant nodules of marcasite in the northwest corner of the county. In some of the stream beds in that section these nodules may be picked up by the bucketful. The red sands in the east part of the county contain practically no marcasite yet this is of little importance. If it had been originally present the marked porosity of the sands and the absence of numerous and persistent clay layers which have prevented the disintegration of the nodules in the Coffee phase in the northwest section, would have favored their rapid disintegration and removal by circulating waters.

Iron carbonate may have been a source of part of the iron.

Age of the Deposits

It has generally been assumed that the conditions most favorable for the formation of ore deposits of this nature are long, deep weathering in a temperate or tropical climate where the land surface is close to sea level and consequently much of the work of rock disintegration is of a chemical nature.

It is generally believed that such conditions existed in this part of Tennessee in early Tertiary time. The logical conclusion is that the bulk of the iron deposits were formed then. This is perhaps essentially true but the fact that a few of the deposits occur near the bottom of the stream valleys as much as 300 feet below the general level of the Highland Rim peneplain shows that the process responsible for the formation of the iron deposits continued up to recent times and is probably in operation today to a certain extent. This is further shown by the fact that many of the terrace gravels, some of which are less than 60 feet above the flood stage of the Tennessee River, are strongly cemented by iron oxides. These lower gravels are probably not older than Pleistocene. It is thus clearly evident that iron-bearing solutions have been precipitating their salts up to fairly recent times and certainly for many tens of thousands of years since the early Tertiary peneplain first started to rise.

Methods of Prospecting

Deposits of this character are prospected in a number of ways. Perhaps the most common method where the overburden is not too great, is to dig trenches or pits or even to sink shafts, at regular intervals over the location of the supposed deposits. Such methods where the overburden is loose material easily handled by pick and shovel, are relatively inexpensive and where intelligently pursued, are of great value in determining the size and shape of the deposit. Where the overburden is excessive it is generally more practical to "prove up" a deposit by use of a core drill.

The latter method would be more practical in many places in Hardin County yet there are a great number of promising showings which could easily be prospected by pits and trenches. Such activities could be carried on during those seasons of the year when other types of work were slack. It is surprising that no prospecting has been done when the county has been settled such a long time and some of the favorable showings have been known to exist for decades, especially when similar activities were taking place a few miles to the east long before the Civil War.

Deposits in the Eutaw Sand and Tuscaloosa Gravel

Many of the limonite showings in the county occur intimately associated with the red sands of Cretaceous age which cap the hills and ridges over much of the county and with the underlying chert gravels. These deposits therefore, occur principally on the hills or ridges or on the hillslopes. The deposits are siliceous, containing usually a considerable quantity of sand or pebbles and often much clay. The limonite has usually been deposited in the pore spaces between the sand grains or pebbles, cementing the whole into a tough sandstone or conglomerate. Blocks of this material three feet in diameter sometimes occur. Some replacement has also taken place.

Some of the ore is of the "bomb shell" type, single masses occasionally weighing more than 100 pounds. The bombs consist of thin shells of fairly pure limonite some of which are hollow but many enclose masses of clay or sandy clay. Where distinct clay layers are interstratified with the sands, thin irregular layers of limonite often occur just above the clay.

Analyses showing the composition of some of the better grade deposits of brown iron ore from the Eutaw sand in the Cretaceous sediments are given as Nos. 24–27, p. 69.

Deposits in the Warsaw Limestone and Fort Payne Chert

Many of the better showings occur intimately associated with the residual weathered products of the Warsaw limestone and Fort Payne chert of Mississippian age. They are confined to the east and southeast parts of the county.

The deposits associated with these rocks differ only superficially from those in the Cretaceous sediments. In general a great deal more replacement has taken place in the older rocks. The limonite was deposited in the cracks, fractures, and pores of the brecciated Mississippian cherts and has often replaced the chert along these openings. Locally the cherts have been almost completely converted to solid limonite.

The deposits are as irregular in form and extent as are those in the overlying Cretaceous and later rocks. They have been formed by the same processes and have a common origin.

Because of the relatively large amounts of unreplaced chert in the deposits of this type they are very siliceous. Some of the silica could be removed by crushing and washing but the silica content of the washed ore would still be very high. A very little wad occurs with some of the deposits but no other minerals were observed except the clay and various forms of silica. Because of the total absence of prospecting of any kind, no estimate of the quantity of ore available can be made. It is safe to say, however, that with sufficient prospecting considerable quantities might be proved up. Analyses of iron ores from the Waresaw limestone and Fort Payne chert are given as Nos. 30 to 33, p. 69.

Deposits in the Selma Clay

Considerable limonite float sometimes occurs associated with the Selma clay which overlies the Eutaw sand in the west and northwest parts of the county. Although such showings of iron ore are rarer than in the other formations described, the possibility of the Selma containing workable iron deposits should not be overlooked.

Deposits in the Bear Branch Limestone

The Bear Branch member of the Olive Hill formation of Devonian age contains considerable iron in the vicinity of Olive Hill. The iron content is variable, however, and apparently decreases rapidly away from this small local area. The deposit is very different from the limonite deposits described above.

The Bear Branch member is a fossiliferous, often cross-bedded, limestone which contains in the vicinity of Olive Hill a variable quantity of small specks of red hematite giving a reddish color to the rock. The hematite is a primary deposit. That is, it was deposited with the shells and lime mud on the sea floor and has not been introduced into the rock subsequently by circulating ground water.

Where the Bear Branch has been exposed to the weather as at the Sander's Mine near Clifton, Wayne County, the iron content has been concentrated by secondary enrichment into a fair grade of ore. Instances similar to the Sander's deposit were not observed in Hardin County though a careful search might bring to light small deposits of like character between Clifton and Olive Hill. In the vicinity of Hardin Creek where it crosses the county line the Devonian rocks are absent and residual deposits, therefore, from the Bear Branch could not be expected to occur over much of the area.

The ferric oxide content of the fresh rock in the vicinity of Bear Branch is very erratic, varying from a little less than 7 percent to nearly 45 percent. The average content of a bluff 25 feet high on Bear Branch about 1¾ miles east-southeast of Olive Hill is slightly less than 30 percent. This is probably a little too high as there has been some slight enrichment on the surface and it was not possible to get absolutely fresh material for analysis. The deposit contains in addition to Fe_2O_3, two to four percent Al_2O_3, $\frac{1}{2}$ to $2\frac{1}{2}$ percent $MgCO_3$, 44 to 93 percent $CaCO_3$, and the average phosphorus content is less than 1/10 of one percent.*

This ferruginous limestone could not, therefore, be used alone as an ore. It might be used to advantage as a flux with nearby ores should conditions improve sufficiently. The great quantity of over-burden lying on the Bear Branch limestone in most places would require underground mining methods.

Deposits in Other Rocks

Very small quantities of limonite were observed in some of the other formations in the county but they are insignificant and of no economic value.

If prospecting should uncover bodies of sufficient size and quality there is no reason why Hardin County should not become a producer of iron ore. In such an event adequate rail transportation would be imperative. Tennessee River is a valuable asset in this respect but many of the most promising showings are many miles from the river. There is no coal of any kind in the county. This would make it necessary either to transport the ore to existing furnaces or else bring the necessary fuel to the ore.

There is water enough in the larger creeks for washing purposes though in some cases extensive pipe lines would be necessary. Limestone suitable for flux is abundant and would offer no problem.

*—See next page for detailed analyses.

ANALYSES OF THE BEAR BRANCH LIMESTONE ON BEAR BRANCH, 1 7-10 MILES EAST-SOUTHEAST OF OLIVE HILL.

Sample		Silica (SiO_2)	Iron (Fe.)	Alumina (Al_2O_3)	Calcium Carbonate ($CaCO_3$)	Magnesium Carbonate ($MgCO_3$)
1	(a) 1 ft.	2.84	----------	----------	90.98	2.04
2	2 ft. 11½ in	7.24	21.52	3.04	57.14	1.96
3	4 ft	4.42	12.20	.85	75.31	2.04
4	5 ft	4.60	20.82	3.12	60.41	2.02
5	6 ft. 1 in	3.02	4.82	2.92	85.55	1.50
6	7 ft	2.88	14.54	3.15	71.08	2.18
7	8 ft. 7 in	5.38	25.07	2.54	53.69	2.42
8	9 ft. 6 in	4.80	26.06	2.37	53.57	1.94
9	10 ft. 8 in	4.88	26.03	2.46	53.41	1.90
10	11 ft. 4 in	1.46	5.66	3.87	84.69	2.01
11	12 ft. 5 in	5.64	13.16	3.28	70.36	1.78
12	13 ft. 3 in	3.72	19.81	2.96	62.66	2.45
13	14 ft. 8 in	----------	----------	----------	----------	----------
14	17 ft. 3 in	4.88	26.71	3.42	51.35	1.87
15	18 ft. 3 in	----------	----------	----------	----------	----------
16	19 ft. 11 in	4.46	23.72	2.84	56.11	2.82
17	21 ft. 3 in	4.90	31.48	4.17	44.05	1.76
18	22 ft. 2 in	----------	----------	----------	----------	----------
19	23 ft. 5 in	1.88	----------	----------	92.80	.62
20	24 ft	----------	----------	----------	----------	----------
21	25 ft. 3 in	3.86	23.25	2.62	59.42	.60

(a) Distances measured from the Ross-Bear Branch contact.

Phosphorus was determined from a composite sample made by mixing equal portions of every other sample and analysed 0.08 percent.

DESCRIPTION OF IRON ORE SHOWINGS.

The following brief description will serve to indicate the general nature of the iron ore showings. The writer considers numbers 19, 23, 24, 28, 33, 35, 39, 40 and 44 the most promising for further prospecting.

1. Small amounts of sandy float rock of low iron content were noted in the Selma Clay in roadside gullies six-tenths of a miles[36] north of Old Hurricane Church and two-tenths of a mile south of the Hardin-Henderson County line.

2. On Squire Newman's land small bombs of sandy limonite, one to two inches in diameter occur in the Coffee phase of the Eutaw sand. They appear most thickly scattered along the sides and bottoms of rain gullies one-tenth of a mile west of Newman Cemetery and 5–2/10 miles north–northwest of Saltillo.

3. Some sandy shot limonite occurs in the Selma clay one-tenth of a mile directly west of Morris Chapel, along the north side of the road.

4. Sandy shot limonite from the Selma Clay was noted on both sides of the road 2–2/10 miles south of Morris Chapel.

5. On the east side of a small hill on both sides of the road 3–3/10 miles west of the intersection of highways 17 and 69 a small patch of fair grade float limonite has been derived from the Selma Clay. Some of the float is massive, some porous, and some sandy. None of the fragments are more than eight or nine inches in greatest diameter. The Selma clay is weathered here to a brownish yellow loam. Analysis of a sample of massive float is given as No. 34, page 69.

6. One hundred yards southeast of Goodman's filling station in Shiloh Park, low grade siliceous float limonite from the Eutaw sand was noted in rain gullies on the slope south of the road.

7. Considerable low-grade sandy float limonite and shot ore, derived from the Eutaw sand, occur by the roadside on the east side of a hill 2–1/10 miles east-northeast of the Pine Rest Hotel in Shiloh Park.

8. Considerable sandy float and shot limonite have weathered out of the Eutaw sand in the vicinity of Mt. View School. The float occurs on the hill slopes and in the bottom of the stream gullies as well as on top of the flat ridges.

9. Small amounts of float limonite formed by replacement of the Fort Payne chert were noted in the head of a small stream on the north side of the ridge road 1–1/10 of a mile north of highway 15 and 1–7/10 miles east-southeast of Bethlehem.

10. Good looking float limonite was noted down the road from Cross Roads Chapel to Smith Fork, which has evidently been washed down from the overlying Eutaw sand.

[36]Distances measured in an air line.

11. Small limonite bomb shells washed out of the Eutaw sand were noted on the hillsides 1-3/10 miles east of Whitlow.

12. Shot ore and very low-grade float limonite from the Eutaw sand were noted on the tops of the hills and ridges 2-1/10 miles north of highway 15 and approximately one mile southwest of Smith Fork.

13. Oolitic hematite is present in the Bear Branch limestone member of the Olive Hill formation. A good exposure of this phase of the formation occurs on the south side of Bear Branch about 1-7/10 miles east-southeast of Olive Hill. At this place 35 feet of beds are exposed just above low water level, displaying the following section. The beds dip three to four degrees west-northwest. The analyses given (p. 59) indicate the composition of the exposed lower portion of the beds.

SECTION OF ROCKS EXPOSED ON BEAR BRANCH 1-7/10 MILES EAST-SOUTHEAST OF OLIVE HILL

Formation	Thickness in Feet	Lithology
Chattanooga shale	15+	Top not exposed. Black fissile shale.
Hardin sandstone	12	Very dark, marcasitic, phosphatic, cross-bedded sandstone.
	Unconformity	
Bear Branch limestone	10	Distinctly bedded, slightly ferruginous, gray limestone.
	25	Massive, ferruginous, reddish-brown limestone.
Ross limestone	2+	Base not exposed. Thin-bedded, cherty, dense, bluish-gray, siliceous limestone.

14. Small pieces of float and shot limonite occur near the base of the Eutaw sand by the roadside 1–5/10 miles northeast of Mt. Hermon Chapel.

15. Andrew Abel's place. Very low-grade float limonite from the Eutaw sand and also from the Tuscaloosa gravel occurs scattered over the hillside west of Mr. Abel's barn about 1–5/10 miles north of highway 15 and one mile east of Steel Creek.

16. On the west side of Smith Fork about one mile south-southeast of Union Chapel and School, small amounts of shot ore and float limonite were observed in the Eutaw sand on the east slope of the ridge that divides Smith Fork from Boone Creek.

17. Along the road 1–7/10 miles south of Thompson's store on the east side of Smith Fork occurs a thickness of 45 feet of Fort Payne chert. The float shows that a portion of the chert has been partially replaced

by limonite, forming a breccia. The small amount of float limonite would not indicate a large deposit. The material (if ore) is also of very low grade since it contains a large amount of unreplaced chert.

18. On Judge Watson's land three miles south of Thompson's store a very little low grade float limonite replacement of the Fort Payne chert was found in the stream bed. This stream valley is called "Baugus Hollow" by the local residents.

19. There is a pocket of limonite 1-1/10 miles southeast of Old Town, on M. L. Hosey's land, just across the road from Mr. Hosey's barn. The pocket is in the base of the Eutaw sand just above its contact with the Silurian limestone. The pocket is about seven feet long and 20 inches wide, and is very irregular in outline. Small bomb shells of limonite up to 12 or 14 inches long also occur as float in the washes close by. An analysis of a sample from the larger pocket is given as No. 28, p. 69.

20. Shot ore and fair looking float limonite from the Eutaw sand were noted along the north side of the road at Covey Chapel.

21. On the hill which rises directly behind Burnt Church and School, limonite float, principally of the bomb-shell type, occurs near the top of the hill which is capped by the Eutaw sand. None was seen in place and the amount of float is small.

22. At A. K. Irwin's place, on the west side of Choate Creek, float limonite along the hillside evidently has been washed down from the Eutaw sand which caps the hills and ridges in this vicinity. This is approximately one mile north-northeast of the Seaton prospect (No. 23), and three-tenths of a mile up the creek from the Pinhook road.

23. On the west side of Choate Creek about 1-2/10 miles south-southwest of Burnt Church, is the former Nunley Croots place, now owned by R. D. Seaton. At a point 250 feet southeast of Seaton's saw mill at the base of the hill in the lower part of the Eutaw sand just above its contact with the Silurian limestone is an occurrence of limonite, apparently as a pocket in the Eutaw sand. Some of it was apparently deposited in shells around limestone boulders. There is little wad, or impure manganese oxide, associated with the ore. The ore outcrop shows a thickness of five feet and about the same length. It is apparently in place, although this is not certain since no prospecting has been done. Float limonite is thick around the base of the hill on either side. Fragments of white chert lying around may indicate the presence of a little Fort Payne chert though none is exposed. There is a possibility that the ore may be a pocket in the latter formation, though from the appearance of the ore this is considered unlikely. An analysis of a picked sample from the outcrop is given as No. 25, p. 69.

24. Bombs of limonite occur on Herbert Reynold's place on the south side of Turkey Creek about eight-tenths of a mile southeast of Burnt Church. The bombs are scattered over the lower slope of the hill a

few hundred yards south of the Reynold's house and are rather abundant in the first ravine southeast of the spring back of the house. They apparently come from near the base of the Eutaw sand. The bombs are generally hollow but sometimes contain clay or sandy clay around which the limonite has been deposited in a thin shell up to 1, or $1\frac{1}{2}$ inches thick. Most of the bombs are rather small but several were noted that had a maximum diameter of 20 inches. No ore was seen in place. An analysis of a sample from one of the large bombs is given as No. 26, p. 69.

25. On the south side of Little Turkey Creek 1-3/10 miles east of Burnt Church considerable float limonite in the gullies and along the slopes, evidently having been washed down from the Eutaw sand which caps the divide between Turkey and Little Turkey Creeks.

26. On the north side of Turkey Creek a quarter of a mile west of the road between Gillis Mills and Thompson's store, 25 feet of Tuscaloosa gravel cover the Fort Payne chert. The lower portion of the gravel is firmly cemented by limonite into a very hard, coarse conglomerate though some seams are more firmly cemented than others. There is not enough limonite here to make ore unless there are richer pockets which are covered.

27. On the east side of Choate Creek a little less than a mile north of Tom Irwin's place and about 1-6/10 miles south of Burnt Church, there is a very little limonite float on the hillside, apparently washed down from the Eutaw sand.

28. At the northeast side of the road on Tom Irwin's place, 2-1/10 miles south of Burnt Church, there is a large showing of float limonite much of which is of good quality. This float extends southeastward down the hill slope but becomes scarcer and finally disappears above the level of the creek. The limonite occurs near the base of the Eutaw sand. An analysis of a picked sample of the ore is given as No. 29, p. 69.

29. Float limonite from the Fort Payne chert and the Eutaw sand appears along the south side of the valley and in the creek bed four-tenths of a mile east of the Middle Savannah road on Tom Irwin's place. This locality is about 2-4/10 miles south of Burnt Church.

30. About one mile southeast of Ross Mill on the Ross Farm on the east side of Horse Creek $5\frac{1}{2}$ miles southeast of Savannah, shot ore and small pieces of float limonite occur scattered over the surface about the middle of the Eutaw sand. None was seen in place.

31. Shot ore and small pieces of float limonite were noted on the hill slopes one-tenth of a mile east of the Middle Savannah road, approximately 1-2/10 miles north-northwest of Lowryville. This material has evidently been derived from the Red Eutaw sand.

32. Low-grade, siliceous limonite float from the Eutaw sand was noted on the hill slopes west of W. J. Frank's residence two-tenths of a mile east of Gillis Mills.

33. Half a mile north of Abram Chapel, on the north side of Horse Creek on land belonging to W. J. Franks, the hill slope is thickly scattered with float limonite. This material has replaced chert of the Warsaw limestone. Some of the fragments are two to three feet across and several inches thick, though most of the pieces are much smaller. No ore was seen in place, but the large quantity of float would possibly warrant prospecting. An analysis of a piece of the better grade float is given as No. 31, p. 69.

34. Three-fourths of a mile up Perry Branch from Horse Creek and 1–3/10 miles south of Gillis Mills there is considerable sandy low grade limonite float from the Eutaw sand scattered over the hill slopes.

35. Along the hillside on land belonging to W. J. Franks, on the southwest side of Horse Creek, a quarter of a mile west of the Wayne County line, there is apparently the outcrop of a pocket of brown ore in place. No prospecting has been done and it may be merely a boulder. It is three feet thick where exposed and is uncovered laterally for $4\frac{1}{2}$ feet. The material represents a replacement of the chert in the Warsaw limestone. There are small seams and pockets of limonite exposed by the roadside a few hundred feet to the east. There is also considerable limonite in the overlying Tuscaloosa gravel at this point. This area would probably be worth prospecting. An analysis of a sample from the outcrop in the Warsaw limestone is given as No. 30, p. 69.

36. On the north side of the North Fork of White's Creek 3–5/10 miles southeast of Gillis Mills, low grade float limonite was observed, probably derived from the Tusacloosa gravel.

37. A little shot ore and limonite float from the Eutaw sand occur on the side of the hill half a mile south-southwest from Lowryville.

38. A few hundred feet east of Arthur Stansel's house at the "Burnt Stand" in the gulley at the side of the road, a six inch layer of brown limonite occurs in the base of the Fort Payne chert at its contact with the Ridgetop shale. The upper two to three feet of the Ridgetop are leached to a dirty white clay. The limonite bed is an incomplete replacement of the Fort Payne chert.

39. At the top of the bluff along Tennessee River between Haw and Bluff branches, and along the lower slopes on land belonging to Arthur Stansel, there are large quantities of low grade sandy limonite float washed down from the Eutaw sand which caps the hills and ridges here. Some of the boulders are three feet in diamater though most of them are much smaller. A very large percentage contains too much sand to be of value as an iron ore. This area north of Pyburn's Bluff might bear prospecting for richer pockets. An analysis of a picked sample of the best grade float is given as No. 27, p. 69.

40. One-tenth of a mile west of the main road from Walnut Grove to Savannah and about two miles north of Duncan's Landing on the northeast side of a small branch tributary to Bruton Branch, there is

a bluff 10 feet high composed of deeply weathered, porous, Fort Payne chert. A small portion of the chert here has been partially replaced by limonite forming a breccia. It may be that concentrated pockets of ore could be found by prospecting in this vicinity. An analysis of a picked sample from the bluff is given as No. 33, p. 69.

41. On the hillside west of Holland's Creek eight-tenths of a mile south of the Lowryville-Savannah road there is a little float from the Fort Payne chert which has been partially replaced by limonite.

42. Shot ore and small pieces of float limonite as large as a man's fist occur along the ridge north of Pompey Branch about eight-tenths of a mile east of the Walnut Grove-Savannah road and are residual from the red Eutaw sand which caps the divide north of Pompey Branch. Most of the float is very sandy.

43. On the north side of Pompey Branch a little over a mile from the main river road there is a small amount of limonite deposited in the Hardin sandstone in the vicinity of a slightly crushed zone on the east side of a fault having a throw of 75 to 100 feet. There is not enough ore to be of any importance. The Hardin sandstone on the east side of the fault butts up against the Fort Payne chert on the west side, the Ridgetop shale being cut out. Float limonite (replacement of the Fort Payne chert) is scattered sparsely over the hillside on the west side of the fault.

44. On the north side of Pompey Branch 1-5/10 miles from the main river road, a woods road leads off to the north up a small branch tributary to Pompey Creek. One-tenth of a mile up this woods road on the east side of the small branch, a bluff of deeply weathered porous Fort Payne chert is exposed for a thickness of six feet, 20 feet above the bottom of the small branch. The rock in place contains a considerable quantity of limonite as a complete or partial replacement of the chert, but its distribution is very irregular. On the small talus pile below the bluff and in the stream bed very striking blocks of solid limonite occur two to three feet in diameter and up to one foot thick. Some of them show a mammillary surface. A few of the partly covered blocks in the stream bed look as if they might be in place. If so, there would be 20 feet or more of ore-bearing rock here. Most of the blocks have undobtedly broken off from the bluff above and many of the float blocks contain considerable amounts of incompletely replaced chert fragments. One-tenth of a mile farther up the branch the Fort Payne chert contains practically no limonite so that the pocket is only a local concentration. No prospecting has been done. This showing is considered as indicating one of the most promising points to prospect that has been noted anywhere in the county. The land belongs to Bill Williams. An analysis of a picked sample from this deposit is given as No. 32, p. 69.

45. Much iron-oxide-cemented sandstone residual from the Eutaw sand was observed on the hill slopes north of the Dry Creek road four miles east of Paulk's store. Some of the float passes into low grade sandy limonite.

46. A very little limonite in the deeply weathered Mississippian cherts, probably Fort Payne, was noted along the roadside southeast of the Florence-Walnut Grove road, approximately 4–5/10 miles south-southeast of Lowryville.

47. On the east side of Bumpus Creek and about six-tenths of a mile north of the Alabama line there is some low grade limonite float from the Tusacloosa gravel which is 28 feet thick here. The over-lying Eutaw sand also contains some sandy limonite. Nothing was seen here to indicate ore of value.

48. One mile southeast of Duncan's Chapel and school, 90 feet of Tuscaloosa gravel overlie the Warsaw limestone. There is some limonite in both formations. In the Tuscaloosa the limonite is of very low grade (occurring as a ferruginous cement of the gravel) and in the Warsaw it consists of small pockets and seams a few inches thick as a replacement of the chert. No sign of prospecting was seen anywhere in this southeast section of Hardin County.

MANGANESE DEPOSITS

Although manganese is intimately associated with the brown iron ore deposits in the county, no deposits were observed by the writer which could be of value for their manganese content alone. There are a few low grade manganese deposits that have been worked in Wayne County to the east, but they are considered of little importance by Miser[37].

Manganese deposits to be of much value, regardless of their size, should contain from 35 to 45 percent of manganese. High silica phosphorus content is objectionable and penalties are imposed for silica in excess of 8 percent and for phosphorus in excess of two-tenths of one percent. The following analyses show that even picked samples representing the best grades observed by the writer contained too much silica or phosphorus, or both, to be of any importance as manganese ores. Only one analysis showed more than 35 percent of manganese. Deposits might be found by prospecting, however, that would be suitable for the manufacture of manganese alloys such as speigeleisen and ferro mangenese. Analyses of manganese ores from Hardin County are given as Nos. 35 to 39 on p. 69.

The manganese minerals in Hardin County are: (1) Wad, a low grade, earthy, impure, brown to black material containing 40 percent or

[37]Miser, H. D. op. cit. p. 120.

less of manganese. It has a low specific gravity and is easily cut with a knife. (2) Psilomelane, a black hydrated oxide of manganese which usually contains some potassium and barium. It is hard and rather heavy, having a specific gravity of 3.7 to 4.7. It contains 45 to 60 per-cent manganese. Of these two, wad is more abundant. The manganese minerals wherever seen were always intimately associated with the limonite deposits. All the iron ores analyzed showed variable quantities of manganese. In most cases the porportion of manganese oxide to iron oxide is very small. This intimate association occurs because of the common origin of both the iron and manganese minerals. Both were deposited by circulating ground water, having been dissolved from the overlying rocks during the process of weathering and decay which affected them for long periods of time. The manganese content does not seem to be higher in the deposits in one type or age of rock than in another. The deposits in the Eutaw sand, Selma clay, Warsaw limestone, and Fort Payne chert alike contain variable quantities of manganese oxide.

OTHER METALLIC MINERALS

Other metallic minerals observed in the county by the writer or reported to him by local residents are: galena, sphalerite, chalcopyrite, stibnite, pyrite, and marcasite. These occur in only minute quantities and are of no economic importance. It is possible that one or two of them may not occur in the rocks of the county at all.

Galena.

Galena or lead sulphide was observed only as minute crystals in some of the limestones. Numerous good specimens of galena were shown to the writer by various persons, but in all cases such specimens were picked up on Indian camp sites. There are many reports of galena deposits from which material for making bullets was secured in the early days of settlement. The writer was taken to at least half a dozen of these localities but in no case could the supposed deposit be found. There is no reason, however, why small veinlets and pockets of lead sulphide should not be present; but, if so, they are extremely rare and very small.

Sphalerite and Chalcopyrite.

Sphalerite, or zinc sulphide, and chalcopyrite, or copper iron sulphide, were not seen anywhere in place in the county. A small specimen sent to the writer by Mr. Morris who lives on the headwaters of White's Creek, consists of a mixture of sphalerite, chalcopyrite, galena, and pyrite. It is not known where this specimen was obtained. It is certain that there are no deposits of sphalerite or shalcopyrite in Hardin County large enough to be even of passing interest.

ANALYSES OF LIMESTONES FROM HARDIN COUNTY, TENNESSEE

<table>
<tr><th>Sample No.</th><th>SiO_2</th><th>Al_2O_3</th><th>Fe_2O_3</th><th>$CaCO_3$</th><th>$MgCO_3$</th></tr>
<tr><td>1</td><td>24.15</td><td colspan="2">3.94</td><td>69.25</td><td>2.60</td></tr>
<tr><td>2</td><td>23.48</td><td colspan="2">4.02</td><td>69.70</td><td>2.85</td></tr>
<tr><td>3</td><td>14.19</td><td>2.95</td><td>1.05</td><td>79.23</td><td>1.04</td></tr>
<tr><td>4</td><td>3.92</td><td colspan="2">3.20</td><td>91.16</td><td>1.75</td></tr>
<tr><td>5</td><td>3.85</td><td colspan="2">3.74</td><td>90.08</td><td>1.24</td></tr>
<tr><td>6</td><td>4.06</td><td colspan="2">3.23</td><td>90.07</td><td>2.67</td></tr>
<tr><td>7</td><td>1.96</td><td colspan="2">1.08</td><td>95.04</td><td>1.88</td></tr>
<tr><td>8</td><td>18.85</td><td>2.04</td><td>8.92</td><td>68.88</td><td>1.24</td></tr>
<tr><td>9</td><td>3.02</td><td colspan="2">1.56</td><td>93.31</td><td>2.02</td></tr>
<tr><td>10</td><td>1.67</td><td colspan="2">2.32</td><td>94.28</td><td>1.77</td></tr>
<tr><td>11</td><td>56.20</td><td>2.21</td><td>1.14</td><td>37.11</td><td>3.10</td></tr>
<tr><td>12</td><td>38.04</td><td>2.92</td><td>1.16</td><td>52.22</td><td>5.56</td></tr>
<tr><td>13</td><td>51.74</td><td colspan="2">1.12</td><td>43.89</td><td>3.18</td></tr>
<tr><td>14</td><td>2.79</td><td colspan="2">2.96</td><td>92.85</td><td>1.31</td></tr>
<tr><td>15</td><td>16.04</td><td colspan="2">3.16</td><td>78.63</td><td>2.10</td></tr>
<tr><td>16</td><td>.62</td><td colspan="2">3.08</td><td>94.53</td><td>1.84</td></tr>
<tr><td>17</td><td>21.89</td><td colspan="2">3.04</td><td>70.65</td><td>2.94</td></tr>
<tr><td>18</td><td>71.27</td><td colspan="2">4.05</td><td>21.40</td><td>3.11</td></tr>
</table>

1. Hermitage limestone from Willoughby Creek.
2. Hermitage limestone from Poney Creek.
3. Hermitage limestone from Clifton, Wayne County[5].
4. Fernvale limestone from Poney Creek, northeast of Swift.
5. Brassfield limestone from right bank of Indian Creek, about half a mile above bridge between Cerro Gordo and Swift.
6. Brassfield limestone from Valley of Poney Creek, northeast of Swift.
7. Lego limestone from Horse Creek, east of Scott's store.
8. Red Dixon limestone from Paulk's Mill, on right bank of Horse Creek, 2½ miles northeast of Savannah.
9. Bob limestone from bluff below Grandview Landing.
10. Decatur limestone from exposure a tenth of a mile southeast of Burnt Church.
11. Ross limestone, core from bottom of hole No. 1 at Pickwick dam site, taken by U. S. Army Engineers.
12. Ross limestone, core from eight inches above bottom of hole No. 4, at Pickwick dam site, taken by U. S. Army Engineers.
13. Ross limestone from bluff at Chalybeate Spring on Horse Creek.
14. Ross limestone from cut three-tenths of a mile east of Olive Hill on highway 15.
15. Pyburn limestone from Haw Branch.
16. Flat Gap limestone from Bear Branch east-southeast of Olive Hill.
17. Ridgetop shale from Germany Branch.
18. Ridgetop shale a quarter of a mile south of Dry Branch School.

[5]Miser, H. D., op. cit. p. 124.

ANALYSES OF CHERT, SAND AND GRAVEL FROM HARDIN COUNTY, TENNESSEE

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on Ignition
19	93.56	3.67	1.94	------------	------------	.88
20	60.42	3.85	30.22	------------	------------	4.62
21	64.09	12.87	18.46	------------	------------	4.62
22	72.55	14.30	5.01	1.24	.94	5.55
23	38.92	8.84	2.55	13.26	1.16	------------

19. Weathered white chert in Fort Payne formation.
20. Cemented Tuscaloosa gravel from Turkey Creek.
21. Red Eutaw sand from near Mt. Hermon Chapel.
22. Orange colored sand from Coffee Bluff.
23. Selma clay from 2½ miles south of Morris Chapel.

ANALYSES OF IRON AND MANGANESE ORES FROM HARDIN COUNTY, TENNESSEE

Sample No.	Fe	SiO_2	P	Mn
24	46.88	15.02	0.72	0.90
25	49.04	12.30	0.65	0.88
26	50.13	10.45	0.58	0.82
27	36.21	30.38	0.60	1.05
28	52.42	8.04	0.91	1.03
29	45.83	17.01	0.55	1.16
30	48.10	12.62	0.82	0.85
31	33.55	31.10	0.72	0.81
32	33.16	30.98	0.45	1.89
33	30.57	36.66	0.48	0.67
34	48.88	12.95	0.60	0.74
35	39.45	26.17	0.42	4.15
36	10.65	8.62	0.46	47.84
37	12.87	21.03	0.39	30.24
38	15.03	16.90	0.37	32.40
39	15.84	15.05	0.40	30.26

Brown Iron Ores from the Eutaw Sand

24. W. B. Hargrove's place on Smith's Fork.
25. R. D. Seaton prospect.
26. Herbert Reynold's place on Turkey Creek.
27. Pyburn's Bluff.
28. M. L. Hosey's place on Turkey Creek.
29. Tom Irwin's place on Choate Creek.

Brown Iron Ores from the Warsaw Limestone, Fort Payne Chert and Selma Clay

30. W. J. Frank's prospect on Horse Creek.
31. Float from half a mile north of Abram Chapel.
32. Up Pompey Creek 1-5/10 miles from main river road.
33. Two miles north of Duncan's Landing.
34. Float from Selma clay 3-3/10 miles west of intersection of high ways 45 and 69.

Manganiferous Ores

35. W. J. Frank's place at head of Horse Creek.
36. Sample supplied from upper Horse Creek by W. J. Frank; not seen by writer.
37. Reynold's place on Turkey Creek.
38. Seaton prospect.
39. Sample supplied from head of White's Creek by Mr. Morris; not seen by writer.

STIBNITE

Stibnite, or antimony trisulphide, was not seen in the county by the writer. Mr. John Vanhoose, who lives near Pyburn, reports that in excavating an Indian grave on the river bottom nearby, he found a mineral specimen which he at first took for galena. His description of the color, crystal habit, and decrepitation which it showed when heated in a blacksmith's forge make it probable that this mineral was stibnite. Its original source is problematical.

Mr. Buck Martin, who lives between Cerro Gordo and Russell in the northern part of the county, reports that he found a metallic mineral on the head waters of Poney Creek near Swift. He does not remember the exact location of the find or whether it occured as float or in place. Mr. Henry Williams of Savannah, who had the material analyzed, reports that it contained antimony.

PYRITE AND MARCASITE

Pyrite and marcasite are both iron sulphides but crystallize in different crystal systems. They both occur widely distributed in small quantities in the county but are of no economic importance. Pyrite occurs usually as small cubical crystals an eighth of an inch or less in diameter disseminated in the cherts, shales, and limestones of Paleozoic age. Marcasite occurs in spherical and irregular nodules up to three or four inches long or in massive lenses two to three inches thick in the Hardin sandstone, Chattanooga black shale, Ridgetop shale, and in the Coffee phase of the Eutaw sand. The nodules generally consist of a radiating crystal aggregate. Marcasite rapidly disintegrates upon exposure to the air and frequently gives rise to a white powdery substance called melanterite or iron sulphate. This material tastes something like alum. Livestock are sometimes found licking it from the surface of the rocks where it has formed.

PHOSPHATE ROCK

Phosphate rock is any rock which contains large quantities of tricalcium phosphate ($Ca_3(PO_4)_2$). The phosphate may occur in limestone, shale, sandstone, etc. Under present conditions a rock must contain 50 percent at least of tricalcium phosphate to be economically important. Deposits containing 70 to 75 percent or more command much higher prices.

Tennessee is second to Florida at present in production but the recent mapping of vast reserves in southeastern Idaho by the U. S. Geological Survey will probably result in the development of a great phosphate industry in that section of the west.

Phosphate rock is used chiefly in the manufacture of fertilizer but some of the higher grade material goes to the chemical trade. The phosphate as it occurs in the rock is not available for plant food and must be treated. The rock is generally treated with sulphuric acid producing what is known as acid phosphate. Treatment in furnaces without the use of acid is, however, coming into wider use. Deposits not suitable for acid treatment are adaptable to this method. The raw rock mixed with sand and coke is ignited. White phosphorus fumes are driven off and combine with the moisture in the air to form phosphoric acid. The electric furnace is also used in this volatilization process where electric power is cheap.

Another method of utilizing phosphate rock is to mix the raw ground rock with sulphur and use it directly as a fertilizer without further treatment. The sulphur soon oxidizes to sulphuric acid which reacts on the phosphate to form phosphoric acid directly in the soil.

Although the deposits in Hardin County do not seem to be of special importance at the present time because of their thinness and low grade character, there is no reason why they should not be used locally as raw phosphate applied directly to the land.

The phosphates in Tennessee are known as brown, white, and blue rock. The brown rock, of which the best known center of production is at Mount Pleasant, represents the residue left behind upon the disintegration and weathering of phosphatic limestones. The brown phosphate occurs as a mantle over the source rock and in pockets. Much of the product from the Mount Pleasant section runs 70 percent or more $Ca_3(PO_4)_2$. Of the tests conducted by the writer on many weathered products from the limestones in the county, none of them showed more than a mere trace of phosphate. There are probably, therefore, no economic deposits of the brown rock type present.

The white phosphate, occurring chiefly in Perry and Decatur counties, is also of secondary origin, much of it having formed apparently by the action of underground water, according to Maynard[38]. The deposits occur chiefly in the Decatur limestone of Silurian age, in the Linden and Camden formations of Devonian age, and in the base of the Mississippian series. Although Hardin County lies directly south of Decatur County and most of the rocks which contain the white phosphate are present here, the conditions essential to the formation of white phosphate deposits appear to have been absent. No white rock of any kind was seen in Hardin County. There may be, however, deposits of this type present in some of the underground openings of the limestones.

Blue phosphate rock occurs in beds like coal and such deposits are much more uniform and more easily prospected than the irregular pocket type. Its origin is entirely different from that of the brown or white

[38]Maynard, T. P., "White rock phosphates of Decatur County, Tennessee." Tenn. Geol. Survey, Resources of Tennessee, Vol. III, No. 3, p. 164, 1913.

varieties. The blue rock is a primary deposit, accumulated along with the rock which contains it. Much of the bedded phosphate is not blue but brownish in color. The term "blue phosphate" is used, since the term has come to imply a definite type of origin. The bedded phosphate rocks are widely distributed in the county but most of them are of too low grade to be economically important at the present time. Analyses of some of the higher grade deposits are given below.

ANALYSES OF PHOSPHATE ROCK FROM HARDIN COUNTY, TENNESSEE

Sample No.	Locality	Bed	Thickness in Feet	Tri-Calcium Phosphate $(C_3(PO_4)_2)$	Insol. Siliceous Matter	Iron Oxide (Fe_2O_3)
40	Head of English Creek	Maury glauconitic member	2½	0.44	94.92	1.89
41	Head of English Creek	Sandstone layer in Ridgetop shale	½	3.71	71.08	10.62
42	Cain Creek	Hardin sandstone	½	32.97	52.68	4.05
43	Mouth of Holland's Creek	Maury glauconitic member	6	6.98	85.72	3.85
44	"Slate" hill east of Lowryville	Sandstone bed in Chattanooga black shale	1	14.63	72.28	7.78
45	Dry Creek School	Sandstone bed at base of Ridgetop shale	1	1.75	69.60	4.67
46	Baugus Hollow	Sandy Black shale in Chattanooga formation	4½	1.97	89.12	1.54
47	Indian Creek 7-10 of a mile south of Highway 15	Sandstone bed in Chattanooga shale	½	1.74	82.15	3.88
48	E. L. Beckham's land 2 miles S. SE. of Highway 15 and 1¼ miles E. NE. of Indian Creek	Phosphate nodules top of Chattanooga black shale	½	5.46	83.04	3.20
49	Andrew Abel's place head of Steel Creek	Maury glauconitic member	1	53.65	------	------
50	Same	Same	1	4.15	86.46	7.81
51	Same	Nodules in Maury glauconitic member	½	76.62	------	------
52	Same	Sandstone bed in Chattanooga black shale	½	8.30	81.64	7.28

Numerous tests conducted by the writer showed that practically all the phosphate rock in the county of even slight importance occurs in the Hardin sandstone, the "black shale", the Maury glauconitic member, and the Ridgetop shale.

Description of Occurrences

1. On the headwaters of English Creek in the stream bed two miles south of the road to Covey Chapel, 28 inches of greenish gray, sandy, Maury limestone and shale overlie the "black shale". The upper two to three inches of this bed contain many phosphate nodules up to two inches in diameter. The whole 28 inches is phosphatic. A few limestone nodules occur in the top of the Maury member. The analysis of an average sample of the Maury member at this place is given as No. 40, p. —.

The Ridgetop shale appears to lie disconformably on the Maury member and contains some phosphate nodules in the thin basal limestone bed. They may represent reworked nodules from the underlying Maury member. Lying on the dense basal limestone member is an irregular bed of dark greenish sandstone a few inches thick which is phosphatic. The analysis of an average sample of this sandstone is given as No. 41, p. 72.

Because of the steep slopes the amount of overburden increases rapidly away from the stream bed.

2. In the bed of Cain Creek, just south of the Savannah-Walnut Grove road, two to six inches of Hardin sandstone rest uncomforably on the dark blue, siliceous Ross limestone of Devonian age. The Hardin sandstone is greenish-gray and contains in addition to the disseminated phosphate, phosphate nodules and chert pebbles derived from the underlying Ross limestone. The Hardin is overlain by about eight feet of Ridgetop shale which, in the upper part, has been leached to a dirty white clay. Six feet of deeply weathered Fort Payne chert overlie the Ridgetop and are in turn overlain by the Red Eutaw sands of Cretaceous age. The analysis of a grab sample of the Hardin sandstone is given as No. 42, p. 72.

3. In the stream bed of Bevins Branch three-tenths of a mile south of the Savannah-Lowryville road 15 feet of Ridgetop shale are well exposed. The Ridgetop here consists of fissile shale and shaly limestone. When freshly broken the shaly limestone has a strong odor of petroleum and tests show that it also contains some phosphatic material. The Ridgetop is overlain by 35 feet of Fort Payne chert which in turn is overlain by nearly 100 feet of red Eutaw sand.

4. Half a mile east of Holland Creek, on the south side of the Savannah-Lowryville road, eight feet (base covered) of black Chattanooga shale and interbedded sandstone are exposed in the gully by the roadside. The Chattanooga shale is overlain apparently conformably by six feet of the Maury glauconitic member. This member consists of green and gray shale and greenish sandstone, and is phosphatic. The beds strike N. 50° E. and dip 4° SE. The Maury here is overlain by 35 feet of Ridgetop shale. The basal twenty inches of the Ridgetop is a glauconitic sandstone containing phosphate nodules, chert, limestone and sandstone pebbles. In places the pebbles are so thick that the

sandstone passes into a conglomerate. The upper few feet of the Ridgetop has been weathered into a white clay. It is overlain by the Fort Payne chert. The analysis of an average sample of the Maury member is given as No. 43, p. 72.

5. Three-eights of a mile east of Lowryville, on the road to Gillis Mills, there is a steep though low hill known locally as "Slate" hill. The road passes directly over the exposed edges of the Chattanooga formation. A fifteen foot exposure shows beds of coal-black shale separated by thin layers and lenses of variegated sandstone (gray-yellow-almost black). The lower eight feet of the shale are platy and extremely fissile while the upper six feet are slabby and contain considerable pyrite. The two shale phases are separated by a persistent sandstone bed a foot or more thick. The black shale is overlain by the red Eutaw sands. The shale contains some phosphate and the sandstone beds are strongly phosphatic. An analysis of the sandstone beds is given as No. 44, p. 72.

6. South of Dry Creek School on Dry Creek there is a V-shaped valley with slopes up to 40 degrees. A quarter of a mile up this ravine 35 feet of Ridgetop shale are exposed in a vertical bluff over which a small stream cascades. The bulk of the Ridgetop here is a dark shaly limestone which has a strong odor of petroleum. The base of the Ridgetop at the foot of the falls consists of two feet of dark pyritic sandstone with a little shale. This is overlain by seven inches of shale and the shale by another dark pyritic sandstone bed a foot thick. An analysis of this last bed is given as No. 45, p. 72.

Over the sandstone bed lies shaly limestone to the top of the bluff. The sandstone beds at the base are phosphatic. Under the Ridgetop is four to ten inches of very platy Chattanooga shale with some thin sandstone beds. The black shale rests on $4\frac{1}{2}$ feet of dark gray, cross-bedded, pyritic Hardin sandstone with a small amount of interbedded shale. The Hardin rests on the dark gray Pyburn limestone of Devonian age. The beds at the foot of the falls dip eight degrees southwest. The Hardin sandstone and sandstone beds in the black shale are also phosphatic.

7. Three and three-tenths miles south of Thompson's store a small tributary in what is known locally as Baugus Hollow, joins Smith Fork from the southeast. Near the mouth of this hollow there are 52 inches (base covered) exposed of sandy, phosphatic, Chattanooga shale. The Chattanooga is overlain by typical Ridgetop shale. The land belongs to Judge Watson of Savannah. The overburden here is 20 to 25 feet and increases rapidly going up stream. The analysis of a sample taken eight inches below the Ridgetop is given as No. 46, p. 72.

8. Seven-tenths of a mile south of highway 15 on the east side of Indian Creek a few feet of Chattanooga shale are exposed where the creek makes a bend to the east. The Chattanooga here is composed principally of black shale, but contains a few grayish brown sandstone layers

up to a few inches thick which are phosphatic. The beds at this point dip four to six degrees south. The analysis of a sample from one of the thicker sandstone layer is given as No. 47, p. 72.

9. On E. L. Beckham's land, two miles south-southeast of highway 15 and 1-1/4 miles east-northeast of Indian Creek, near the headwaters of a small branch tributary to Indian Creek, 15 feet of Hardin sandstone rest, with an angular unconformity of one degree, on the Beech River limestone of Silurian age. The sandstone is gray and massive and grades gradually through sandstone and sandy shale into typical "black shale" above. The latter contains some sandstone layers. The black shale is here 25 feet thick, making a total of 40 feet for the Chattanooga formation. The upper fifteen feet of the black shale is much more slabby than the lower ten feet. The upper two feet of the Chattanooga shale is very black and coaly looking and contains at the extreme top a two to three inch bed of phosphatic nodules. The entire 40 feet of the Chattanooga is overlain disconformably by 55 feet of Ridgetop shale which causes falls in the stream bed up to 20 feet in height. The lower 20 feet of the Ridgetop is fissile shale while the upper part consists of dense, dark oily limestone and some shale. The dense limestone is slightly phosphatic and contains numerous nodules and layers of black flint speckled with small well formed pyrite crystals. An analysis of a sample from the phosphate nodule bed at the top of the Chattanooga is given as No. 48, p. 72.

10. On Andrew Abel's place on the headwaters of Steel Creek and about 1-1/4 miles north of highway 15, twelve to fourteen inches of the Maury glauconitic member lie on the "black shale." The bed is highly phosphatic throughout and is well exposed just southeast of Mr. Abel's barn. The lower three to four inches is composed essentially of phosphate nodules while the upper part is a glauconitic sandstone. The Maury is overlain in Still Hollow a quarter of a mile southeast of the barn, by 40 feet of Ridgetop shale. Much of the shale has been leached to a white plastic clay. The Maury member strikes N. 30° W. and dips 2° NE. Two analyses of the glauconitic sandstone are given as Nos. 49 and 50, p. 72.

A nodule from the base of the Maury showed 76.62 percent of calcium phosphate. An analysis of a sample of a sandstone bed in the black shale is given as No. 52, p. 72.

There are other rocks in the county which contain some phosphate but in such small quantities that it is certain they will never be of any importance. Among them are the following:

1. Cherty shaly limestone which usually composes the top of the Ridgetop formation. Where a complete section can be seen it generally contains small amounts of phosphatic material as do also the residual clays derived from it.

2. Micaceous greensands which occur in the Coffee phase of the Eutaw formation contain small quantities of phosphate as do some of the darker sands of the Tombigbee phase in the vicinity of Counce.

3. The residual clays of the Beech River limestone of Silurian age also contain very small amounts of phosphate as do some of the shale beds of the Hermitage formation.

With the large reserves of high grade brown rock which are adaptable to stripping operations in Central Tennessee in the vicinity of Mount Pleasant and the large production in Florida, the bedded phosphate rocks have ceased, for the present, to compete with them. It is probable that the bedded deposits in Central and West Tennessee cannot be worked economically for some time to come. The high grade deposits in Idaho will also probably have their effect on the market in the near future.

Raw phosphate rock is being used more and more as a fertilizer and there seems to be no reason why the deposits in Hardin County cannot be used locally in this way.

LIMESTONE

Lime

Quick lime is calcium carbonate that has been burned. During the burning the water, carbon dioxide, and other volatile constitutes are driven off. When "slaked" with water quicklime forms a hydroxide which, upon exposure to the air, takes carbon dioxide and "sets." For the manufacture of quicklime pure limestones are essential. Limestones suitable for making lime are present in the Flat Gap, Decatur, and Bob limestones.

The Flat Gap is confined to structural basins near Olive Hill, Dry Creek School, and Grandview Landing. It is a massive coarse grained, pinkish limestone which takes a good polish. It reaches a maximum thickness of 35 feet at Olive Hill and areas should be found where it could be quarried without the removal of excessive overburden.

Analyses of the Flat Gap limestone show an average calcium carbonate content of 94 percent.

The Decatur limestone is a massive to thin bedded, dense to crystalline, light gray to pinkish limestone. It is largely confined to the northeast quarter of the county. It varies in thickness up to 60 feet with an average thickness of 25 to 30 feet. In the bluffs below Cerro Gordo and Grandview landings the Decatur limestone is well exposed and large quarries could be opened with little trouble. The formation outcrops favorably in other places as well, but these are not so advantageously situated with regard to river transportation.

The Bob limestone is a massive, crystalline, light gray to white rock which contains some chert in places. It outcrops so far as known, in only the northeast part of the county though it is probably present beneath the overlying rocks at many other places. It varies up to 20 feet in thickness with an average of about 14 or 15 feet. The most favorable localities seen for opening quarries are in the bluffs below Cerro Gordo and Grandview Landings.

The uses of quicklime for mortar in building purposes as for neutralizing acidity in soils, as well as for almost innumerable purposes, are well known. Raw limestone may also be used without burning for acid soils though it is somewhat slower than quicklime.

The soils of Hardin County could be greatly improved by the erection of small local kilns run on a cooperative basis for making quicklime or by application directly to the soil of ground raw limestone rock.

Flux

Although there has been no production of iron ore in the county and probably will not be in the near future, there is abundant limestone present suitable for flux. The ferruginous Bear Branch limestone of Devonian age which runs as high as 45 percent iron oxide would in places make a good flux, although it cannot be used as an ore. On Bear Branch southeast of Olive Hill, where this limestone reaches a thickness of 35 feet, the content of iron oxide seems to be highest. In the bluff along the right bank of Indian Creek at Olive Hill it is approximately 45 feet thick but here the iron content is much lower. Until such time as furnaces may be operated in the surrounding area the deposits have no value.

The Brassfield limestone of Silurian age, containing up to 17 percent iron, has been used as a flux in Wayne County with brown iron ores from Pinkney. The Brassfield, where it outcrops on the right bank of Indian Creek 2¾ miles northeast of Cerro Gordo in Hardin County, contains at its base seven feet of Massive brown limestone which, where weathered at the surface, is red. An analysis showing the composition of the more feruginous portion of this bed is given as No. 5 p. 68.

The Laurel, Lego, and Bob limestone, as well as limestones in the Ridgetop shale, have been used for flux in Wayne County. The limestone in the Ridgetop shale in Hardin County is not pure enough for use as flux, but the Laurel, Lego, Bob, and probably also the Decatur and Flat Gap limestones would prove suitable for this purpose. The Silurian limestones, especially the Lego, outcrop over wide areas in the northeast section of the county with practically no overburden. Many of these exposures are far from Tennessee River and in the absence of a railroad only those deposits near the river could be used.

Structural Use

Many of the limestones in the county would make good building stones. Those suitable for this purpose are exclusively of Silurian and Devonian age. Their restriction to, and distribution in, the northeast quarter of the county is shown on the accompanying geologic map.

The limestones in question have been used only for foundations and wall and rubble work but with the increasing demand for stone or stone-faced structures, they may in future become important. The limestones which may prove important as building stones are the Laurel, Lego, Bob, Decatur, Ross, and Flat Gap. The first four are of Silurian age and the last two are of Devonian age.

Both the Laurel and Lego limestones are heavy bedded, dense, tough, stylolitic, light gray to pinkish rocks. The beds vary in thickness from four to five inches up to one and a half feet. The limestones are resistant to the weather and after long exposure have a smooth light gray surface. Both the Laurel and Lego have a maximum thickness of about 35 feet. They are favorably exposed, expecially the Lego, in many places with little or no overburden. The Lego is exposed on the bank of Tennessee River below the Cherry mansion at Savannah and stone secured there has been used in some of the buildings in Savannah. Much better exposures occur, however, at Cerro Gordo and in the northeast corner of the county. Certain beds in the Lego take a fairly good polish.

The Bob is a crystalline, massive, white to light gray limestone which would probably make a good building stone. It occurs up to 20 feet in thickness but is well exposed at only two places, Cerro Gordo and Grandview.

The Decatur is a massive, heavy bedded, dense to coarsely crystalline, white to gray limestone, having a thickness up to 60 feet. It outcrops in many places in the northeast section of the county where quarries could easily be opened. It would make a good building stone, but it was not reported to the writer as having been used as such.

The Ross is a dense, siliceous, dark blue limestone which weathers to a yellow porous sandstone. Where not so deeply weathered, however, it changes to a light gray sandstone of microscopic fineness. Parts of the Ross are very massive and would probably make a durable building stone. The localities, however, where it could be easily quarried are limited.

The Flat Gap is a light pink, coarsely crystalline, extremely massive limestone. Stylolites are numerous in it, but bedding planes are far enough apart so that dimensional blocks could be gotten out. It weathers to a creamy white. The Flat Gap limestone takes a good polish and might, therefore, be called marble. It may prove suitable for interior decorative purposes. The most favorable locality for quarrying is at Olive Hill. At most of the other exposures the large amount of overburden would be prohibitive.

CEMENT

The rapid spread of a network of paved roads over the entire country, the building of bridges, and the great increase in the erection of buildings of stone, brick, cement and concrete has greatly increased the demand for various types of cements. It has been estimated by Payne[39] that "If every cement plant now built or building in the South were to operate at full capacity, there would still be a shortage of 3,000,000 barrels per year in this territory."

Although, so far as known, there has been no production of cement in Hardin County, there was for many years a small plant on the outskirts of Clifton in Wayne County near the Hardin County line. The plant closed in 1888 and has never operated since. The product was apparently of good grade. The rock burned was the dense limestone layers in the Hermitage formation. An analysis of this rock is given as No. 3, p.68.

This is very close to the percentages used in the manufacture of Portland cement. With the increased demand for cement it would seem that this section of Tennessee might become a center of cement production.

The limestone beds in the Hermitage formation, which were burned at Clifton in the last century, also outcrop in Hardin County in the vicinity of Willoughby Creek three miles southeast of Savannah. The calcareous shale layers interbedded with the limestone beds of the Hermitage formation were not used at Clifton, yet the author sees no reason why they should not be used. The calcium carbonate of the entire formation is probably too low to make a good cement, but there are limestones in the county of high purity which could be added to supply this deficiency. The Hermitage limestone and shale exposed near Russell is at least 60 feet thick and probably much thicker.

There are also other limestone and shale beds of great extent and sufficient thickness distributed widely over the northeast section of the county which might be used in the manufacture of Portland cement. Many of them are near Tennessee River which would serve as a means of transportation for both the cement and coal supplies. It would seem that if a market could be established and adequate distributional transportation supplied, a cement plant near the river in this section might prosper.

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[39]Payne, H.M., The undeveloped mineral resources of the South, American Mining Congress, p. 331, 1928.

Should a process ever be developed whereby both the phosphate and petroleum content of phosphatic oil shales could be extracted, the residue might be utilized in the manufacture of cement. In such event the Chattanooga and Ridgetop shales might prove of great importance.

MILLSTONES

Small millstones for grist mills were formerly secured at scattered localities from the thick chert layers in the Fort Payne chert. Small unfinished stones were observed in the stream bed in Baugus Hollow near the headwaters of Smith Fork. They were apparently secured in the immediate vicinity from beds in the Fort Payne chert. The millstones in an abandoned mill near the head of Neighbor's Branch are also of white chert. It is not known where they were quarried. So far as known, no millstones have been produced in the county for many years. Chert beds that are free from joints, fractures, or other blemishes which would render them adaptable for millstones are very rare in the county and it is not thought that the cherts will ever be of any importance for this purpose.

TRIPOLI

Tripoli is an indefinite term signifying a highly siliceous, generally porous and crumbly material of white or yellowish color, used principally as an abrasive. Some varieties are valuable for making filters, blotter blocks, and scouring bricks. The less coherent material is ground, sized and sold as tripoli flour for polishing, burnishing, as an ingredient in scouring soap, etc.

Tripoli is formed by leaching of calcareous cherts or cherty limestones. It is known locally as "chalk". Aside from a general resemblance, it is difficult to imagine two substances more widely different. Chalk is a limestone composed almost wholly of calcium carbonate and made up of myriads of the small microscopic shells of Foraminifera and related forms, minute unicellular animals which lived in the upper portions of the ocean. Chalk is easily dissolved by hydrochloric acid. Tripoli, on the other hand, is composed almost wholly of silica, is not easily affected by acid, its constituent grains or particles are hard instead of soft, and the fossils it may contain are not usually the microscopic varieties present in chalk. Chalk is an unaltered sediment, while tripoli results from the chemical changes induced by rock decay and is not the result of deposition in bodies of water. Many deposits of tripoli contain 98 percent or more of silica, the other common oxides being present in very small amounts. Analyses of some of the more important deposits in Hardin County are given below.

ANALYSES OF TRIPOLI FROM THE WARSAW LIMESTONE AND FORT PAYNE CHERT

Sample No.	Locality	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on ignition
53	W. J. Frank's prospect on upper Horse Creek	96.92	1.68	0.40	0.10	0.03	0.78
54	F.L.Brown's prospect in Scott Hollow	95.89	2.55	0.53	0.11	0.02	0.98
55	Head of White's Creek	92.37	4.64	0.26	0.08	0.02	2.46
56	Tom Irwin's place on Choate Creek	92.52	4.48	0.30	0.24	0.05	2.28

The deposits occur exclusively with the Fort Payne and Warsaw formations, but principally with the former. The white residual clays from the Ridgetop shale are also sometimes extremely siliceous and may pass into tripoli in places.

The unaltered Fort Payne chert and Warsaw limestone are not exposed in the county. In the adjacent area to the east the Fort Payne is a calcareous chert and the Warsaw a cherty limestone. It is probable that the original rocks which gave rise to the tripoli deposits in Hardin County were of this character. These rocks underwent deep weathering during the long interval of erosion previous to Upper Cretaceous time and it is possible that the tripoli deposits were formed largely during that period. The overlying Cretaceous gravels and sands are, however, very porous and there is at present a marked circulation of ground water through them into the underlying chert and tripoli as evidenced by the numerous springs issuing from the base of the Fort Payne, especially along Holland Creek. It is possible, therefore, that part or all of the leaching has taken place fairly recently.

During the time that the Fort Payne chert and Warsaw limestone have been exposed to the solvent action of rain water the original constituents, except the silica (and that probably to a considerable degree), have been largely leached away, leaving the small particles of less soluble silica. Where the original beds were especially cherty, the deposits are very coarse and gritty, containing an abundance of white or yellowish chert rubble. All gradations may be observed from the fine grained, powdery, pure white tripoli of nearly flour-like consistency to great masses of chert breccia and rubble, with little or no fine grained material. The deposits containing much chert would have to be crushed and ground to separate the tripoli, and are of less economic importance.

Where the proportion of chert rubble is small the chert fragments could be removed by washing.

The deposits have not been prospected in Hardin County so that little is known of their thickness and extent. It is certain, nevertheless, that enormous quantities are present. There is no reason why, with proper transportation, these deposits should not be successfully developed. Mr. W. J. Franks stated that samples from his place on Horse Creek which were sent to New York City firms brought an offer of $20.00 per ton delivered. This is much higher than the average value of tripoli flour produced in the United States during the year 1923. The better grade deposits, however, are in the east and southeast parts of the county far from Tennessee River. In the absence of a railroad and even fair dirt roads, the deposits are of little importance at present. The tripoli is too incoherent to be used as filter stones and would have to be marketed as tripoli flour.

Many of the exposures of the Fort Payne chert, though they contain some tripoli, are made up largely of chert rubble. They would be of little value as tripoli sources but constitute enormous and excellent road metal deposits.

The Mississippian cherts and cherty limestones in Hardin County have everywhere been deeply weathered so that at no place were the unaltered rocks observed. For this reason all the areas underlain by either the Fort Payne chert or Warsaw limestone may contain workable deposits of tripoli. Small amounts were observed wherever these formations outcrop. Their distribution is shown on the accompanying map and prospecting should be confined to those areas. The washings from the deposits could be used advantageously for road metal.

Description of Occurrences

1. Half a mile west of the Wayne County line on the left bank of Horse Creek just south of the road, on land belonging to Mr. W. J. Franks of Gillis Mills, an excellent tripoli deposit is exposed. The hills rise sharply to the south. The tripoli is residual from the Mississippian cherts. From the fact that the Warsaw outcrops at the level of the road half a mile to the southeast, this deposit was probably derived from it rather than from the Fort Payne. The exposure shows a thickness of 10 feet, most of which is of good grade. Practically no prospecting has been done so that the exact thickness is unknown. Further prospecting will probably show much more than 10 feet. At the surface the deposit is slightly stained by iron oxide but is snow white below. Some chert rubble is present in the upper portion and the tripoli is somewhat gritty in some places. The entire deposit is soft and incoherent and could easily be prospected with a shovel. The amount of overburden is slight at the

outcrop but increases rapidly away from the creek. An analysis of a selected sample of this tripoli is given as No. 53 p. 81.

Considerable tripoli is present in the weathered cherts along Horse Creek near the Wayne County line and close search would probably uncover other deposits similar to the one on Mr. Frank's place.

2. The deeply weathered Fort Payne chert is well exposed in the stream bed of Boone Creek near its source about 1-5/10 miles south-southeast of highway 15. A steep bank or bluff on the west side of the creek shows more than 35 feet of deeply weathered chert, much of which is a good grade of tripoli. A large portion of the deposit, however, is coarse and gritty. Fifteen hundred feet up the creek, 12 feet of good tripoli are exposed. The tripoli at the latter locality contains less coarse chert than the former. The sides of the valley rise rapidly to the ridges capped by the red Eutaw sand so that the amount of overburden is great at short distances from the creek bed.

The Fort Payne formation is at least 60 feet thick at the head of Boone Creek and the amount of tripoli or "chalk", as it is called locally, is large. The tripoli and chert in this area are overlain by 12 feet of Tuscaloosa gravel.

3. There is a good exposure of tripoli 2-3/8 miles north of the Alabama state line in Scott's Hollow, a small tributary to the South Fork of White's Creek from the south. The exposure is a steep bluff on the right bank of a small stream a few yards east of F. L. Brown's house. The top and bottom of the deposits are covered but the exposed portion shows a thickness of 24 feet. Mr. Brown has a "storm house" cut into the bank. The deposit is fairly free from chert and contains very little grit, but is slightly discolored from iron oxide. The overburden is only a few feet for some distance back from the outcrop. Fossils in the chert fragments indicate that the deposit was derived from the Warsaw limestone. The analysis of a picked sample of this tripoli is given as No. 54 p. 81.

4. Along Holland's Creek, a stream of good size, which takes its source in the "Flatwoods" in the southeast corner of the county and flows northwest to join Horse Creek about two miles west of Lowryville, are exposures of the Fort Payne chert. For six or seven miles along this creek and particularly along the road on the east side the chert is well exposed and nearly everywhere contains tripoli. Most of the exposures are cherty and gritty. The Fort Payne in this section reaches a thickness of more than 100 feet. Deposits of good grade would undoubtedly be found if the section were properly prospected. The valley walls, however, are rather steep and consequently the overburden increases rapidly away from the valley floor.

5. On the north Fork of White's Creek, three-eighths of a mile from the junction of the North and South Forks the fissil Ridgetop shale crops out by the roadside. Overlying the Ridgetop 115 feet of

Fort Payne chert crops out on the hill slope north of the creek. The Fort Payne is deeply weathered into chert rubble and coarse tripoli. The material examined is of low grade, but better deposits could probably be found in the vicinity. The Fort Payne chert is overlain by the Eutaw sand which contains, at this locality, much gravel and some low grade iron ore.

6. In the steep hill three-eighths of a mile southwest of Big Ivy School, on the right bank of Horse Creek, there is a good exposure of Fort Payne chert. The formation is well over 100 feet thick, probably about 120 feet. Near the top the Fort Payne contains massive chert beds up to 6 feet thick, but the bulk of it consists of chert rubble and tripoli, some of which is of good grade.

7. Along the Dry Creek road 2-3/4 miles east of Paulk's store at Walnut Grove, the Fort Payne formation is well exposed. About 45 feet of Devonian limestone (Pyburn?) is exposed at the ford. This limestone is overlain successively, going up hill to the east, by 10 feet of Chattanooga shale, 55 feet of Ridgetop shale, and 50 feet of Fort Payne chert. The chert here is deeply weathered into chert rubble and tripoli. Much of the tripoli is coarse and gritty but some of it is of good grade.

8. On the road from Thompson's store to Gillis Mills, on the south side of Turkey Creek, the Fort Payne formation is more than 65 feet thick. This formation is deeply weathered and contains much chert rubble and some tripoli. The tripoli is stained considerably by iron oxide.

9. A quarter of a mile west of Rogers Creek the Pinhook road follows a small stream valley. In the bed of the stream south of the road, approximately 25 feet of tripoli and chert fragments, residual from the Fort Payne formation, are exposed. The tripoli is overlain by coarse Tuscaloosa gravel and is underlain by Ridgetop shale. The upper two to three feet of Ridgetop have been leached into greenish white clay containing phosphate nodules. The tripoli would have to be washed to remove the coarse chert fragments. The portion of the deposit free from chert is nearly pure white and contains no grit. It feels like fine flour.

10. One and one-fourth miles east-southeast of Burnt Church, on the hillslope south of Little Turkey Creek, occur 45 feet of Fort Payne chert. The chert rests on the Silurian limestone, probably the Decatur, and is overlain by the red Eutaw sands. The Fort Payne here is deeply weathered into chert rubble and white to dirty white tripoli and clay.

11. In the bed of a small stream tributary to the North Fork of White's Creek, 1-7/10 miles west of the Wayne County line and four-tenths of a mile north of the main creek, 10 feet of tripoli are exposed on the left bank of the small stream. The tripoli contains much chert rubble and grit and is discolored by iron oxide. Most of the chert could probably be removed by washing. It is uncertain whether this deposit

was derived from the Fort Payne chert or from the Warsaw limestone, but probably from the former. The analysis of a picked sample of the best material is given as No. 55, p. 81.

12. In the bed of a small stream, on Tom Irwin's land, on the east side of Choat Creek, four-tenths of a mile east of the middle Savannah road, the Fort Payne is deeply weathered into white clay and tripoli with some chert. Mr. Irwin reported that at this place the Tripoli, which was white and free from chert, had a thickness of seven feet. The writer saw some three or four feet of it at another point on the same stream. The analysis of a picked sample of the material is given as No. 56, p. 81.

TUBE MILL LININGS

Dimensional blocks of flint, chert or other hard material are used for lining tube mills. Most of the supply is furnished by Belgium. During the World War, however, when the Belgian supply was cut off, there was considerable domestic production. The return of the Belgian product has greatly decreased the output from Tennessee, Florida, Minnesota, and other states. At present the deposits in the United States are of little importance for tube mill linings.

During 1916, 1917, and 1918 several thousand tons were produced in Wayne County. The material came from beds in the Fort Payne chert and though it proved satisfactory it was not as effective as the Belgian flint.

Hardin County has produced no dimensional chert for tube mill linings and probably will not as long as present conditions exist. There are however, in the south and east portions of the county, beds in the Fort Payne chert of sufficient thickness to be used for this purpose. Should present conditions change, the deposits may become important.

GRAVEL

Gravel occurs in enormous quantities in Hardin County and if suitable transportation existed and a market were developed, it would prove a most valuable resource. The gravel is coarse and occurs mainly in the series of terraces along Tennessee River, in the basal member of the Cretaceous series or Tuscaloosa formation, and along the upper reaches of the streams tributary to Tennessee River in the east half of the county. Although the gravel contains considerable sand and some clay, it is easily screened or washed. The pebbles consist almost entirely of chert derived from the Mississippian beds with locally a few quartz and quartzite pebbles. The gravel has been used extensively for local road building but, so far as known, no gravel has ever been shipped out of the county. The washed gravel makes excellent concrete and was used during the summer of 1927 for concreting the basement of the new high school at Savannah, as well as for other structural purposes.

The writer has made a conservative estimate of 300 million short tons of coarse gravel and sand in the single terrace on which Savannah is built. In the whole county there are many times this amount. Gravel pits are numerous in the terrace gravels but very little gravel has been used from the Tuscaloosa formation or from the beds of the present streams.

The stream gravel consists entirely of chert pebbles and sand except where it contains reworked material from the Tuscaloosa in which case it may contain a few pebbles of glassy quartz. The pebbles, which become coarser up stream, are rounded or subangular. In general the smaller pebbles are better rounded than larger ones. Some of the cobbles are distinctly angular.

The terrace gravels are made up almost wholly of well rounded, though frequently flattened, pebbles of chert with some quartz and quartzite, and much sand. The proportion of quartz increases rapidly with decrease in size of the material until the sands of 28 mesh or finer are practically all quartz.

The Tuscaloosa gravels are in general coarser than the terrace gravels, and the pebbles more distinctly spherical. In addition they contain a smaller proportion of sand. The pebbles are well rounded, though some cobbles and larger pebbles are sub-angular to angular.

Some beds in the Tuscaloosa and terrace gravels have been cemented by iron oxides into a hard conglomerate. Most of the terrace gravels, however, and a good portion of the Tuscaloosa are unconsolidated and could be easily dug by steam shovels. The terrace gravels, especially, are advantageously situated so that little or no over-burden would have to be moved.

RAILROAD BALLAST

The chert rubble from the weathered Fort Payne and Warsaw formations would make good railroad ballast, though, as it occurs with considerable fine tripoli and clay, it would probably be advisable to remove the clay. The chert derived from washing tripoli deposits, should they ever be developed, would make admirable railroad ballast as well as road metal. Some of the coarser gravels along the streams, especially where they have not been rounded appreciably, would also probably prove suitable for ballast.

ROAD METAL

By road metal is meant any material which is suitable for and used in surfacing roads and highways. Some of the most widely used materials are limestone, gravel, chert, and trap rock. All of these, with the exception of trap rock, occur in the county. The available deposits of limestone, chert and gravel are practically inexhaustible.

Nearly all public roads in the county except the main highways are in poor condition, notwithstanding the fact that excellent road metal would in no case have to be hauled more than a few miles. Progress is, however, being made in improving this situation.

The roads that cross the outcrops of the road metal deposits are usually in fair shape, even though they receive no more or, in some cases, not so much attention as the other roads.

Road metals in Hardin County include 1, limestone; 2, residual cherts from the Fort Payne and Warsaw formations; 3, Tuscaloosa gravel; and 4, terrace and alluvial gravels.

Of the limestones the Ross, Laurel, Lego and Decatur are suitable for road metal. The Ross would probably be more suitable than the others because of its high silica content (50 percent or more in some cases) and hence greater hardness, but the Lego, Laurel, and to a less extent the Decatur, are also well suited for this purpose. All of them are dense tough stones. Limestone, however, will probably not be used for road building to any great extent because the cost of quarrying and crushing would be much greater than open cut production of the chert and gravel. Because of their greater hardness and longer wearing qualities, chert and gravel make superior road metal and roads made from these materials are less dusty than those made from crushed limestone. The residual cherts, especially of the Fort Payne formation, make admirable roads. The cherts are many feet thick and could be easily quarried with very little trouble at numerous localities. In addition, the cherts contain fine tripoli and clay which would act as a binder. In some cases crushing would be necessary to break up the larger blocks.

The Tuscaloosa gravel, which occurs almost exclusively in the southeast corner of the county, is in some places 100 feet thick. It could easily be dug at many places with a steam shovel. Certain beds in it have been cemented by iron oxides and these would have to be discarded or crushed. The gravel is coarse and consists almost entirely of chert pebbles and cobbles. The sand and clay content would act as a binder. It is a good road metal but has not been used to any extent for this purpose in Hardin County.

The alluvial gravels along the upper reaches of some of the creeks consist of chert pebbles and cobbles which in most places are fairly clean. They could also be used successfully for road metal. Many of the roads in the east half of the county follow these gravels for variable distances and except where they cross the creeks are in fair shape.

The terrace gravels are by far the most important road metal in the county because of their easy accessibility and great quantity. They have been used extensively and give good results at a very low cost.

The fine system of roads in Shiloh Military Park are surfaced with gravel dug from the terrace on which the park is located. Mr. DeLong Rice, former superintendent of the park, stated that the cost of these roads was about $2100.00 per mile.

So far as known, no official tests have been made on the road materials in the county. The following mechanical analyses of terrace gravels and sands were made by the writer.

MECHANICAL ANALYSES OF TERRACE GRAVELS, HARDIN COUNTY, TENNESSEE.

	(57) Percent	(58) Percent
Retained on 3 inch screen	0.0	0.0
Passing 3 inch, retained on 1.5 inch screen	10.8	0.0
Passing 1.5 inch, retained on 1.05 inch screen	6.2	8.9
Passing 1.05 inch, retained on 0.371 inch screen	24.4	45.8
Passing 0.371 inch, retained on 4 mesh screen	15.5	19.2
Passing 4 mesh, retained on 8 mesh screen	8.1	8.3
Passing 8 mesh, retained on 14 mesh screen	4.7	6.6
Passing 14 mesh, retained on 28 mesh screen	6.3	7.5
Passing 28 mesh, retained on 48 mesh screen	19.8	6.06
Passing 48 mesh, retained on 100 mesh screen	3.1	2.2
Passing 100 mesh	1.06	0.3
	99.96	99.86

(57). Terrace gravels from the Savannah terrace, altitude 420 feet, one-tenth of a mile south of highway 15 on road to Pyburn.

(58). High terrace gravels, altitude 530 feet, from roadside pit one-fourth of a mile west of the intersection of highways 69 and 17.

Situated on the border between Middle and West Tennessee, Hardin County holds a strategic position for supplying West Tennessee with road metal. The counties in West Tennessee, having a combined area of more than 9,000 square miles, are underlain largely by sands and clays. Road metal is in great demand there and if Hardin County had adequate rail transportation to this part of the state the supply and demand might be met with advantage to both sections.

SAND

Sand, as usually defined, is detrital material less than one-fourth of an inch in diameter, but coarser than silt. It is composed usually of quartz grains mixed with which are small amounts of other hard resistant minerals such as magnetite, limonite, garnet, zircon, etc. Many sands contain considerable quantities of white mica or muscovite, though eolian or wind blown sands usually contain very little or none of this material. In addition, some sands are composed largely of minerals other than quartz, such as magnetite, pyroxene, olivine, calcium carbonate, etc., and in rare cases contain no quartz. These peculiar sands are, however, not widely distributed and none of them occur in this county.

Sand is used for many purposes and is one of the chief non-metallics. Millions of tons are used in the United States each year, most of which is used for construction work. Large quantities are also used in making glass, for moulds, scouring soaps, and many other purposes.

Hardin County contains vast quantities of sand in the Eutaw formation, in the terrace gravels, and in the alluvium along the present streams.

Building Sand

Nearly all sands in the county are suitable for building purposes. They are composed almost entirely of angular quartz grains which are coated or partially cemented with a variable quantity of iron oxide and contain white mica as the chief minor constituent. Rarely grains of magnetite and other minerals are present.

The most abundant sands occur in the Eutaw formation. Much of the county is covered by these sands, which vary in thickness up to 300 feet. The bulk of them are colored a brick to purplish red by iron oxide, which occurs as red clay between the sand grains and as a film around the grains. Some of this iron oxide can be removed by washing. Sand washed in an agitator for 71 hours by the writer was reduced to a pale orange, the oxide films having been almost entirely removed.

Orange to red colored sands are now finding an extensive use in the manufacture of naturally tinted plasters and stucco work. Much of the sand used in Nashville for this purpose is called "cedar red" sand. It makes a tan tinted plaster which needs no refinishing. The red sands of Hardin County could probably be used in this way. The alluvial sands along the present streams have been used locally for building purposes.

Glass Sand

Certain beds in the Coffee phase of the Eutaw formation are clean white sands that are suitable for glass making. The beds and lenses of pure sand, however, are very thin and are separated by thick beds of impure sand and clay so that they are of little importance.

MOLDING SAND*

The formations in this county which are likely to contain deposits of molding sand are the Eutaw of Cretaceous age, the Quaternary terrace deposits, of which there are several patches along Tennessee River, and the recent alluvium of the Tennessee River which occurs as a nearly continuous strip on each side of it.

As there are no railroads in the county outcrops were examined only near a few of the boat landings on the river.

Opposite Pittsburg Landing, at the ferry landing seven miles southwest of Savannah. The east bank of Tennessee River is composed of a soft, grayish-brown alluvial sand of rather fine texture. The sample (No. 60) represents the upper eleven feet of the deposit, excluding six inches of sandy loam soil at the top. The bottom of the bank as sampled is ten to fifteen feet above the ordinary summer stage of the river, but the entire bank is covered at extreme high water. Below the part sampled the bank consists of material fallen down from above.

The bond of this sand is clay and varies in amount in layers several inches in thickness, but the differences are not too great to prevent thorough mixing. There is no clay separate from the sand, and no concretions.

The land along the river is owned by F. C. Williams of Corinth, Mississippi.

The results of the tests of sample (No. 60) from the eleven feet of bank below the top soil at the ferry landing opposite Pittsburg Landing, are as follows:

Lab. No. 60.

Locality.—Bank of Tennessee River directly opposite Shiloh National Cemetery, (Pittsburg Landing). Upper 11 feet of bank.

Owner.—Dr. F. C. Williams, Corinth, Miss.

Formation.—Alluvial. *Grade if used.*—Not used.

FINENESS TEST

	Screen	Percent
On	6 mesh	------
On	12 mesh	------
On	20 mesh	------
On	40 mesh	0.10
On	70 mesh	10.71
On	100 mesh	12.16
On	140 mesh	11.82
On	200 mesh	19.01
On	270 mesh	1.54
Through 270		1.26
Clay substance		43.03
	Total	99.63

*From a manuscript on molding sands of Tennessee, by J. H. C. Martens, for the Tennessee Division of Geology.

Water content percent	Bonding test	Permeability test
6.1	-------------	10.74
8.1	194.21	24.30
9.6	236.52	22.52
10.6	214.30	-------------

Near Savannah. Sand similar to that just described forms the bank of the river, but was caved in so that no representative sample could be obtained.

At Savannah and extending a few miles to the north and to the south there is a considerable area of terrace deposits. The character of the material varies widely from place to place. Gravel and sandy clay with chert pebbles are common. The only outcrops seen, which indicate a possible deposit of molding sand of sufficient size and uniformity to be worth sampling, are on land owned by Sam Williams, situated three miles north of Savannah and four miles south of Cravens Ferry, on the west side of the road between these places. The exposures are in shallow gullies along two or three abandoned roads which cross a pasture lot on the south side of a private road 400 feet west of the public road. The land slopes gently to the south.

The sample (No. 62) represents a thickness of from three to six feet, averaging about four feet, in the banks along the gullied road. No stratification could be seen and the molding sand appears to be a surface deposit which follows the topography. Four inches of top soil would have to be scraped off to remove most of the grass roots. Below this is the reddish-brown clayey sand, somewhat streaked and mottled with gray, especially in the lower part. The sand is limited below by a light gray, pebbly clay, too tough and impervious to be of any value. The boundary is not sharp, but the gradation takes place within a few inches.

This sand, or more properly sandy clay, has a strong bond and the bonding material is uniformly distributed, except that about a foot at the top is softer than the rest, probably on account of weathering. It contains a very few cherty pebbles. This deposit is not cemented, but the bond is so strong that loosening would be necessary. The deposit is at least two or three acres in extent and may be much more.

The road at the boat landing at Savannah, a distance of three miles, is passable for small motor trucks, but the steep hill going down to the river is dangerous.

The results of the tests of an average bank sample (No. 62) representing the three to five feet immediately below the top soil, are as follows:

Lab. No. 62.

Locality.—Three miles north of Savannah, Tenn. Deposit three to five feet thick.

Owner.—Sam Williams, Savannah.

Formation.—Quaternary Terrace.

Grade if used.—Not used.

FINENESS TEST

Screen		Percent
On	6	------
On	12	0.34
On	20	0.87
On	40	1.66
On	70	2.57
On	100	2.89
On	140	1.50
On	200	1.28
Through 270		1.24
Clay substance		84.66
Total		99.78

Water content percent	Bonding test	Permeability
7.3	-------------	1.98
8.7	240.66	9.10
10.1	267.15	7.16
11.9	234.65	3.76

GREENSAND

Greensands are green colored sands of marine origin which contain variable quantities of the mineral glauconite, a hydrous silicate of iron and potash. They also contain small amounts of phosphate and are valuable chiefly as fertilizer because of the potash and phosphate content. These sands may be either spread on the soil in a raw state or treated for use in commercial fertilizers. Greensands from New Jersey, which are valuable as fertilizer, contain as low as 0.09 percent P_2O_5 and 0.37 percent K_2O. Most of the commercial greensands, however, have considerably more potash and phosphoric acid than this.

Analyses of some of the greensands in the county are given below.

ANALYSES OF GREENSANDS, HARDIN COUNTY, TENNESSEE:

	(59)	(60)	(61)
Phosphates ($Ca_3(PO_4)_2$)	0.60	0.15	0.20
Potash (K_2O)	2.28	2.46	3.10

(59) Greensand on Rudolph Goodman's land half a mile south of Pittsburg Landing.

(60) Greensand from the Coffee phase of the Eutaw formation at Coffee Landing.

(61) Greensand from the Coffee phase of the Eutaw sand at Crump Landing.

The greensands occur, so far as known, exclusively in the Coffee phase of the Eutaw sand of Cretaceous age. The younger sediments in McNairy county to the west contain extensive and thick beds of greensands. They were noticed particularly along Coon Creek south of Enville, Tennessee.

At Coffee Landing five miles below Savannah on the west side of the river, beds of greensand are exposed at the water's edge during periods of low water. The beds are strongly micaceous and contain a large quantity of clay. Because of the large amount of overburden here it would probably not be feasible to mine them. An analysis of this material showed 0.15 percent of tricalcium phosphate and 2.46 percent of potash.

Similar beds are exposed near and at water level at Crump Landing. The greensand beds occur up to ten inches thick separated by impure sands and carbonaceous clays. The exposed greensands do not aggregate more than three or four feet in thickness. Picked samples showed 0.20 percent of tricalcium phosphate and 3.10 percent of potash.

A much more promising exposure of greensand occurs in the bed of a small ravine on Mr. Rudolph Goodman's land adjoining Shiloh Park half a mile south of Pittsburg Landing. Mr. Goodman reports that it is a good fertilizer when spread on the land in a raw state. Over 15 feet of dark greensand are exposed in the ravine overlying white and orange sands which outcrop at water level. The greensands are overlain by 35 to 40 feet of terrace gravels, a good portion of which are cemented by limonite. A picked sample of this material showed 0.60 percent of tricalcium phosphate and 2.28 percent of potash.

CLAY

Clay is the exceedingly fine sediment deposited by streams or the residual material resulting from deep chemical weathering, and generally contains a relatively high percentage of alumina. The chemical composition of a clay is of small value in indicating its adaptability in industry. Its value and uses are largely controlled by its physical properties such as color, plasticity, fusibility, etc. Clay is used extensively in making chinaware, pottery, tile, brick and for many other uses.

No tests have been made, so far as known, on the clays of the county and hence whether or not they are suitable for manufacture into clay products is not known. It is not thought by the writer that they will assume any importance, unless they prove especially adaptable, because of the great quantities of high grade clays in West Tennessee. Much of the clay in the county would probably prove suitable for the manufacture of common brick and tile.

The most important deposits for the manufacture of brick are the laminated clays in the Coffee phase of the Eutaw sand and the residual clays from the Ridgetop shale and some of the Paleozoic limestones. Practically all of the Selma formation of Cretaceous age is a clay, but it contains too much sand to be of any importance. The carbonaceous clays in the Coffee phase of the Eutaw also contain variable quantities of sand.

The white residual clays from the Ridgetop shale, as a general rule, are thin, limited in extent, and contain much chert or flint. The residual clays from the limestones are also rather thin and in most cases contain much limestone rubble.

The most promising clay deposits observed were the reddish brown clays, residual from the Dixon limestone, in the vicinity of Old Town and those residual from the Ridgetop shale on Mr. Andrew Abel's place at the head of Steel Creek. At no place have any prospect pits been dug so that the thickness of the deposits is not known.

The clays in the vicinity of Old Town are at least eight to ten feet thick and may be considerably thicker. The white clay residual from the Ridgetop shale, on Mr. Abel's place underlies $1\frac{1}{2}$ to 2 acres and is probably at least ten feet thick. This clay, though extremely plastic when wet and having all the physical characteristics of true clay, contains an extremely high content of silica. It might prove suitable for making fire brick. An analysis of the clay follows:

ANALYSIS OF CLAY FROM PROPERTY OF MR. ABEL:

	(62)
Silica (SiO_2)	90.12
Alumina (Al_2O_3)	6.61
Iron (Fe_2O_3)	0.62
Lime (CaO)	0.20
Magnesia (MgO)	0.06
Loss on ignition	2.34

MINERAL PIGMENTS

Mineral pigments are deposits which when finely ground in oil or gum water make paints. They are sometimes improved by the addition of other substances which change the shade or color. There are no high grade mineral pigments in the county. Some of the red clays mix well with oil and give a brownish red paint which would probably be suitable for painting iron work or rough outside work such as box cars, etc. These pigments might be considerably improved by the addition of small amounts of other pigments.

The chief deposits are the brownish-red residual clays of the Dixon limestone described under "clay" and the red clays occurring in the Eutaw sand. Experiments conducted by the writer on both of these clays were not highly satisfactory. The color was somewhat improved by roasting but even then required addition of higher grade pigments to give other than a very low grade paint.

The red clays of the Eutaw sand contain nearly everywhere far too much sand to be of any value. Specimens sent to the writer by Mr. E. H. Millegan, who lives on the Dry Creek road $4\frac{3}{4}$ miles east of Walnut Grove, proved to be the best pigment examined. The material is a brick red clay containing very little sand and mixes well with oil. Unfortunately the writer was unable to visit the locality where the clay was reported to have been found. Its extent, therefore, is not known. From the general appearance of the specimens and the general area from which they are reported to have been secured, it is very probable that they represent a particuarly clayey phase of the red Eutaw sand.

COAL AND LIGNITE

The Chattanooga black shale contains much carbonaceous matter and much of it will burn when placed on a hot fire. For this reason it is often mistaken for coal. No coal has ever been produced from this formation, notwithstanding the fact that it covers an area of several hundred thousand square miles in Tennessee and adjoining states. The black shale locally called "slate", does contain in Hardin County, thin seams of true coal one-eighth of an inch or less in thickness, which are of no economic value.

Small quantities of lignite or carbonized wood fragments occur in the Coffee phase of the Eutaw sand in the northewst section of the county This material will also burn and has been used to a small extent in blacksmith forges. In nearly all cases it contains large quantities of marcasite, a form of iron sulphide, which has replaced the woody material. The lignite generally occurs in impure beds a few inches thick. The thickest seam observed was at a small spring a short distance west of the house on Tom Johnson's land, eight-tenths of a mile north of Newman Cemetery. The seam consists of beds of lignite a few inches thick separated by layers of white and yellowish sand and is not over 3 feet in aggregate thickness. The lignite contains a great deal of marcasite and small pellets of amber.

Lignite is used to some extent in making briquettes, and in the manufacture of gas, tar, ammonium sulphate, chemicals, etc. There is not enough lignite in Hardin County to be of any importance.

OIL AND GAS

The rocks of Hardin County contain some petroleum where they are exposed at the surface. The dense limestone layers in the Ridgetop shale in some places smells strongly of petroleum. There are, however, no oil seeps or other phenomena indicating the presence of oil pools. This means little in itself since such surface indications are wholly absent in many of our greatest oil fields.

In general there are certan definite conditions which must be satisfied before oil or gas pools of any size may exist. These may be classified as:

1. Source of the oil and gas.

2. Porous beds to serve as reservoirs, capped and underlain by relatively impervious beds.

3. Suitable structures in the bed rock to serve as collecting grounds.

The source of oil is generally considered to be the organic matter furnished by the bodies of dead animals and plants. These bodies settling to the sea floor are covered by sediments and their organic content preserved in the sediment. During deep burial or structural distortion the head and pressure produced cause a distillation of the buried material which then collects in the pore spaces of the rock as oil or gas and under suitable conditions may migrate into so-called oil "pools".

A great many of the rocks in the county are fossiliferous, and show evidence of having once contained large numbers of dead bodies. We have, therefore, a possible source of oil.

The proper structures are also present in the form of low domes and anticlines of sufficient dip and area to impound large quantities of oil. The folds are generally gentle, having an average dip of only two to three degrees or less. Such folds are described above in the section on *Structure*.

There are also beds porous enough to serve as reservoirs which are capped by impervious beds but they are very thin as a general rule. These include the crystalline limestones and the Hardin sandstone. All of the formations from the middle Ordovician up to and including the Cretaceous are, however, found outcropping at many places in the county Some of these beds probably contained oil at one time but because they outcrop at the surface in so many places, their original oil content has long ago escaped. The beds older than the Hermitage limestone of Ordovician age do not outcrop in the county. At other places these older rocks are mostly dense limestones of low porosity and are therefore not good reservoirs. Any oil they may contain is probably held in joints and fissures.

The conditions in Hardin County are much the same as in Wayne County where several prospect wells have been bored and small showings of oil and gas encountered. No producing wells, however, have been brought in. So far as known, no wells have been drilled in Hardin County. It is the writer's opinion that no oil pools of commercial extent occur here though small showings would probably be found in drilling. It would be unfair, however, to condemn this area in the absence of test holes.

The three best chances of finding oil, if it exists in quantity, are:

1. In the rocks below the Hermitage limestone and shale, particularly if they should prove to be much jointed and fissured. Test wells should be located on domes or upwarps described in the section on structure. The domes in the vicinity of Russell and of Willoughby Creek should prove the best locations for testing the limestones that underlie the Hermitage formation.

2. In the Hermitage limestone and shale of Ordovician age or in the beds directly over or under it. Locations for wells to test this horizon should be made on folds, the exposed centers of which show rocks of Silurian or younger age. Such folds occur at Lowryville, White's Creek, Roger's Creek, Horse Creek, near the mouth of Germany Branch, Turkey Creek in the vicinity of Burnt Church, Dry Creek, Pyburn Bluff, and Smith's Fork. Drilling on these domes should proceed down to the Hermitage at least and preferably through it.

3. In the Paleozoic rocks particularly the Mississippian shales and sandstones which are buried under the loose Cretaceous and terrace sediments in the west part of the county. Locations for test wells in this area cannot be made with any accuracy. Tests would have to be of a strictly "wildcat" nature until sufficient wells had been drilled to map the buried structure Wells drilled in this area should go through the black shale, of the Chattanooga formation. A dry well in this part of the county should not prove discouraging until the structure is known.

It is from rocks of the Carboniferous period, of which the Mississippian is a part, that the gas comes in northeastern Mississippi near Amory. There these rocks are buried many hundreds of feet, but at no place in Hardin County is the hard rock floor more than 300 to 400 feet below the surface. Wells located on the stream bottoms in the west part of the county should strike hard rock at a depth much less than that—probably in most cases less than 100 feet.

It should be borne in mind by anyone starting to prospect for oil or gas in Hardin County that the chances for success are slight.

The boiling or bubbling springs in the county and the "boils" in the river bottoms after high floods have no sifnificance in indicating the presence of oil or gas.

Both the Chattanooga black shale and the Ridgetop shale contain considerable quantities of bituminous material. This was well illustrated by the spontaneous combustion of a pile of the black shale in the river above Hamburg in 1915 which burned for nearly two months. This would indicate a rather high content of oil and bituminous material. The black shale almost always contains some oil and gas that may be distilled off in retorts. It has not, however, so far as the writer is aware, ever been utilized successfully as an oil shale.

Oil shales at the present time are not considered profitable for the extraction of petroleum in the United States though they may at some future time become important.

CHAPTER IV
OTHER RESOURCES
WATER

This section of Tennessee receives about 50 inches of rainfall a year and where there are suitable reservoirs, water is abundant. The extremely porous Cretaceous sediments and the terrace gravels of Pleistocene age act as large sponges which absorb the rainfall and gradually permit it to emerge as springs. Many of the limestones are cut by large numbers of ramifying channels as shown by the presence of caves and some large springs. The porous, weathered cherts of the Fort Payne and Warsaw formations are also suitable for reservoirs. The lower contact of these porous rocks where they rest on impervious beds is almost always marked by a line of springs of variable size.

The water issuing from the limestones is generally hard and not well suited for washing and drinking purposes. It contains a considerable quantity of carbonates in solution. The water coming from or contained in the siliceous cherts of Mississippian age, the quartz sands of Cretaceous age, or in the porous terrace gravels is in general "freestone" water, that is, the proporton of dissolved carbonates is relatively low. Most of this water is excellent for drinking purposes or other uses. Some of it is high in dissolved iron salts. A few springs contain considerable sulphur, for instance, Sulphur Well near Saltillo, Sulphur Spring on the Ross farm on Horse Creek, and White Sulphur and Red Sulphur Springs in the south part of the county. Three of these springs and possibly the fourth issue from limestone or shale.

The springs issuing from the limestones, as for example the big spring near Paulk's store at Walnut Grove, may be dangerous for drinking purposes as they are apt to be contaminated by surface drainage. Practically all the springs issuing from the cherts, sands, or gravels are good for drinking purposes.

The water supply for all the towns and private homes in the county, where not obtained from springs, is obtained from wells. At no place in the county are these wells more than 100 feet deep and most of them are 50 feet or less. In the extreme northwest corner of the county a few wells are 80 to 100 feet deep. These are sunk through the Selma clay, which carries little or no water, to the porous Eutaw sands underneath.

The amount of water in the terrace gravels is very great and sufficient to supply the needs of much larger communities than will exist in the near future. Several wells in the town of Savannah cannot be pumped dry by the small pumps employed. Water is struck in the gravels at a depth of from 35 to 40 feet. Similar abundant water supplies would also be encounted in the Cretaceous sands and gravels and in the porous Mississippian cherts. There is also water enough in the larger creeks for any washing which might be necessary in the development of the mineral resources of the county.

No flowing wells may be expected in Hardin County.

WATER POWER

BY WARREN R. KING

INTRODUCTION

This examination was made by the writer and Mr. Penn P. Livingston, assistant engineer, during the early part of June, 1928, lasting about a week. During the first two days out, owing to almost continuous rain, rivers and streams were at almost bankfull stage. They did not remain long at this high stage, although they were considerably above normal during the entire period. No very intelligent idea could be obtained as to the low water discharge which is the most important factor in determining the water power possibilities of streams of this character. A later trip was made during August, by Mr. Warren Withee and additional discharge measurements were made which show nearly the average yield during the summer or low water season. His results, together with those obtained in June, are the basis for this reconnaissance report. Funds were not available for any appreciable amount of field work in connection with the investigation and there being no topographic map of the area from which elevations and drainage areas can be determined, this report is necessarily of a most preliminary nature. Notwithstanding these unfavorable conditions and the speed with which the examination was accomplished, every part of the county was covered and all streams of consequence were studied, so that, in the main, the conclusions that are reached are not far from representing the actual facts.

All of Hardin County lies in the Tennessee River basin. Tennessee River enters Hardin County near the center of the southern boundary and flowing in a northerly direction to the northern boundary of the county, it turns easterly and forms the boundary between Decatur and Hardin County leaving the county at its northeast corner, near Clifton. The remaining important streams of the county include Chambers, Lick, Snake and White Oak Creeks, which enter Tennessee River from the West and Mud, Horse, Indian and Hardin Creeks, which are tributary from the east. These will each be discussed separately in the order named.

TENNESSEE RIVER

It would doubtless prove uneconomical to build an hydroelectric plant on Tennessee River for a head of much less than 40 feet. There are many economic considerations which govern and determine the feasibility of such developments; namely, the physical characteristics of the dam site and reservoir; foundation condition; cost and extent of overflow lands; transportational facilities; damage to highways, railways, homes, towns and villages; the location with respect to suitable market or to existing and proposed transmission lines, and many other factors equally important.

During the last few years the United States Army Engineer Corps has made a thorough and extensive survey of the entire Tennessee River and its principal tributaries, with a view to determining the extent of its power and navigation resources and of laying out a systematic scheme of development that will lead to the fullest utilization of the entire river system They have prepared detailed maps of the entire river valley, including that stretch lying in Hardin County, and have selected tentative dam sites for the future development of electric power and for navigation improvement. One plan proposes a power-navigation dam in Hardin County at Pickwick Landing, which is located about eight miles north of the state line and about 18 miles by river south of Savannah.

The dam at this site would back Tennessee River up to Wilson Dam at Florence, Ala., creating a pool 70 miles long and developing a head at the dam of 56 feet. A double lock for navigation is proposed, together with a power house having an installed capacity of 402,000 Kilowatts or 540,000 horsepower. This capacity appears to be too high for economic installation as it could be fully utilized only about 12 percent of the time. A capacity of 375,000 horsepower which could be fully utilized 25 percent of the time, or 3 months in the average year, would be more nearly adequate. This dam site has been carefully examined both as to surface features and to foundation, and on the whole, it is said to be very satisfactory for a large development. The reservoir created would submerge approximately 39,000 acres of land, and the total cost of the development, including locks, power house, dam and all accessory equipment is estimated to be about $50,000,000.

Alternate sites have been chosen at other points upstream and only recently the Federal Power Commission granted a preliminary permit to the Mississippi Power Company for a proposed power dam below Riverton, Alabama, and south of the Tennessee line. The Permittee in this case is required to prepare cost estimates and other data to show that the site they have chosen is better adapted to the utilization of this stretch of Tennessee River than the site at Pickwick Landing. At the present time it is impossible to state which of these sites, if either, will finally be adopted for the location of this proposed development. In case the Pickwick Landing site is adopted, Hardin County and the State of Tennessee will have the full benefit of this huge development, but if the upper site is approved and the dam is built outside the state, it would of course preclude the installation of any other power dams on Tennessee River within the limits of Hardin County. From a practical viewpoint, therefore, two things may result; whether Hardin County will have a very large development on Tennessee River or none at all, depending on which location is adopted for the project now under permit.

To summarize, we might state that on Tennessee River Hardin County possesses one undeveloped site for a dam which might be utilized to develop the entire fall of the river below Wilson Dam and provide a possible economic capacity of nearly half a million horsepower.

Figure No. 3 shows a daily duration curve for Tennessee River at Savannah, Tennessee, based upon 33 years of records. The total drainage area of Tennessee River above Pickwick Landing is approximately 34,000 square miles, hence, the mean flow would be about 58,000 cubic feet per second and the minimum discharge would be about 8,500 cubic feet per second.

Chambers Creek

Chambers Creek heads in McNairy County, Tennessee, flows south across the northern part of Alcorn County, Mississippi, thence in a northeasterly direction across the southwestern corner of Hardin County to join Tennessee River at a point about two miles south of Hamburg. It traverses Hardin County for a distance of six miles and has a drainage area at its mouth of about 80 square miles. The elevation of the dividing ridge at the head of this creek is approximately 600 feet above mean sea level and that of Tennessee River is approximately 350 feet, making a total drop from the divide to the mouth of about 250 feet. The banks are low throughout its length, usually less than 10 feet, and the stream flows through an alluvial valley having an average width of more than half a mile. Near the state line the stream divides into the Right and Left Forks. A drainage canal has been dug along the Right Fork for several miles but the remainder of the stream is still in its natural condition. The stream elevation at the state line is approximately 400 feet above sea level so that at times of low water in Tennessee River there is approximately 50 feet fall between this point and Tennessee River. The river at this point, however, has a range of stage of nearly 40 feet so that at times of high water much of the Chambers Creek Valley in Hardin County is flooded. The stream at low water has a discharge of not more than 20 cubic feet per second. There are no rock shoals or rapids that would afford suitable dam foundation.

In conclusion, it may be safely said that this stream offers no opportunity for the practical development of hydroelectric power, even in a small way.

Lick Creek

The valley of Lick Creek is similar in all respects to Chambers Creek which we have just described, except that Lick Creek is very much smaller, having a drainage area of only about 30 square miles, as against 80 square miles for Chambers Creek. The stream bed has a fall of between five and ten feet and the valley has an average width of nearly half a mile. The valley is fertile and is highly cultivated. A drainage canal has been dug the full length of the valley in Hardin County and extending beyond this several miles into McNairy County. The entire flow of the stream is carried by the canal during ordinary stages. The canal has a width of about 10 feet near the upper end and about 20 feet near the lower end, and the water flows with good velocity. The valley is flooded occasionally by backwater from Tennessee River. The discharge of the Creek during low water is less than 10 cubic feet per second. This offers no opportunity for the practical development of hydroelectric power.

Snake Creek

Snake Creek heads in McNairy County and follows a westerly course emptying into Tennessee River about a half mile below Pittsburg Landing. The drainage area at its mouth is about 90 square miles. In its physiographic features the water shed is similar to that of Lick Creek. Most of the land in the basin except that which lies within the Shiloh National Park is farmed and has a rather high agricultural value.

The Creek valley is wide and the banks are very low. In its natural state the creek follows a meandering, tortuous course but the main fork has been provided with a drainage ditch which carries all of the water except during heavy rains and freshets. This drainage canal and the floor of the valley has a general slope of about ten feet to the mile. There are no suitable sites for dams on account of the low earth banks and the extremely wide valley.

The principal tributary of Snake Creek is Owl Creek which joins the former about two miles from its mouth. This creek is still in its natural state and is too small to be of any consequence for power purposes. The lower end of this stream is within the boundaries of Shiloh National Park.

High water in Tennessee River backs up in these valleys for a distance of several miles and in conclusion, it may be safely stated that neither Snake Creek nor Owl Creek offer any opportunity for development of hydroelectric power even in a small way.

Hurricane Creek

This stream is locally known as White Oak Creek. Its several forks head in Henderson, Chester and McNairy counties and flow in a southeasterly direction across the northwest corner of Hardin County to join the Tennessee River two miles upstream from Saltillo. It is the largest creek in the western part of the county, draining an area of about 150 square miles. The basin is fan-shaped and is drained by numerous lateral streams, most of which have been replaced by drainage canals extending well up to the head. These canals converge with the main stream about five or six miles above its mouth and the main stream below that point is still in its natural condition.

This stream, toward the lower end, differs from the others on the west side in that there is a high bluff on one side and a medium high bank on the other, affording a fairly good site for a power dam 30 to 40 feet high. The best site for such a dam appears to be about 100 feet upstream from the state highway bridge, on the Saltillo-Savannah road, two miles south of Saltillo. The right bank here is steep and rises abruptly to a height of 75 to 100 feet, the channel is narrow (less than 100 feet) and the left bank is about 30 or 35 feet high rising thence gradually to higher ground a mile or so back from the stream. A dam and power house might be constructed in the present channel and a spillway provided at a small ravine, about a quarter of a mile away on the left side. No account was taken of foundation conditions and it may be that these would be such as to destroy the site even though it were otherwise a feasible project which is extremely doubtful.

The great drawback to this as a power site is the very large amount of land that would be overflowed by such a dam. The surface of the stream at the site at low water is about 345 feet above mean sea level and if a dam were built raising the water 30 feet to an elevation of 375 feet it would submerge approximately ten square miles of land or about 6,500 acres. Nearly all of this land was originally swamp but it is now provided with drainage ditches which render it useful for pasture and probably for certain kinds of crops. No idea was gained as to the value of this land but at only $25.00 per acre the total cost of the land would be $160,000 which is more than the power project would be worth.

As to the power possibilities at this site, the immense reservoir, which would be seven miles long and from one to two miles wide, would create a very large amount of usable storage which could be used to equalize the stream flow so that instead of having a low water discharge of only about 30 cubic feet per second this might be released in such a way as to yield a minimum flow of 100 cubic feet per second and perhaps more. For the sake of arriving at some definite figures, let us assume that a dam is built at the site mentioned raising the water level 30 feet and that the upper five feet of this reservoir is used as live storage to supplement the low water flow. This upper five feet would contain 25,000 acre-feet of water which would be sufficient in the average year to maintain a minimum of 100 cubic feet per second. The average head at the power house would be only about 25 feet and the resulting power output would be 250 horsepower continuously, or figured on a basis of 50 per cent load factor, the output would be 500 horsepower. With the enormous quantity of water in storage, a plant might of course be designed to develop a much greater quantity for relatively short periods by turning more water through it, but for continuous operation it would develop only 250 horsepower. If we assume that this power is worth only $40.00 per horsepower per year, over and above operating expenses, the value of the power generated would be $10,000 per year, which, capitalized at 10 per cent would show the value of the development to be about $100,000. In other words, this amount might reasonably be expended on the project. The value of the land alone would doubtless exceed this figure leaving nothing for the construction of the dam, power house, equipment and accessories. This would seem to indicate that the project would not be an attractive investment.

If this plant with its large storage and relatively large peak carrying capacity were interconnected with other plants not having storage it is possible that its value as a peak load plant might justify its cost, but standing alone on its own merits as an isolated development it is certainly not a feasible proposition at this time, and probably will not be for many years to come.

At times of high water on Tennessee River the head on the plant at this site would be materially reduced by backwater and the power output would be reduced accordingly.

Mud Creek

Mud Creek is a small stream lying almost wholly in the Tennessee River bottom. It has a drainage area of about 20 square miles, all of which is agricultural land. The slope of the stream is flat and the banks are low. It offers no opportunity for development of power even in a small way and need not be considered further in that connection.

Horse Creek

Horse Creek drains a larger part of Hardin County than does any of the other streams. It heads in Wayne County but 90 per cent of its drainage area of 200 square miles lies in Hardin County through which it flows for a distance of 30 miles. The principal tributaries of Horse Creek are Whites Creek, Rogers Creek, Hollands Creek and Turkey Creek, the last with a drainage area of about 50 square miles, being the largest.

The crest of the dividing ridge at the head of Horse Creek has an elevation between 800 and 900 feet above sea level and where the creek crosses the county line its elevation is about 650 feet above sea level. Four miles downstream from this point and one mile below the entrance of Germany Creek is Gillises Mill Post Office. This mill was abandoned years ago as have been all other mills on the stream. The elevation at this point is approximately 600 feet above sea level. The low water elevation of Tennessee River at the mouth of Horse Creek is about 350 feet so that between Gillises Mill and the mouth, a distance of 25 miles, the stream has a fall of about 250 feet, or an average of ten feet to the mile. Near the lower end the slope is only about four feet per mile. Near the head waters the slope increases to about 25 feet per mile.

Above White's Creek the stream is too small to provide any appreciable amount of water power for the reason that it would almost go dry during periods of drouth. The low water flow from this part of the stream might be as much as ten cubic feet per second, which under a 12-foot head would produce about 10 horsepower; enough to drive an average grist mill and to furnish enough electricity for a small community of a dozen or more homes, but not enough to transmit any appreciable distance; a mile or so would be the limit of practicability. There is perhaps some field for small water power developments for community service but usually the cost is so high as to place them in the class of a luxury which the average small farming community cannot afford.

Two old grist mills on Horse Creek were visited: these are Ross' Mill and Paulk's Mill. Both of these have long since been abandoned, the dams are washed out and the buildings wholly or partially collapsed. These give evidence of the fact that the old-fashioned water power mill is a thing of the past, much to our disappointment and much to the regret of all of us who have sentimental recollections about "the old mill dam". They have very largely given way to more modern methods and more modern machinery for accomplishing the same purpose.

Horse Creek has a wide overflow bottom on one side or the other or on both sides for almost its full length. In our search for a suitable dam site we found no place where there were high banks on both sides. Ordinarily, the banks of the main channel are only five to eight feet high and the bottom land from a quarter to half a mile wide. There is no place below Hollands Creek where the creek valley is less than 1,000 feet wide. Rock bluffs on one side or the other may be found at a number of places and it is probable that a suitable foundation could be found for dams of medium height. The channel varies in width from 30 to 75 feet with an average width of about 50 feet below Hollands Creek.

The creek bottom lands are by far the most valuable in the county and it is not at all likely that it would pay to erect a high dam that would submerge a great deal of this land. The valley is so wide and the flood discharge of the stream is so great that a dam with a spillway of sufficient size to accommodate the floods would necessarily be very expensive. Theoretically, this stream could produce a considerable amount of power but it is doubtful if it would prove at all practical of development.

There are two ways in which this stream could be utilized for production of power; one would be by a series of low dams and small plants built wholly within the banks, which would require the purchase of little or no overflow land and which would allow the passage of floods unobstructed as at present. Such dams would be limited to eight or at most ten feet in height and in times of extreme high water would be drowned out. Complete development by this method would require twenty-five or more small dams and power plants. The plants furthest downstream could generate 50 to 60 horse power at low water, the others would produce relatively smaller amounts until near the head at Gillises Mill, not more than 10 horsepower could be made available with a 10-foot dam. With a stream fully developed by this method it would be possible to develop as much as 800 to 1,000 horsepower during low water, and correspondingly larger amounts during the remainder of the year except during the very high water when the head would be materially reduced or totally eliminated.

The other method would be by a series of high dams 30 to 60 feet in height. Such dams as previously explained would submerge a large area of valuable bottom lands and would require spillway adequate for carrying floods. Five dams with an average height of 50 feet would utilize all available fall and an average of 200 horsepower could be generated during low water or approximately 1,000 horsepower all told. This method is the least practical.

There is one possibility that might be mentioned and that is the construction of a 60-foot dam on the Blount farm, or Williams farm near Cain Branch, about eight miles southeast of Savannah. Here the river flows against the left bank which is a steep solid rock bluff 60 feet high. The stream is about 50 feet wide and the right bank is only about eight feet high. The bottom land on the right bank is about 600 to 800 feet wide, so that a dam 60 feet high would be about 1,000 feet long on the crest. The average slope here is about eight feet per mile and the dam would back the stream up to near White's Creek creating a reservoir seven or eight miles long and averaging about a quarter of a mile wide. It would submerge at least 1,000 acres of bottom land. The upper 10 or 20 feet of this reservoir might be used for regulating the stream flow and to increase the quantity of water and power available at low water. This dam would raise the water level to about 500 feet above sea level. The lake would extend well up Cain Branch and from here a short tunnel could carry the water through to the north bank of Tennessee River which is 350 feet above sea level. Thus by the construction of a 60-foot dam across Horse Creek and diverting this stream through the ridge to Tennessee River a total head of 150 feet could be created. The reservoir would serve to regulate the stream flow to a minimum of 75 cubic feet per second with the resulting minimum output of 1,000 horsepower developed all at one site. This is more power than could be derived through any other method of development. The practicability of this scheme would depend on the cost of overflowed lands, cost of the dam and power house and upon the legality feature of diverting Horse Creek from its natural channel. Naturally, if the last method were made use of it would preclude the future development of any other water power projects on Horse Creek below the Blount farm or wherever the diversion dam is located.

Turkey Creek. Turkey Creek, the largest tributary of Horse Creek enters the latter about four miles above its mouth. It has a drainage area of about 30 square miles. In all essential respects it is similar to Horse Creek except that it is much smaller. The creek channel is small; only 10 or 15 feet wide and the valley is several hundred feet wide. The stream has a gradual slope which is fairly steep approximately 10 feet per mile, and has a low water flow of about 10 cubic feet per second. This flow is too small for any practical development of water power except perhaps for small community service for a dozen houses or so at a single site.

In conclusion, it might be said of Horse Creek, that it does possess a considerable amount of potential power, probably around 2,000 horsepower figured on a load factor of 50 per cent and that all or part of this might at some time prove practical of development. At the present time, however, it is believed that there is not sufficient market for power in this region to warrant any major project on this stream.

Indian Creek

Indian Creek is similar to Horse Creek in many respects. It drains much the same character of country and the streams have about the same slope. The valleys in both cases are wide although in general Indian Creek has less bottom land than Horse Creek. There is a noticeable difference in the character of the channel of the two streams. Generally speaking, Horse Creek is rather deep and narrow while Indian Creek is wide and shallow. The bed of Indian Creek is composed of small gravel while Horse Creek is a series of deep pools and rock or boulder shoals. The drainage area of the two streams is nearly the same, about 200 square miles, although Horse Creek appears to have somewhat the greater flow during the low water season.

Indian Creek rises in the high ridge land in Wayne County and flows in a northwesterly direction to its junction with Tennessee River, about two miles below Saltillo. Two-thirds of the drainage area is in Wayne County and one-third in Hardin County. The elevation of the dividing ridge at the head is about 1,000 feet above sea level. The descent of the head waters is very steep, about 400 feet in the first five miles. Below this point the slope is somewhat more gradual, falling only 100 feet in the next six miles down to the mouth of Weatherford Creek, which is about two miles above the Hardin County line. The elevation of the stream at the Hardin County line is about 480 feet above mean sea level. From this point it flows through Hardin County a distance of 20 miles, the total fall in this stretch being about 140 feet, or an average of seven feet per mile.

Near the lower end, the slope is about four feet per mile and near the county line it is about 10 feet per mile. There are no abrupt falls or steep rapids in Hardin County, the slope being quite uniform. There are no drainage canals.

In the opinion of the writer Indian Creek offers the best opportunity of any stream in the County for the development of water power, and possibly this stream is worthy of more careful investigation in that respect. Damage to farm lands due to the building of high dams would be much less than on Horse Creek or any of the streams on the west side. A large portion of the potential power, however, is in Wayne County. From our very short reconnaissance there appears to be two or three possibilities worthy of consideration, when, and if, the market for power is sufficient to warrant further developments in this region. These will be discussed in order, proceeding downstream from the point about one mile above the Hardin County line.

There appears to be a fair dam site for a dam 60 or 70 feet high, about half a mile below the mouth of Weatherford Creek. Here the hills come fairly close together and the valley spreads out above so as to afford a large reservoir area. Such a dam would back the water up Indian Creek for about six miles and about four miles up Weatherford Creek, creating a lake of about four square miles or approximately 2,500 acres. The drainage area above this point is about 140 square miles and the average annual run-off is about 200 cubic feet per second. The minimum discharge is around 30 feet per second. If the dam were built 70 feet high, the upper 20 feet of the reservoir would contain approximately 50,000 acre-feet of water which by proper operation would probably be sufficient to maintain a minimum flow of 100 cubic feet per second throughout the year. This flow would be sufficient to generate 500 horsepower continuously or 1,000 horsepower on the basis of a 50 per cent load factor at the one dam. At the same time, this stored water would be available at any and all other power plants that might later be installed below. Storage on streams of this character is practically a necessity for the ceonomic development of water power. With this storage reservoir created, the stored water could be used through a total head of nearly 200 feet at several dams between this point and the Tennessee River and with this head completely developed, approximately 2,000 horsepower could be generated continuously or 4,000 horsepower on a basis of 50 per cent load factor. This project, therefore, should be considered a part of any development program for the generation of power on Indian Creek.

Considered alone, this project would probably not prove to be economical on account of the large area of overflowed land, but taken as a part of the general scheme it appears to have some merit. Taking the value of the power generated as $40.00 per horsepower per year over and above operating costs, the value of the power would be about $20,000 per year and the project would apparently warrant an investment of around $200,000. The overflowed land would probably cost at least $100,000, leaving about $100,000 for the construction of dam, power house, machinery and transmission lines. This project by itself would not be feasible and a more thorough analysis would be necessary to show whether or not it would pay as a part of the complete development. This project would be entirely in Wayne County but its development would be necessary to make other plants downstream in Hardin County at all feasible.

The second site which appears to have merit, particularly with storage developed at the site mentioned above, is at Olive Hill. Here there is a good natural site for a dam about 40 feet in height and the project might prove economical if land damages were not too high. The channel is only 100 feet wide and the bed and banks are solid rock. State Highway No. 15 crosses on a concrete arch bridge at this point. About 50 feet above the bridge is the remains of an old grist mill and dam. The dam was a timber structure about six feet high and is now washed out at one side.

The left bank consists of a solid rock hill or mound and during high water a large part of the flow passes around the left side mound, this overflow channel being about 400 feet wide. The proper development of this project would appear to require the power house to be built in the main channel and the spillway to be in the overflow channel.

The low water flow at this point is only about 30 cubic feet per second and without storage there would be only about 100 horsepower available continuously at low water with a 40-foot dam. In all probability this would not be an economical development without the storage dam above. However, with that regulation there would be about 400 horsepower available continuously at low water or 800 horsepower figured on 50 per cent load factor. Under this condition the project would doubtless be attractive. This site is, I believe, the best in the entire county and is worthy of further investigation. It would back water up to the county line, utilizing the entire fall in that stretch of river.

The third site proposed for a power dam is immediately below the mouth of Smith Fork. This site is not so good because of the wide bottom land on one side of the stream. It is possible, however, that an earth dam could be built across most of this at a moderate cost and only the spillway and power house sections would need to be of masonry. The flow here is about 15 per cent greater than at Olive Hill due to the addition of Smith Fork. This project is similar to the one at Olive Hill in that its feasibility will depend largely upon creating of storage at the upper dam. The height of this dam in order to use the available fall below Olive Hill would be about 50 feet, and the power that could be generated at low water without storage would be about 175 horsepower, while, with the large storage above, it could generate more than 500 horsepower continuously or 1,000 horsepower on the basis of 50 per cent factor. This project would have a considerable amount of usable storage of its own which would serve to further increase the amount of promary power available.

On the whole, these three developments worked in combination with each other would appear to offer a good source of power, sufficient for the needs of this region for some years to come. The big problem at this time, however, is a market for the power that might be developed. Without this, they could not be successful. There is still some fall available below this lower development but there is probably no suitable dam site and also the damage to overflowed agricultural lands would be so heavy as to eliminate the possible use for power purposes. Then again the head on a lower plant would frequently be reduced by high water in Tennessee River which has a range of stage of about 30 feet. The three developments previously described appear to offer the only opportunities for power development on this stream worthy of consideration.

Smith Fork, the largest tributary of Indian Creek, lies entirely in Hardin County. It has a very steep slope, averaging about 15 feet per mile, but due to its small drainage area it goes almost dry during periods of drouth. It is too small for consideration in connection with water power development.

Hardin Creek

Hardin Creek rises in Wayne County and flows west to the Hardin County line; thence northwest across the northeastern corner of Hardin County, a distance of about eight miles to its junction with Tennessee River. This stream heads in the ridge near Waynesboro at an elevation somewhat lower than Indian Creek. Generally speaking, the water shed is not so steep as that of Indian Creek. The drainage area of Hardin Creek at the mouth is about 135 square miles, of which approximately 100 square miles lies in Wayne County. The valley of Hardin Creek is rather wide and straight. The stream bed is composed of gravel and the banks are very low. The stream has a steep slope, averaging about 10 feet per mile. It is subject to violent freshets immediately after heavy rain and in general these rains have a very quick run-off so that in dry weather the flow gets very low. The flow at the mouth during dry seasons probably does not exceed 25 cubic feet per second.

The stream has a fall of about 60 feet through Hardin County. There are no dam sites worthy of consideration either in Wayne County or in Hardin County and in view of the low flow during dry weather and in the absence of suitable reservoir sites for equalizing the stream flow it is believed that it may be safely said, the stream possesses no water power that can be economically developed. Back-water from Tennessee River during high water extends up Hardin Creek a distance of at least four miles or nearly half way to the county line.

Eagle Creek, the principal tributary of Hardin Creek, possesses the same characteristics as the main stream and is too small for consideration in the matter of hydroelectric development.

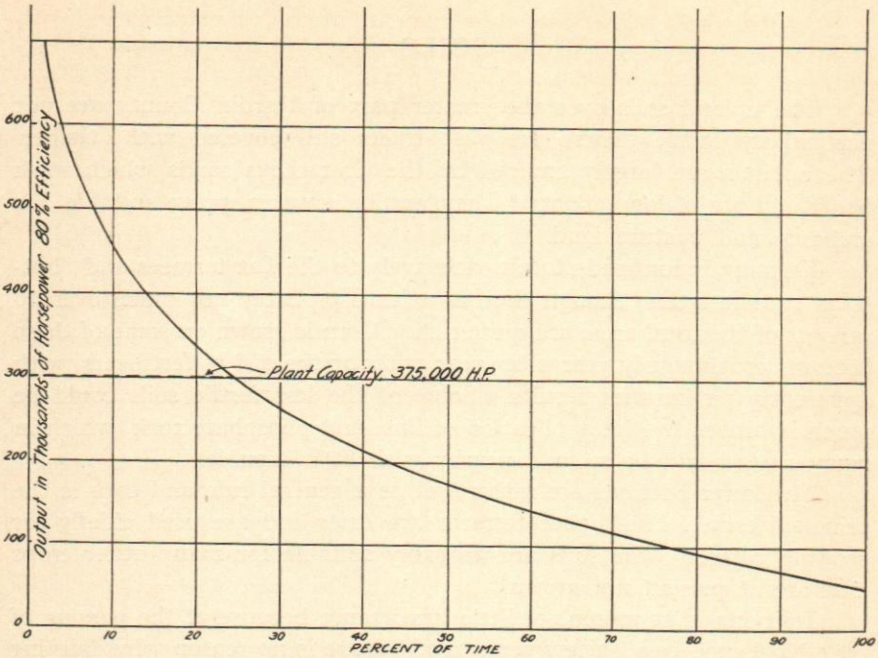

FIGURE 2—Tennessee River at Pickwick Landing, power output curve.

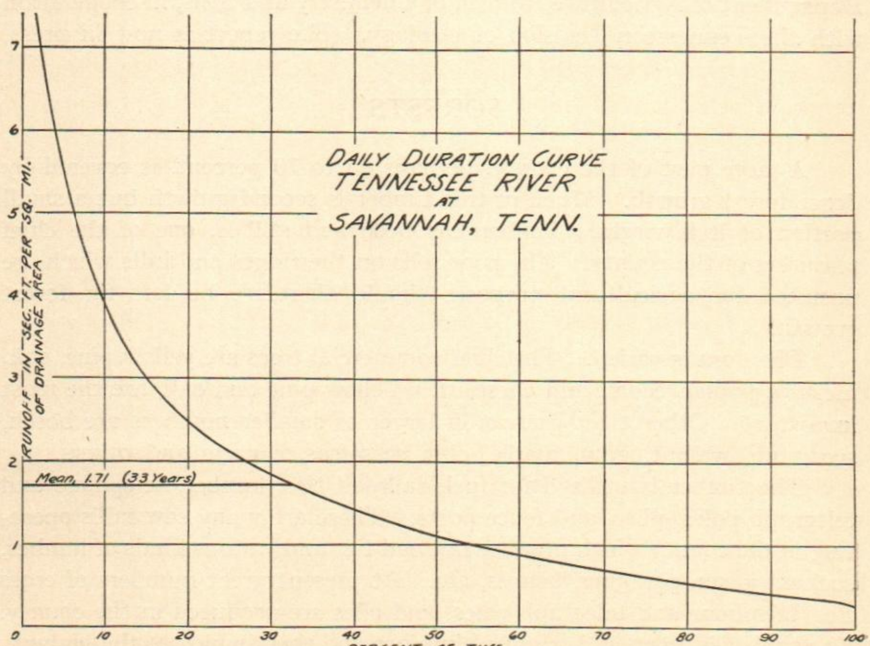

FIGURE 3.

SOILS

The upland soils over the greater part of Hardin County are not particularly fertile There are vast tracts still covered with timber. The uplands are largely covered by the Cretaceous sands which wash badly and are of low fertility They would, however, prove suitable for orchards and pasture land.

Farming is confined almost exclusively to the flat terraces and "bottoms". The latter, though they constitute probably not much over 10 percent of the total area, are quite rich. Corn is grown on some of these bottoms continuously year after year without the aid of fertilizers, with apparently no harmful results. Some of the less fertile soils could be much improved by the application of lime and phosphate rock, which in many cases could be secured nearby with little trouble.

The lower bottoms are rather wet as a general rule and corn is the principal crop. The higher terraces are drier and are used chiefly for growing cotton. The soils are probably suitable for many other crops that are at present not grown.

Dairying is at present of little importance because of the passing of the "No Fence Law" a few years ago. There is no reason why dairying should not be much more important in the future.

A complete soil survey has been made of the county by the U. S. Department of Agriculture, Bureau of Chemistry and Soils, in cooperation with the Tennessean Division of Geology. The report is now in press.

FORESTS

A large part of the county, perhaps 65 to 70 percent, is covered by dense forest growth. Much of this timber is second growth but a small portion of it is virgin. Timber has been and still is, one of the chief resources of the county. The poor soils on the ridges and hills which are unsuited for agricultural purposes should therefore be left for forest growth.

The flora is varied. The chief commercial trees are yellow pine, oak, hickory, poplar, cedar, and chestnut. Yellow pine and oak, are the most important. Other trees present in larger or smaller numbers are beech, sycamore, walnut, gum, maple, elm, sassafras, cypress and others.

The timber is utilized for fuel, railroad ties, lumber, telephone and telegraph poles, piles, and fence posts. There are many saw mills operating in the county which produce railroad ties and various kinds of lumber, such as joists, planking, boards, etc. At present great numbers of cross ties, telephone and telegraph poles, and piles are produced in the county. The timber is felled and trimmed in place and then hauled to the highway by teams and trucks. There is also one short logging railroad operating with gasoline locomotive and somewhat over a mile of track. It is planned to extend the logging railroad in the near future.

Many of the poles and ties are hauled by truck to Savannah where they are loaded on barges and shipped down the river to treating plants but many are also hauled to other landings along Tennessee River.

The yellow pine is largely confined to ridges and "flatwoods" underlain by Cretaceous sands. The siliceous soils on the ridges capped by Fort Payne chert in the northeast corner of the county seem unsuited for yellow pine. In that section pine is rare or absent, its place being taken by oak, hickory, and other hardwoods.

Some timber has been burned over especially in the southeast part of the county. In spite of the humid climate the woods get very dry in the late summer and early fall and forest fires at that time are hard to control.

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Numbers in italics refer to illustrations.