DESCRIPTION OF THE BESSEMER AND VANDIVER QUADRANGLES

By Charles Butts

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

The Bessemer and Vandiver quadrangles, which are called in this folio the Bessemer–Vandiver area, are in Jefferson and Shelby counties in the north-central part of Alabama. (See fig. 1.) The area is bounded by parallels 33° 15′ and 33° 30′ and meridians 86° 30′ and 87°. It covers one-eighth of a square degree and has an area of 498 square miles. The area was surveyed in cooperation with the Geological Survey of Alabama.

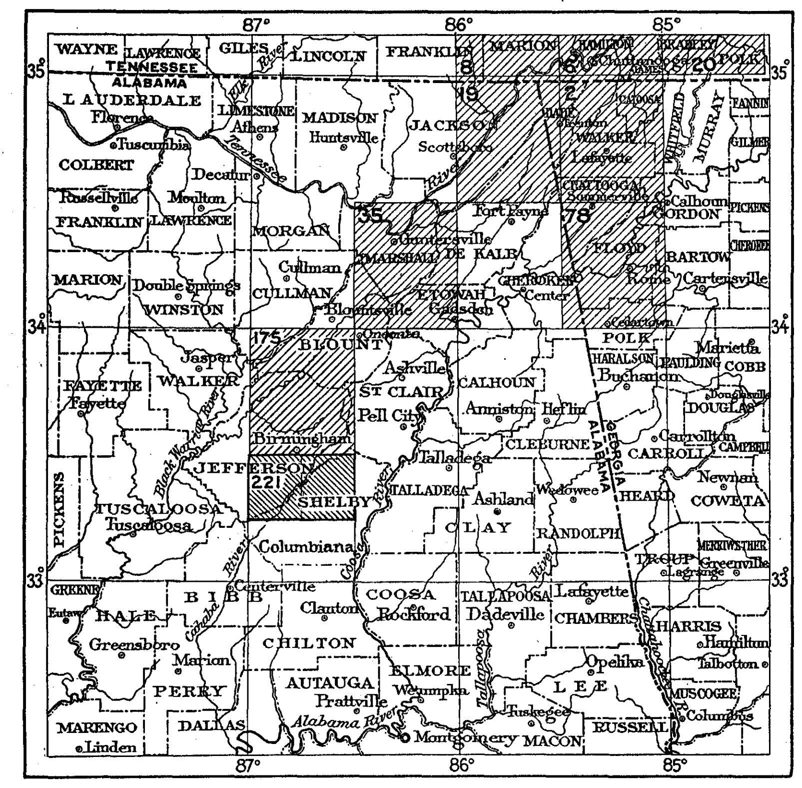

Figure 1.—Index map of northeastern Alabama and portions of adjacent States

The location of the Bessemer and Vandiver quadrangles, covered by Folio 221, is shown by the darker ruling. Published folios describing other quadrangles, indicated by lighter ruling, are the following: Nos. 2, Ringgold; 6, Chattanooga; 8, Sewanee; 19, Stevenson; 20, Cleveland; 35, Gadsden; 78, Rome; 175, Birmingham

THE APPALACHIAN HIGHLANDS

EXTENT

Northern Alabama is in the southern part of the Appalachian Highlands.[1] This major physiographic division of the United States extends from the Atlantic Coastal Plain on the east to the Interior Plains on the west and from Canada and Lake Erie on the northeast to Alabama and Georgia on the southwest. The boundaries of this major division and of its larger subdivisions are shown on the sketch map (fig. 2).

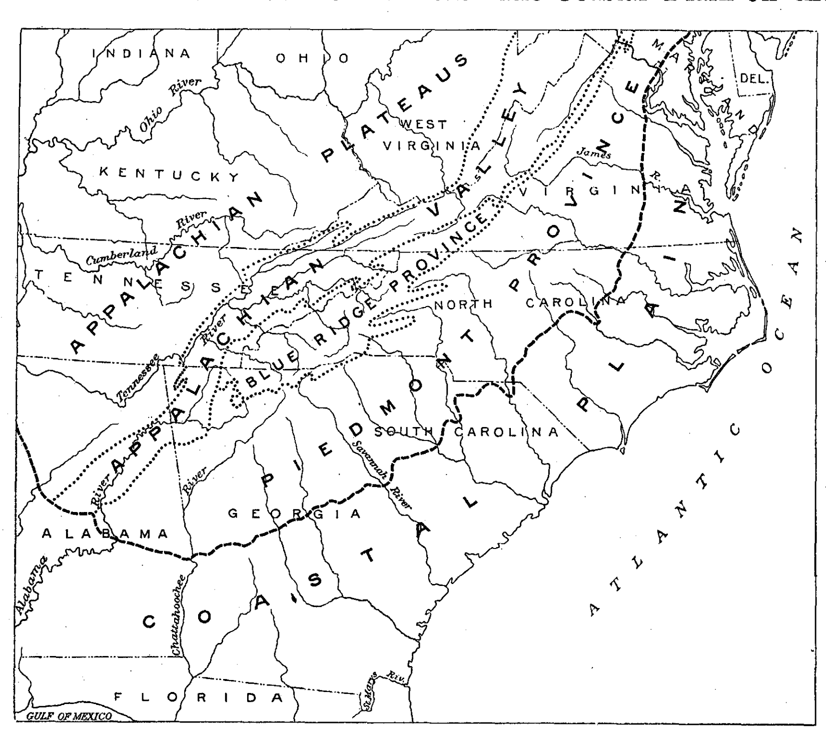

Figure 2.—Map of the southern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain

SUBDIVISIONS

On the grounds of differences in topography, rocks, and geologic structure, the Appalachian Highlands can be divided into four parts called provinces. These provinces are from southeast to northwest the Piedmont, the Blue Ridge, the Appalachian Valley, and the Appalachian Plateaus. On the west of the Appalachian Plateaus are the Interior Low Plateaus, which are included in the Interior Plains by the United States Geological Survey but which in the opinion of some, including the writer, should be included in the Appalachian Highlands.

The boundary between the Piedmont and Blue Ridge provinces is the east foot of the Blue Ridge and the foot of the high but irregular eastern scarp of the mountains of western North Carolina and northern Georgia which form the southern extension of the Blue Ridge. The boundary between the Blue Ridge and Appalachian Valley provinces is the west foot of the Blue Ridge of Virginia and of the high mountains of eastern Tennessee. This boundary continues into northwestern Georgia to the point where it intersects the boundary between the Piedmont and Blue Ridge provinces, about 15 miles southeast of Dalton. The Blue Ridge province thus terminates in northwestern Georgia. Thence southwestward the Piedmont and Appalachian Valley provinces are contiguous, the indefinite boundary between them running southwestward through Sylacauga, Ala., to the Coastal Plain in Chilton County, Ala. The boundary between the Appalachian Valley and the Appalachian Plateaus is, in Pennsylvania, the escarpment known as the Allegheny Front or Allegheny Mountain; in southwestern Virginia and through Tennessee, the Cumberland escarpment or Cumberland Mountain; and in Alabama, the eastern scarp of Lookout Mountain and the eastern boundary of the Warrior coal field. The western boundary of the Appalachian Plateaus through Tennessee, about midway between Knoxville and Nashville, is a broken escarpment 800 to 1,000 feet high, separating the Cumberland Plateau from the Highland Rim. Northeastward the boundary, though not sharply defined, is extended through central Ohio to the vicinity of Cleveland.

PIEDMONT PROVINCE

The Piedmont province is a rolling upland 1,100 feet above sea level at the east foot of the Blue Ridge and 500 feet or less above sea along the well-known "fall line," which extends from Washington, D. C., to Columbus, Ga., through Richmond, Va., Raleigh, N. C., Columbia, S. C., and Augusta, Ga. Its generally flat surface has been deeply trenched by the streams that flow across it. It is underlain by very ancient and crumpled crystalline rocks, both igneous and metamorphic.

BLUE RIDGE PROVINCE

The Blue Ridge province, which is narrow at its northern end in Virginia, is over 60 miles wide in North Carolina. It is a rugged region of hills and ridges and of deep, narrow valleys. The altitude of the higher summits in Virginia is 3,000 to 5,700 feet, and in western North Carolina Mount Mitchell, 6,711 feet high, is the highest point east of Mississippi River. Throughout its extent this province stands conspicuously above the bordering provinces, from each of which it is separated by a steep, broken, rugged front 1,000 to 3,000 feet high.

The rocks of this province are closely folded quartzite, slate, schist, gneiss, granite, and greenstone.

APPALACHIAN VALLEY PROVINCE

GENERAL FEATURES

The Appalachian Valley province, in the south end of which the Bessemer–Vandiver area is situated, is a belt of country 50 to 80 miles wide, which extends from Canada into Alabama and which is on the whole lower than the Blue Ridge on the east and the Appalachian Plateaus on the west. In the vicinity of Big Stone Gap, Va., the crest of the Big Black Mountains is 3,000 feet above the valley on the northwest side, and in northern Tennessee Holston Mountain, near the northwest front of the Blue Ridge, rises to nearly 3,000 feet above the valley on the southeast side.

In other places, as in the Birmingham district, the valley is not so distinctly defined by high escarpments. Nevertheless the altitude of the limestone and shale valleys constituting the larger part of the Appalachian Valley province in the Birmingham district is considerably lower than that of the adjacent provinces.

The rocks and structural conditions that occur in the Bessemer–Vandiver area prevail throughout the length of the Appalachian Valley province. The rocks are not crystalline, like those of the Piedmont and Blue Ridge provinces, but sedimentary, including limestone, dolomite, conglomerate, sandstone, and shale, which have been greatly disturbed by folding and faulting, as hereinafter described.

SUBDIVISIONS IN ALABAMA

Cahaba Ridges.—Although the province is in general a valley, there are within it many high ridges that extend parallel to its general direction, of which Red Mountain is a good example. These ridges are generally grouped along the west side of the valley from New York to Alabama. In Alabama the ridge section includes all the valley west of the east margin of the Coosa coal field and of a line in continuation of that margin southwest through the middle of the southern part of the Cahaba coal field. The north end of the ridge section curves eastward and narrows to a point a few miles southeast of Gadsden. It includes Blount and Chandler mountains. The name Cahaba Ridges is here proposed for this part of the valley in Alabama.

Birmingham Valley.—The belt of relatively low land within the Cahaba Ridges lying between Shades Mountain on the southeast and Sand Mountain on the northwest and extending the full length of the Cahaba coal field is commonly known and spoken of as Birmingham Valley. It includes Shades, Jones, and Opossum valleys and Red Mountain and Enon or Flint Ridge.

Coosa Valley.—East of the Cahaba Ridges is the Coosa Valley, which is the broad, generally flat, low country occupied by Coosa River and its tributaries and farther southwest by Cahaba River and its eastern tributaries.

APPALACHIAN PLATEAUS PROVINCE

The Appalachian Plateaus division of the Appalachian Highlands is relatively high, ranging from 500 feet above the sea, as in the Warrior coal field, to more than 4,500 feet in Pocahontas County, W. Va., and about 2,000 feet in western New York. In Tennessee it slopes somewhat westward from about 2,000 feet above sea level on the east to about 1,800 feet on the west, where it terminates in a steep scarp 800 to 1,000 feet high that descends to the Highland Rim of middle Tennessee. The original plateau has been dissected into parts or, in places, obliterated by the streams that cross it so that it is now spoken of as a dissected plateau. One of these parts is the Cumberland Plateau of Tennessee, which is the part of the province that now most nearly answers to the conception of a plateau. The high knobs of Madison and Jackson counties are outliers of the Cumberland Plateau.

The rocks of the Appalachian Plateaus comprise sandstone, conglomerate, shale, and coal. The province is in general coextensive with the Appalachian coal field. In contrast with the beds of the Appalachian Valley province the strata of the plateaus have been but slightly disturbed from their originally horizontal attitude.

TOPOGRAPHY OF THE AREA

GENERAL FEATURES

Nearly all of the Bessemer–Vandiver area is in the Appalachian Valley province, only a few square miles in the northwest corner of the Bessemer quadrangle being in the Appalachian Plateaus. The Appalachian Valley province in the Birmingham district has two natural subdivisions named the Cahaba Ridges and the Coosa Valley, which are defined and described above. The southeast third of the Vandiver quadrangle falls in the Coosa Valley; the rest of the area except the small part in the Appalachian Plateaus lies in the Cahaba Ridges.

The area is one of mature topography. The streams are approximately graded and reach all parts of it, so that no extensive undrained surface remains.

RELIEF

The altitude of the area ranges from 340 feet above sea level on Cahaba River at the south margin of the Bessemer quadrangle to 1,520 feet on Signal Mountain, in the Vandiver quadrangle. Throughout most of the area the relief ranges from 100 to 300 feet. The relief is notably greater, however, near Birmingham, where the summit of Red Mountain is 400 feet above the level of Jones Valley, and in the vicinity of Oxmoor, where the escarpment of Shades Mountain rises

[1] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 6, pp. 19–98, 1917.

abruptly to a height of 500 feet above Shades Valley. The greatest local relief, 500 to 1,000 feet, is along the belt of high ridges traversing the Vandiver quadrangle diagonally from the vicinity of the southwest corner to the northeast corner.

TOPOGRAPHIC TYPES

There are in the area two distinct types of topographic features which may be designated the linear and diffuse types. The linear type is characterized by parallel ridges and valleys that trend northeast, and the diffuse type by an irregular arrangement of ridges and valleys. The diffuse type prevails in the part of the quadrangles lying in the Appalachian Plateaus province and in the Coosa Valley; the linear type distinguishes the Cahaba Ridges.

The two types of topography are the result of differences in the character and attitude of the strata, as is well exhibited in section B–B′ on the structure-section map of the Bessemer quadrangle. In the Cahaba Ridges the strata of unequally resistant rocks (limestone, sandstone, conglomerate, and shale), generally inclined at high angles and striking northeastward, have determined the position and trend of the valleys and ridges. The valleys coincide with the outcrops of the limestone and shale, which are easily eroded, whereas the ridges coincide with the outcrops of the more resistant sandstone and conglomerate. The valleys are wide and flat. (See Pl. I.) Especially noteworthy examples of the ridges are Oak, Double Oak, and Double mountains, which cross the Vandiver quadrangle. These are formed of the highly inclined basal sandstones ("Millstone grit") of the Pottsville formation ("Coal Measures") of the Coosa coal field. Signal Mountain, the highest point in the quadrangles, is situated at the point of a canoe-shaped syncline of one of these basal sandstone strata. The rocks of the plateau region in the northwestern part of the Bessemer quadrangle are all shale and sandstone, which lie practically flat. On account of their flatness their resistance to erosive forces has been equal in all lateral directions, so that the arrangement of the valleys and ridges is irregular. The ridges extend in all directions; they vary greatly in breadth from point to point, and no two are alike in length. They are generally separated by deep, crooked valleys and send off innumerable short, narrow spurs that are separated by narrow ravines. The one-third of the Vandiver quadrangle in Coosa Valley is characterized by low relief and irregularly arranged streams and ridges and spurs. Although the rocks in this area are steeply inclined and intensely plicated, they are in general fairly uniform in hardness and without thick and persistent hard strata that would have a controlling influence on the topography. The topographic features resulting from erosion are similar to those resulting from the erosion of flat rocks.

DRAINAGE

The Bessemer and Vandiver quadrangles lie in the Black Warrior, Cahaba, and Coosa drainage basins. About 70 square miles in the northwest corner of the Bessemer quadrangle is drained by Valley Creek, a tributary of Black Warrior River, which it joins about 15 miles west of Bessemer. An area of about 1 square mile in the southeast corner of the Bessemer quadrangle is drained by South Fork of Yellow Leaf Creek, a tributary of Coosa River. The remainder of the quadrangle is drained by Cahaba River and its tributaries. An area of about 80 square miles in the western and northwestern parts of the Vandiver quadrangle is in the Cahaba River basin, and the remainder of it is in the Coosa River basin.

None of the streams are navigable. Some, like Valley Creek, Shades Creek, and Little Cahaba River, occupy limestone valleys and are fed by numerous copious springs. Cahaba River, though it flows through the coal field, receives the spring-fed streams of Cahaba Valley such as Little Cahaba and Buck creeks. Even during droughts these streams afford good supplies for stock, small power plants, coal washing, and irrigation.

The total fall of Cahaba River in the quadrangles in a distance of 70 miles is 270 feet, an average of nearly 4 feet to the mile; the fall of Valley Creek is 100 feet in 12.7 miles, or nearly 8 feet to the mile; and the fall of Shades Creek is 365 feet in 36.5 miles, or practically 10 feet to the mile. The grade of these streams is representative of the streams of the region generally.

CULTURE

The chief centers of population are Jones and Opossum valleys. Jones Valley contains Birmingham (population in 1920, 178,806), the southern outskirts of which are in the Bessemer quadrangle, and Bessemer (population, 18,674), 12 miles southwest of Birmingham. The part of Jones Valley between the two cities is thickly settled, but though mainly a residential section it is also the site of small manufacturing towns like Grasselli. In Opossum Valley, just north of Wylam, are the manufacturing towns of Ensley and Fairfield; and several great manufacturing plants are located in the valley southeast of Wylam. The concentration of population in this district is due to geologic and topographic conditions. The raw materials of iron making—iron ore, coal, and limestone—are most conveniently assembled here; the lay of the land is favorable for building and local intercommunication; and the natural features of the surrounding country present favorable conditions for communication with the outside world.

Outside of the industrial district just described the population of these quadrangles is mainly rural, except for the small towns of Helena, Pelham, and Keystone, in the southeastern part of the Bessemer quadrangle, and small mining towns such as Acton and Coalmont.

All the limestone valleys and the broad, gently undulating surface of Coosa Valley in the southeastern part of the Vandiver quadrangle are largely cleared and cultivated, as are also the gentler slopes of the ridges and the more level tracts within the coal fields. The rougher parts of the coal fields and the steep slopes and crests of the high ridges are wooded. Excellent metaled roads radiate from Birmingham and Bessemer for considerable distances into the surrounding country. The ordinary country roads are conveniently spaced and are kept in good condition, so that communication between different parts of the region is reasonably easy at all seasons.

DESCRIPTIVE GEOLOGY

The geology of this region has been described and mapped by the Alabama Geological Survey. In this folio many new formations and new members in the old formations are recognized and mapped, and a number of formation names that differ from those of the Alabama Survey reports are used in order to bring the nomenclature into harmony with the more general recent usage.

GENERAL CHARACTER OF THE ROCKS

The rocks of the quadrangles are all of sedimentary origin and range in age from Cambrian to Carboniferous; all the Paleozoic systems but the Devonian are well represented. The maximum thickness of rocks exposed is about 20,000 feet. These rocks were originally deposited on the bottom of bodies of water in a nearly horizontal attitude. In small parts of the quadrangles this attitude has been fairly well preserved, but generally the strata have been folded and faulted until their original horizontal attitude and to a considerable extent their original relations have been destroyed. In addition to the consolidated rocks, there are local superficial deposits of Recent age, which are of little stratigraphic significance. The generalized columnar section in the back of the folio gives a condensed expression of the stratigraphy of the area.

In this region there are five dolomite formations which in view of the matters set forth below, are of especial interest. These formations, in ascending order the Brierfield dolomite, Ketona dolomite, Bibb dolomite, Copper Ridge dolomite, and Chepultepec dolomite, are in part the basis of a new geologic system proposed by E. O. Ulrich and named by him[2] the Ozarkian system. The name was taken from the Ozark region of Missouri, from a study of which the idea of a distinct system arose. Ulrich describes this proposed new system as follows:[3]

> Under the term Ozarkian I include all the formations of the Appalachian Valley that can be shown to be younger than (1) the top of the Upper Cambrian Nolichucky shale in northeastern Tennessee and (2) the top of the Conasauga shale in southeastern Tennessee, northwestern Georgia, and northeastern Alabama, and which are older than the base of the Stonehenge limestone of the Canadian system [Beekmantown group] in southern and central Pennsylvania.

Pending the presentation of all the evidence supporting the introduction of this new system, in a monograph now in preparation by Mr. Ulrich, the United States Geological Survey will classify these formations as Cambrian or Ordovician. The present writer, however, believes that the Ozarkian system of Ulrich should be adopted for use in this folio, because in this part of Alabama it reaches its maximum known thickness of about 5,000 feet.

The succession and relations of the several formations of this great dolomite series are fully described in the Montevallo-Columbiana folio.

The table on the back of the columnar-section sheet shows the position of the proposed system in the general stratigraphic succession, its relations to the Knox dolomite of earlier Tennessee and Alabama reports, the general relations of the lower Paleozoic formations of Alabama to those of other regions, and the various classifications followed by the Alabama and United States Geological Surveys.

STRATIGRAPHY

SHALE OF UNKNOWN AGE

In the southeast corner of the Vandiver quadrangle, on Fourmile Creek, occur several detached masses of red shale and of soft yellow, greenish, or grayish shale or rotten slate that have been thrust into their present position from an original source that apparently lay 15 miles or more to the southeast. These rocks are much older than the limestone which they overlie, and their parent formations are supposed also to underlie the limestone at a great depth.

The red shale of these areas is almost certainly of Rome or Watauga age, as described in reports on northwestern Georgia and eastern Tennessee, but the age of the gray shale is uncertain. It is in contact with different formations on different sides—on the southwest with a heavy cherty formation supposed to be the Copper Ridge dolomite, on the north with the Newala limestone, and on the east with the Rome ("Montevallo") formation. It seems impossible to determine the age of this shale from its stratigraphic relations, nor have any fossils been found to reveal its age. Lithologically the shale resembles shale of the Conasauga formation, slates of the Talladega slate mass, and the shale of the Weisner formation of the Columbiana quadrangle, just south of the Vandiver. As in the adjoining area in the northeast corner of the Columbiana quadrangle the shale lies geographically between the Rome ("Montevallo") formation and beds that are thought to be the Copper Ridge dolomite, the gray shale in the Vandiver quadrangle might with the greatest degree of probability be regarded as the Conasauga shale, which is normally between the Copper Ridge and Rome, if it were not for the fact that along Beeswax Creek 2 to 4 miles south of the area of gray shale the Conasauga, which there directly and normally follows the Rome, consists, so far as observed, of several hundred feet of limestone. In view of the uncertainty as to the age and relations of these rocks, it is believed to be most expedient not to assign any definite age to them.

CAMBRIAN SYSTEM

The Cambrian formations that crop out in these quadrangles are the Rome ("Montevallo") formation and the Conasauga ("Coosa") limestone.

ROME ("MONTEVALLO") FORMATION

Name and limits.—The name Rome formation, from Rome, Ga., was introduced by Hayes in 1890. The name "Choccolocco or Montevallo shales" was introduced by E. A. Smith, at about the same time, for rocks in central Alabama now known to be equivalent, in whole or in part, to the Rome formation. The equivalency of the Rome and "Montevallo" was not satisfactorily established, however, until 1908. In the meantime the name Rome had been given wide currency by use in eleven folios of the Geologic Atlas of the United States, and it seemed best to retain it, although the name "Montevallo" has slight priority in publication.

The base of the Rome formation is nowhere exposed in these quadrangles, but it is exposed in the southwestern part of the Rome quadrangle in Georgia and Alabama, and is there underlain by the Shady ("Beaver") limestone, which probably underlies the Rome in the Bessemer-Vandiver area also, as it is exposed beneath the Rome on Beeswax Creek, in the northeastern part of the Columbiana quadrangle. The top of the Rome is fixed at the upper limit of red shale and of the peculiar hard siliceous limestone that weathers to a rusty sandstone characteristic of the Rome. This lithologic boundary is definite and easily recognized. Above it everywhere lies the olive-colored shale or blue oolitic limestone of the Conasauga or equivalent formations.

Distribution.—The Rome formation crops out in a narrow band along the southeast margin of the Cahaba coal field. Helena is situated upon it, and the best exposure of the formation in this area is in that town and its vicinity. It is much better displayed to the north and west of Montevallo, 15 miles south of Helena.

The west boundary of the strip of the Rome is a fault, along which the formation has been thrust westward and upward into contact with the Carboniferous rocks west of the fault. The vertical movement along this fault can not have been much if any less than 12,000 feet. Small areas of the formation occur also in the southeastern part of the Vandiver quadrangle. These are remnants of an overthrust mass that has been nearly removed by erosion.

Character.—The Rome formation is composed predominantly of stiff greenish shale, yellow flaky shale, and red shale, but it includes thin layers of impure limestone, thin cherty layers, thin layers of brown rotten sandstone, which is normally calcareous, thin bands of quartzite, and beds of fine-grained calcareous sandstone as much as 20 or 30 feet thick. It is decidedly variegated in color. Dividing Ridge, which extends both north and south of Helena for several miles, is made by a bed of sandstone 30 feet thick composed of about equal proportions of silica and lime carbonate.

Thickness.—As the bottom of the Rome formation does not crop out, its full thickness in this region can not be determined. At Helena about 1,000 feet appears to be exposed, and it is not unlikely that the formation reaches a considerably greater thickness.

Age and correlation.—Small collections of fossils have been obtained from the Rome formation in the Bessemer quadrangle,

[2] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 281–680, 1911.

[3] Idem, p. 627.

from which the following forms have been identified by C. D. Walcott except the *Olenellus*, which was identified by the writer.

Micromitra (Paterina) major Walcott.
Micromitra (Paterina) williardi Walcott.
Micromitra (Iphidella) pannula White.
Obolus smithi Walcott.
Wimanella shelbyensis Walcott.
Olenellus thompsoni Hall.
Paedeumias transitans Walcott.
Wanneria halli Walcott.

The fossils in this list, except the *Olenellus*, were obtained from two localities, one a quarter of a mile north of Helena and the other 4 miles south of Helena, from a bed that seems to be about 500 feet below the top of the Rome. In the vicinity of Montevallo, about 200 feet below the top of the Rome as delimited in that locality, *Olenellus thompsoni* is abundant. Of the fossils in the list *Micromitra* (*Paterina*) *williardi*, *Obolus smithi*, and *Wimanella shelbyensis* are known only from the Rome of Cahaba Valley. The *Micromitra* (*Paterina*) *pannula* is recorded by Walcott from Lower, Middle, and Upper Cambrian rocks, but the greater number of occurrences are Middle Cambrian. The *Paedeumias* and the *Wanneria* are in some regions, as York County, Pa., associated with *Olenellus*, which is accepted as a Lower Cambrian genus. The paleontologic evidence, as generally interpreted, indicates the Lower Cambrian age of all but the upper 200 feet more or less of the Rome in this region, which may be Middle Cambrian.

On the basis of continuity and lithology as well as on rather meager fossil evidence, the Rome formation has been correlated with the upper part at least of the Watauga shale of eastern Tennessee, the Russell formation of Virginia, and the Waynesboro formation of Pennsylvania. However, fossils collected from the Russell formation in the summer of 1926, throw considerable doubt upon the supposed equivalency of the Rome and Russell formations.

CONASAUGA ("COOSA") LIMESTONE

Name.—The name Conasauga, from Conasauga River, in northwestern Georgia, was introduced by Hayes in December, 1890, and appeared in print in February, 1891. The name Coosa, from Coosa Valley, was introduced by Smith in January, 1891, for the same rocks. For the reasons stated in connection with the name of the Rome formation, the name Conasauga is used in this folio.

Distribution.—The Conasauga limestone underlies much of the width of Opossum Valley from Bessemer to Wylam. It is bounded on the west side by a fault along which it is in contact with the Pottsville. It crops out extensively in Jones Valley, occupying a belt about a mile wide the whole length of the valley within the Bessemer quadrangle. As the Conasauga is absent in the Bessemer quadrangle in Cahaba Valley, it must thin out somewhere underneath the Cahaba coal field.

The gray and yellowish shale of the formation was seen at a number of places in the vicinity of Bessemer. There is also a good exposure of the shale, containing limestone layers, on Eleventh Street in Birmingham, opposite the street-car barn. The limestone is particularly well exposed in the western part of Bessemer and just to the northwest and at many places in Jones Valley between Bessemer and Birmingham.

Topographically the Conasauga forms low, flat, damp valleys known as Flatwoods.

Character.—The Conasauga is made up mostly of rather thin bedded dark-gray finely crystalline limestone, interbedded with more or less soft, fissile, and probably calcareous shale, which weathers gray or yellowish.

Chemically the Conasauga limestone is, so far as analyses at hand show, high in calcium carbonate and low in magnesium carbonate, with still smaller amounts of silica, iron, and alumina.

In places, especially in the vicinity of Bessemer and at old Jonesboro, layers of waxy-looking chert not over half an inch thick occur in the shale. This material is dark within but rusty on the weathered surface. At localities where this chert occurs many small prismatic pieces of it may be scattered on the surface. The interbedded chert and shale are well displayed on Twenty-fourth Street in Bessemer. (See Birmingham folio, No. 175, Pl. I.) The continuous beds of limestone where the formation is best exposed in Jones Valley might suggest that the shale does not exceed one-tenth of the mass and that it occurs for the most part as comparatively thin partings in the limestone. Possibly, however, the proportion of limestone and shale varies much along the strike, and there may be much more shale in some places than in others not far removed. In some localities, as 1 to 3 miles northeast of Montevallo, about 30 miles south of Birmingham, the thick layers of the Conasauga are, on the weathered surface, striped with alternating gray and bluish bands half an inch to 2 inches broad. Such banding is highly developed in the equivalent Rutledge and Maryville limestones of Tennessee. In the vicinity of Bessemer and elsewhere in Jones Valley some of the limestone is shot through by a network of calcite veins.

Thickness.—The thickness of the Conasauga is 1,900 feet, as calculated from the width of the outcrop and the angle of the dip, with the assumption that there are no irregularities in structure to vitiate the result. These figures are comparable to those given by Hayes for the thickness of the Conasauga in northeastern Alabama—1,600 to 2,000 feet. If the bottom of the formation is not brought to the surface along the fault the thickness is still greater by an unknown amount.

Age and correlation.—Fossils are fairly plentiful in the Conasauga, although it appears to be unfossiliferous because the fossils are so firmly inclosed in the rock that they do not appear on weathered or broken surfaces. By close examination, however, numerous sections of trilobites and brachiopods appear on a broken surface of some layers. Fragments of trilobites also are revealed on the weathered surface of a layer here and there. Many layers are full of a branching form that may be of organic origin. Fossils collected from the Conasauga limestone in Jones and Opossum valleys in the Bessemer and Birmingham quadrangles are listed below as determined by C. D. Walcott.

Lingulella buttsi Walcott.
Lingulella desiderata (Walcott).
Lingulella quadrilateralis (Walcott).
Lingulella similis (Walcott).
Dicellomus appalachia Walcott.
Acrotreta kutorgai Walcott.
Micromitra alabamaensis (Walcott.
Westonia.
Obolus lamborni (Meek).
Obolus willisi (Walcott).
Norwoodia simplex Walcott.
Norwoodia ponderosa Walcott.
Norwoodia gracilis Walcott.
Agnostus, 3 or 4 species.
Crepicephalus texanus Shumard.
Crepicephalus thoosa Walcott.

The species of trilobites listed are now regarded by both Walcott[4] and Ulrich as characteristic of the Upper Cambrian, but according to Walcott some of the brachiopods range down into the Middle and Lower Cambrian. It is agreed, however, that at least that part of the Conasauga which carries the fauna listed is of Upper Cambrian age. No exclusively Middle Cambrian fossils are yet known from the Conasauga of Birmingham Valley. But the Conasauga of the areas southeast of the Cahaba coal field in Alabama carries Middle Cambrian fossils and may be all Middle Cambrian. Through the fossils the Conasauga has been correlated with the Rutledge limestone, Rogersville shale, Maryville limestone, and Nolichucky shale of Tennessee, the Honaker limestone of eastern Tennessee and southwestern Virginia, and the Warrior limestone of Pennsylvania. This correlation, however, is correct only for the Conasauga of the State as a whole. The Conasauga of Birmingham Valley, so far as known, is more nearly equivalent to the Nolichucky shale and perhaps the Maryville limestone also.[5]

CAMBRIAN OR ORDOVICIAN SYSTEM

SUBDIVISIONS

Pending a decision as to the adoption of Ulrich's proposed Ozarkian system, five formations are classified by the United States Geological Survey as of either Cambrian or Ordovician age. They are, in ascending order, the Brierfield, Ketona, Bibb, Copper Ridge, and Chepultepec dolomites. They compose the Knox dolomite of earlier reports on this region. The Brierfield and Bibb do not extend into the Bessemer-Vandiver area, but the entire series is developed in the Montevallo quadrangle, and is fully described in the Montevallo-Columbiana folio. Their relations are also shown in the table on the back of the columnar-section sheet. In the writer's opinion there are no grounds for assigning these rocks to either the Cambrian or the Ordovician system, but there are cogent reasons for the conclusion that they constitute a natural system intermediate between the Cambrian and Ordovician and coordinate in time value with those systems.

UNCONFORMITY AT THE BASE OF THE KETONA AND COPPER RIDGE DOLOMITES

In Birmingham Valley the Ketona dolomite succeeds the Conasauga limestone, the Brierfield dolomite, which in the Montevallo quadrangle lies between the two formations, being absent. In Cahaba Valley the Conasauga limestone and Brierfield dolomite are both absent, and the Ketona lies upon the Rome formation. Furthermore, the Ketona itself is almost certainly absent for some distance north and south of Bessemer, where the Copper Ridge dolomite and Conasauga limestone are in contact. The stratigraphic gap in the part of Jones Valley where the Ketona is present is measured by the thickness of the Brierfield dolomite (1,200 to 1,500 feet); the gap in Cahaba Valley, by the thickness of the Conasauga and Brierfield formations as developed elsewhere, amounting to 3,000 feet; and the gap between the Conasauga and Copper Ridge in the vicinity of Bessemer, where the Brierfield, Ketona, and Bibb are absent, amounts to about 2,500 feet.

KETONA DOLOMITE

Name.—The Ketona dolomite was named by Butts from Ketona, 5 miles north of Birmingham, where a large quarry has been opened in the formation.

Distribution.—The Ketona apparently underlies most of Opossum Valley north of Woodward and crops out in a narrow strip on the east side of Flint Ridge northward to Walnut Grove. It crops out around the north end and on both sides of the Salem Hills, southwest of Bessemer. It shows at a few points in the southeast quarter of Birmingham, and a gray apparently pure dolomite referred to the Ketona was thrown out from a well in the vicinity of Cleveland. No trace of it was seen along the east base of Red Mountain south of Cleveland, and it is almost certainly absent, as shown by the fact that the Conasauga limestone is exposed in the vicinity of Jonesboro in practical contact with the Copper Ridge dolomite. In Cahaba Valley the Ketona crops out along the bottom of the narrow valley between New Hope Mountain and the Cahaba coal field. For most of the distance it is separated from the Carboniferous rocks by a narrow strip of the Rome formation.

Character.—The Ketona is almost all thick-bedded light-gray rather coarsely crystalline dolomite, and, unlike the Copper Ridge and Chepultepec dolomites, it is nearly free from silica. Locally, as at the quarry of the Republic Iron & Steel Co. near Thomas, in Opossum Valley, the Ketona has the appearance of a crush breccia through a considerable thickness, as shown in Plate II. The character of the bedding is illustrated elsewhere.[6] Chemically this rock is nearly pure dolomite, as shown by the following average of a number of analyses:

Analyses of Ketona dolomite

	1	2	3
SiO_2		1.31	0.70
Al_2O_3		.96	.638
Insoluble matter	0.64		
$CaCO_3$	54.30	55.08	56.041
$MgCO_3$	43.82	42.47	43.091

1. Average of partial analyses of six samples collected by the author from the Freeman farm, in the SW. ¼ NE. ¼ sec. 33, T. 21 S., R. 3 W., 5 miles north of Montevallo. Samples taken every 40 feet through a thickness of about 200 feet. Analyses by the U. S. Geol. Survey.
2. Average analyses of rock taken out during four months at Ketona quarry. Analyses by Tennessee Coal, Iron & Railroad Co.
3. Average of ten analyses of carload samples, from North Birmingham quarry. aggregating 50 carloads and extending over a period of more than three years. Analyses by Sloss-Sheffield Iron & Steel Co.

These analyses show a very pure carbonate rock. The ratio of calcium and magnesium carbonates is nearly that of the mineral dolomite, which is composed of 45.6 per cent magnesium carbonate and 54.4 per cent calcium carbonate.

The rock is used extensively for flux in the furnaces of the Birmingham district.

Thickness.—The thickness of the Ketona dolomite in Birmingham Valley and in Cahaba Valley north of Helena is 400 to 600 feet. It may be thicker in Opossum Valley and in Cahaba Valley south of Helena, where the outcrop is wider. The greater width of outcrop, however, may with equal probability be due to lower dip or to wavy folding. Exposures are lacking to reveal the facts.

Age.—No fossils of any kind have ever been found in the formation; its age is determined by its stratigraphic position and structural relation to other formations. It is younger than any rocks known from their fossils to be of Upper Cambrian age.

UNCONFORMITY AT THE TOP OF THE KETONA DOLOMITE

The Bibb dolomite, which overlies the Ketona in the Montevallo region, is absent in the Bessemer-Vandiver area and the Ketona is therefore followed unconformably by the Copper Ridge dolomite, described below. The thickness of the absent formation is 275 to 500 feet.

COPPER RIDGE DOLOMITE

Name.—The name Copper Ridge, under the form Copper Ridge chert, was introduced by Ulrich[7] from a conspicuous ridge 8 miles northwest of Knoxville, Tenn., which is made by the formation. The term was subsequently modified[8] by the inclusion of the "Lower Knox" of Tennessee. As now defined the Copper Ridge in Alabama is conformably overlain by the Chepultepec dolomite and conformably underlain by the Bibb dolomite. The formation in Alabama is identified with that in Tennessee on the grounds of sequence, lithology, and the presence of the same species of *Cryptozoon* in both areas, and also because the outcrop is probably continuous from the type locality into Alabama.

Distribution.—The Copper Ridge dolomite is one of the most widespread formations in northeastern Alabama. It was probably deposited over the entire area and is absent now only on the crests of the anticlines from which it has been eroded. There is a small faulted area of Copper Ridge near

[4] Walcott, C. D., Cambrian trilobites: Smithsonian Misc Coll., vol. 64, No. 3, 1916.

[5] For further discussion of this subject and for figures of some of the fossils listed here and elsewhere in this folio see Butts, Charles, and others, Geology of Alabama: Alabama Geol. Survey Special Pub. 14, 1926.

[6] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175). pl. 2, 1910.

[7] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 635-637, 1911.

[8] Ulrich, E. O., Tennessee Dept. Education Div. Geology Bull. 28, p. 34, 1924; Bull. 31, p. 16, 1924.

Pleasant Ridge Church, northwest of Bessemer. It crops out in the Salem Hills, in Flint Ridge, along the west base of Red Mountain, and in New Hope Mountain in Cahaba Valley. It is almost certainly present under the coal fields and under all that part of the Bessemer-Vandiver area east of New Hope Ridge.

Character.—As the Copper Ridge dolomite is not well exposed in the central Alabama region but little knowledge of its real character can be gained through direct observation. Here and there an isolated exposure of dolomite appears in a wide expanse of territory, the surface of which is deeply covered with red, tawny, or gray soil, full of chunks and boulders of chert, which are also strewn abundantly over the surface. Fortunately, however, exposures on Alligator Creek, about 10 miles south of the southwest corner of the Bessemer quadrangle, have revealed the real nature of the Copper Ridge and Chepultepec dolomites. The section of these dolomites on Alligator Creek is followed upward in regular sequence by an almost complete section of the Longview and Newala limestones along Little Cahaba River half a mile east of Alligator Creek and within the Montevallo quadrangle. A compilation of the two sections is given below.

Section along Alligator Creek and Little Cahaba River in secs. 6 and 17, T. 24 N., R. 11 E.

	Feet
Newala and Longview limestones (on Little Cahaba River):	
21. Limestone, largely pearl-gray, noncrystalline or very finely crystalline, brittle, much heavy dolomite, and some chert below	1,000±
Chepultepec dolomite (on Alligator Creek):	
20. Dolomite, dark gray, coarsely crystalline, layers 6 inches to 1 foot thick	280
19. Not exposed	110
18. Dolomite with chert	80
17. Not exposed; much cavernous chert with gastropods	80
16. Dolomite like No. 20	200
15. Limestone, pearl-gray, very finely or not visibly crystalline; a few gastropods show in section on the weathered surface of a layer or two	350
	1,100
Copper Ridge dolomite (on Alligator Creek):	
14. Chert, solid	10
13. Dolomite, thick bedded, dark gray, coarsely crystalline, partly exposed; much chert débris with *Cryptozoon* common	75
12. Not exposed	130
11. Dolomite like No. 13	25
10. Not exposed	40
9. Chert, solid	20
8. Not exposed	80
7. Chert, solid	10
6. Dolomite, like No. 13, not all exposed	250
5. Not exposed, dense chert with two or three species of *Cryptozoon* plentiful	360
4. Dolomite like No. 13, yields much dense jagged chert	375
3. Limestone, light gray, compact	10±
2. Dolomite, mostly light gray, finely crystalline; yields abundant heavy chert	375
	1,750
Ketona dolomite:	
1. Dolomite, light gray, coarse, some slightly magnesian limestone, no chert; exposed to fault	250±

The dolomite that constitutes the main mass of the Copper Ridge is prevailingly a thick-bedded dark-gray and rather coarse grained rock. On Alligator Creek, as shown in the section above (No. 2), the lower part is very finely crystalline and light gray. The appearance of the rock indicates calcium carbonate and magnesium carbonate nearly in the dolomite ratio. No analyses that are surely of Copper Ridge dolomite are known to the writer.

The surfaces underlain by Copper Ridge are thickly strewn with chert ranging from small pieces up to masses several feet in diameter. The larger masses of this chert are especially well displayed on Mahan Creek, in the Montevallo quadrangle a few miles south of Montevallo, where the creek cuts through the chert ridge 1 to 2 miles east of Brierfield. Notwithstanding the great quantities of chert on the surface little appears in the freshly exposed beds in creek sections and other places. The chert is evidently a secondary product developed in the process of weathering. Layers of dolomite or limestone at creek level may be followed to their outcrop higher up on the banks and be found to change entirely to massive chert.

The chert has been shown by Washburne through microscopic examination to be crystalline quartz. It is very dense and tough, weathers with jagged surfaces, and breaks down into small angular fragments, very little of it being mealy or chalky, like much of the chert of the other cherty formations of the region. A typical specimen is shown in Plate III. The prevailing colors are white, yellowish, and pink.

Topographically the Copper Ridge dolomite generally expresses itself as a ridge, on account of the protecting mantle of chert which has accumulated on the surface. Flint Ridge and the Salem Hills, in Birmingham Valley, and New Hope Mountain, in Cahaba Valley, are examples.

Thickness.—The thickness of the Copper Ridge in the Alligator Creek section is 1,750 feet, which may be assumed as the thickness throughout the Bessemer-Vandiver area.

Age and correlation.—No fossils have been found in the Copper Ridge dolomite in either the Bessemer or the Vandiver quadrangle. Two types of *Cryptozoon* in the chert have been observed in the Montevallo-Columbiana region to the south, and a few specimens of gastropods in chert were collected in the southeastern part of the Columbiana quadrangle. A collection obtained half a mile west of Chalkville in the Birmingham quadrangle and another within a mile west of Springville, still farther northwest, are the best that have been obtained from the Copper Ridge in the Appalachian region.

Of the Copper Ridge fossils Ulrich says:[9]

Recognizable fossils are as a rule exceedingly rare in the Copper Ridge, and those found are almost without exception only silicified molds in the chert residue. Masses of a compound cryptozoon resembling *C. undulatum* (Pl. IV), a supposed gigantic calcareous alga, are fairly common in the lower and middle parts of the Copper Ridge. With these occur some of "brainlike" appearance. The rounded masses of another species, *C. proliferum ?* (Pl. V), seem to be confined to the upper half of the Copper Ridge. The other fossils consist chiefly of gastropods, with one or two each of cephalopods and trilobites, all of undescribed species.

The collection from Chalkville seems to come from a higher position in the formation than the Springville lot. It contains four species of *Sinuopea*, a species of a new genus (*Rhachopea* Ulrich) combining characters of *Sinuopea* and *Euconia*, and one species of a new genus of compressed conical limpets (*Lophoconus* Ulrich) that seems to be characteristic of the Ozarkian fauna.

The Springville collection occurs in a cellular, rather mealy chert observed at a few places beneath the middle of the formation. Except the limpet, which is somewhat doubtfully common to both, the fossils in this lower zone are quite different from those found near Chalkville. In the Springville collection we note a new limpet allied to *Tryblidium*, a very tall species of *Scenella*, two species of *Hypseloconus*, three species of *Scaevogyra*—one related to *S. sweezyi* and another to *S. obliqua*—and a small curved rapidly tapering cephalopod of the genus *Levisoceras* Foerste. With the probable exception of the last all these indicate a lower Ozarkian horizon.

Compared with Ozarkian faunas found in Missouri the fossils of the Chalkville collection prove to be most closely related to those that mark the Proctor dolomite and an undescribed unit above it. Those of the Springville collection, on the other hand, are very similar and in part indistinguishable from characteristic fossils of the Eminence dolomite. The evidence in hand, therefore, indicates that the beds referred to the Copper Ridge in Alabama include representatives of the Missouri formations mentioned. Moreover, as those Missouri formations are separated from each other and from the preceding Potosi dolomite and the succeeding Gasconade dolomite by overlap unconformities, and as their maximum aggregate thickness is greatly inferior to the maximum thickness of the Copper Ridge, it seems reasonable to infer that the Copper Ridge includes also beds that fall into the hiatuses known to occur between the mentioned formations of the middle Ozarkian sequence of deposits in Missouri.

Investigations made since the publication of the Birmingham folio have shown that the beds in which were found the first three of the fossils listed in that folio as middle Knox are really much younger than Copper Ridge.[10] Their horizon in fact corresponds to the Longview limestone of this folio.

CHEPULTEPEC DOLOMITE

Name.—The Chepultepec dolomite was established as a formation by Ulrich[11] and named by him from the town of Chepultepec, in Murphrees Valley, 30 miles northeast of Birmingham, near which the formation is well developed and where it has yielded the most species and best-preserved fossils of its characteristic fauna that have been found in Alabama. As now defined it rests conformably on the Copper Ridge dolomite in both Tennessee and Alabama.

Distribution.—In these quadrangles the Chepultepec occurs only in Cahaba Valley, where it crops out in a belt along the east flank of Newhope Mountain. A narrow strip, which is thrust up by the Cahaba Valley fault, occurs along the middle of the northern part of the valley in the Vandiver quadrangle. At the north margin of the quadrangle this fault lies along the crest of a low ridge just east of Hebron Church, and the Chepultepec, which crops out on the east side of the ridge, has been faulted into contact with the Fort Payne chert, which crops out on the west side.

Character.—As shown in the section on Alligator Creek, the Chepultepec consists of limestone in its lower part and dolomite in its upper part. The dolomite appears to be somewhat thinner bedded than the Copper Ridge but of the same gray color and coarsely granular texture. The limestone at the bottom is light gray or pearl-gray and very finely crystalline or in part without visible crystalline texture. This limestone is possibly present at Chepultepec, where there is a valley, probably eroded upon it, between the Copper Ridge and Chepultepec formations, as noted by Ulrich in his original description. The Chepultepec differs from the Copper Ridge mainly in its limestone, its chert, and its fossils. Its chert, unlike that of the Copper Ridge, described above, is predominantly mealy, weathering to a chalky texture, much of it full of irregular cavities as if worm-eaten and but little of it sufficiently dense and resistant to form large boulders. Its character is shown in Plate VI. As a result of the character of the chert, the areas underlain by the Chepultepec have little other than fine débris scattered over the surface, and usually it is easy to distinguish in the field the areas of Copper Ridge and Chepultepec. However, as their contact is practically nowhere exposed, and as the two kinds of chert become mixed along the boundary line on the slopes, precise location of the boundary is generally impossible, and therefore the areas of the two are not separated by a line on the map.

Thickness.—In the section on Alligator Creek the Chepultepec as delimited is about 1,100 feet thick. Its thickness may be different elsewhere, but under the conditions of exposure no reliable determination can be made.

Age and correlation.—The Chepultepec has yielded a considerable fauna, mainly gastropods, which generally occur in the cavernous mealy chert. The fossils are fairly common in the chert wherever the formation crops out in the region, but the most abundant and best fossils have been collected at the type locality near Chepultepec, in the Birmingham quadrangle. The following list, identified by Ulrich, comprises all the determinable species so far found in the typical exposures of the formation in the vicinity of Chepultepec, Ala., and at Jasper, Tenn. Most of the listed species are common to the two localities, and at both places the collections were made from layers of porous chert lying approximately 200 feet beneath the top of the formation:

Archeocyathus ? sp. undet.
Lophoconus sp.
Pelagiella expansa Ulrich.
Sinuopea humerosa Ulrich.
Sinuopea regalis Ulrich.
Sinuopea turgida (Hall).
Rhachopea grandis Ulrich.
Rhachopea strongi (Whitfield).
Ozarkotoma acuta Ulrich.
Euomphalopsis involuta Ulrich.
Helicotoma uniangulata (Hall).
Helicotoma discreta Ulrich.
Ozarkispira typica Ulrich.
Chepultepecia leiosomella (Sardeson).
Gasconadia putilla (Sardeson).
Gasconadia nitida Ulrich.
Ophileta, 4 unnamed species.
Cameroceras huzzahense Ulrich and Foerste.
Walcottoceras obliquum Ulrich and Foerste.
Levisoceras cf. L. mercurius (Billings).
Eremoceras gracile Ulrich and Foerste.
Eremoceras infundibulum Ulrich and Foerste.
Eremoceras major Ulrich and Foerste.
Buehleroceras sp.
Clarkoceras newton-winchelli (Clarke).
Clarkoceras conicum Ulrich and Foerste.
Clarkoceras curvatum Ulrich and Foerste.
Oneotoceras jasperense Ulrich and Foerste.
Hystricurus? n. sp.

Some of these fossils have been found also in the Chepultepec of the Bessemer-Vandiver area.

Ulrich states that 17 of these 31 species occur in Missouri in the chert of the Gasconade dolomite, about the same number in the Oneota dolomite in Wisconsin and Iowa, at least 3 in the small fauna found in the chert bed at the top of the Little Falls dolomite at Little Falls, N. Y., and 3 others in the same formation near Whitehall, N. Y. Evidently the deposits of this age transgressed very widely in northeasterly and northwesterly directions from central Alabama.

ORDOVICIAN SYSTEM

The formations definitely assigned to the Ordovician system, named in ascending order, comprise in Cahaba Valley the Longview limestone, Newala limestone, Odenville limestone, Mosheim limestone, Lenoir limestone, Athens shale, and Little Oak limestone and in Birmingham Valley the partly contemporaneous Chickamauga limestone. All these formations, with the exception of the Longview limestone, were included by the Alabama Geological Survey under the name "Pelham limestone." In subdividing this predominantly limestone mass in Cahaba Valley, it was decided that the name Pelham could not be applied to any of the units without causing confusion, so new names were adopted, except Lenoir and Athens, which have long been in use in Tennessee. The table on the back of the columnar-section sheet shows the equivalence of the "Pelham limestone" to the units here adopted.

CAHABA VALLEY

UNCONFORMITY AT BASE OF LONGVIEW LIMESTONE

In Cahaba Valley there is an unconformity between the Chepultepec dolomite and the Longview limestone, owing to the absence of rocks equivalent to the Stonehenge limestone, 700 feet thick, of central Pennsylvania, which underlies the equivalent of the Longview and is above the horizon of the Chepultepec dolomite.

LONGVIEW LIMESTONE

Name.—The Longview limestone was named from Longview, in the Montevallo quadrangle, which is situated on the outcrop of the formation.

Lack of exposures prevents observations of the contact of the Longview and Chepultepec, but in places the two are exposed within a short distance of each other, so that the boundary between them is located within narrow limits. At the top the Longview appears to merge into the Newala limestone, which has little or no chert. At Longview the lower and upper boundaries of the limestone have not been precisely located, but in the Buck Creek section west of Pelham, in the

[9] Ulrich, E. O., personal communication.
[10] U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175), p. 4 (folio edition); p. 33 (octavo edition), 1910.
[11] Ulrich, E. O., Geol. Soc. America Bull., vol. 22, p. 638, 1911.

Bessemer quadrangle, the bottom of the Longview is about 400 feet southeast of the ford across Buck Creek on the old road from Pelham to Helena, and the top is about 1,500 feet southeast of the ford.

Distribution.—The Longview limestone has been recognized only in Cahaba Valley, where it crops out in a strip a quarter of a mile wide along the west side of the valley. In the Vandiver quadrangle the outcrop is repeated by the fault along the middle of Cahaba Valley north of Newhope Church. It has not been recognized in the southeast corner of the Vandiver quadrangle.

Character.—The formation is made up of alternating bluish-gray fine-grained limestone and light-gray coarse-grained dolomite or magnesian limestone. It contains a greater proportion of dolomite than the next overlying (Newala) limestone and less dolomite than the underlying Chepultepec dolomite. It yields a compact but brittle chert that breaks down into small fragments. Most of it is gray; a little is black. So far as seen in the limestone layers it occurs in plates, there being no cavernous chert like that of the Chepultepec.

Thickness.—The thickness of the Longview limestone west of Pelham, where its boundaries can be most nearly located, is about 400 feet.

Age and correlation.—The Longview is sparingly fossiliferous, but the few species of fossils are widely and apparently uniformly distributed, so that search seldom fails to be rewarded by a few specimens. Fossils have been found from the latitude of Montevallo northward to the north boundary of the Vandiver quadrangle. The characteristic and most common fossil is the gastropod *Lecanospira* (*Ophileta*) *compacta*. This is one of the most reliable guide fossils, being known at this general horizon, to which it is confined, all along the Appalachian Valley from Alabama to Canada. It is characteristic of the Nittany dolomite of central Pennsylvania and of the lower part of division D of the typical Beekmantown of New York, with which the Longview limestone is correlated. The *Lecanospira* and another similarly wide-ranging gastropod, *Roubidouxia*, also show that the Longview limestone is to be correlated with the Roubidoux formation of Missouri.

NEWALA LIMESTONE

Name.—The Newala limestone was named from Newala, a post office on the Southern Railway between Montevallo and Calera, in the Montevallo quadrangle. It is best exposed, however, near Pelham, in the Bessemer quadrangle. The boundary between the Newala and Longview crosses the Pelham-Helena road about half a mile northwest of Pelham. The boundary between the Newala and the overlying Lenoir limestone lies near the east side of the Louisville & Nashville Railroad station at Pelham. The Newala and Longview seem to grade into each other, but the upper boundary of the Newala is, locally at least, a conglomeratic limestone forming the bottom of the Lenoir limestone. (See Pl. VII.)

Distribution.—The Newala limestone is present in Cahaba Valley and throughout the region east of the valley. A belt about half a mile wide lies along Cahaba Valley in the Bessemer quadrangle, and two belts, each about half a mile wide, separated by a narrow strip of Chepultepec dolomite and Longview limestone extend along the valley across the Vandiver quadrangle. The eastern of these two belts has been brought up by the Cahaba Valley fault. There are also two small areas in the southeast quarter of the Vandiver quadrangle.

The Newala is best displayed in the section on Buck Creek immediately northwest of Pelham, in the Bessemer quadrangle. It is also well exposed in the quarries at Keystone, Newala, and Longview and in the adjacent ground in that part of its area that lies in a general way north of Varnons, in the Montevallo quadrangle.

Character.—The Newala is predominantly a limestone. Comparatively thick bedding is the rule. Layers of dolomite a few feet thick occur here and there throughout the mass, more commonly in the lower part, but compose a small proportion of the whole. Some of the layers are mottled and consist in part of blue limestone and in part of gray dolomite in irregular distribution. The layers of dolomite are light gray and coarse grained and have a sandy appearance on the outside, so that they are called sandstone by the quarrymen. The composition of some of these magnesian layers is given in the table of analyses (p. 21). Some of the layers of limestone are dark gray and fine grained; others are dove-colored and fine grained or amorphous; and still others have a peculiar pearl-gray color, with nongranular or amorphous texture, are very brittle, and have a splintery or glassy fracture. Except for specks of clear calcite the material has much the appearance of lithographic stone. Such limestone is very characteristic of the formation from its type locality in Alabama to Tennessee. A fossiliferous layer of this kind at McGuire Ford, in the southwest corner of the Montevallo quadrangle, is sprinkled full of small rounded grains of clear glassy quartz. The upper part of the formation is of high purity and is extensively quarried for lime at a number of points between Keystone and Calera. (See table of analyses, p. 21.)

Thickness.—The thickness of the Newala in Cahaba Valley is 800 to 1,000 feet. The thickness in the southeastern part of the Vandiver quadrangle seems to be much greater than in Cahaba Valley, but owing to uncertainty as to the geologic structure no estimate of the thickness is made.

Age and correlation.—Fossils are not abundant but are generally distributed through the Newala limestone of Cahaba Valley and are confined to only a few species. The following forms from that region have been identified:

Deltatreta (Ulrich) filistriata Butts, n. gen. and sp.	Hormotoma artemesia?
Undescribed syntrophoid brachiopod.	Hormotoma gracilens?
Ceratopea keithi Ulrich. A supposed operculum of an unknown gastropod. Unknown outside of this general zone and highly characteristic.	Coelocaulis linearis?
Ceratopea, slender species.	Maclurea affinis?
	Maclurea oceana?
	Gyronema cf. G. strigillata.
	Ophileta.
	Lecanospira Ulrich, n. gen.
	Eurystomites kellogi?

In addition to the fossils listed above there are a bryozoan identified by Ulrich as a *Nicholsonella* and two species of cephalopods, one a form like *Orthoceras*, and the other a slightly curved form. The species of the list are geographically wide-ranging forms and, according to Ulrich, are restricted to limestone and dolomite formations somewhat younger than the Beekmantown at Beekmantown, N. Y.

The Newala may be compared with the reef deposits at Fort Cassin, in Addison County, western Vermont, and with the overlying division E of the Beekmantown of Champlain Valley; it is older than the St. Peter sandstone of Mississippi Valley and the lowest beds of the Chazy group of New York.

ODENVILLE LIMESTONE

Name.—The name Odenville limestone has been given to beds lying between the Newala limestone below and the base of the Mosheim limestone, the basal formation of Chazy age. Whether the Odenville succeeds the Newala without a break is unknown.

Distribution and character.—The Odenville limestone is exposed only in a cut or borrow pit on the north side of the Seaboard Air Line Railway about one-third of a mile east of Odenville, St. Clair County. It is an impure argillaceous and siliceous dark fine-grained cherty limestone about 50 feet thick. No other exposure of this limestone is known, but its fossils have been found at the same horizon—just above the Newala limestone—at several places in Cahaba Valley between Leeds and Saginaw, in Shelby County.

Age and correlation.—This bed is of great interest on account of its fossils, all of which appear to be undescribed species. A unique form is a species of *Chiton* or of a closely related genus. The most abundant form is an operculum of some unknown but rather large gastropod, probably a *Maclurea*. There are two forms of orthoceroids and at least one species each of two new genera of brachiopods, for which Ulrich (unpublished manuscript) has proposed the names *Deltatreta* and *Taffia*. There are two or three genera of trilobites represented by one species each, a *Goniurus*, a *Cybele*, and possibly a *Hystricurus* cf. *H. conicus*=*Bathyrus conicus* (Billings). There is a good-sized species of *Maclurea* with its operculum and one or two species of sponges. Further description of this fauna is contained in the publication cited in footnote 5 (p. 3).

According to Ulrich and Foerste most of the forms mentioned except *Maclurea* are of types not known above the Beekmantown elsewhere. The *Goniurus* is a Beekmantown form occurring in Canada, and the brachiopods occur in the upper part of the Arbuckle limestone of Oklahoma in beds assigned by Ulrich to the Beekmantown. The orthoceroids have features not known in such forms of an age younger than Beekmantown, and the same is true of the sponges. The Odenville is therefore regarded as of late Beekmantown age.

UNCONFORMITY BETWEEN ODENVILLE AND MOSHEIM LIMESTONES

As shown in the preceding paragraphs, the Odenville limestone carries fossils by which it is correlated with the upper part of the Arbuckle limestone of Oklahoma. Locally in Oklahoma, however, according to Ulrich, there is above the massive limestones of the Arbuckle formation 500 to 1,000 feet of shale that carries graptolites of pre-Chazyan age. This shale is followed above by the Simpson formation, which in addition to beds of older and younger age, also includes beds corresponding in age to the Mosheim limestone, which succeeds the Odenville limestone. In Alabama, however, there is no shale corresponding to that above the massive limestones of the Arbuckle in Oklahoma, mentioned above, and further the well-known still younger St. Peter sandstone of the Mississippi Valley and the associated beds are absent in Alabama. If present in Alabama these beds would also lie between the Odenville and Mosheim limestones, so that there is an unconformity between the two which would be measured by the thickness of the absent strata amounting to 1,000 feet or more.

MOSHEIM LIMESTONE

Name and definition.—Throughout the Appalachian Valley in Tennessee and much of Virginia the limestone of Beekmantown age that corresponds in part at least, to the Newala limestone and that forms the upper part of the Knox dolomite is overlain by the Mosheim limestone, named by Ulrich from Mosheim, on the Southern Railway, about 6 miles west of Greeneville, Tenn. This limestone is lithologically and faunally a well-defined unit, which in Tennessee is separated from the overlying Lenoir limestone by an erosional unconformity.

Distribution.—In Alabama the Mosheim has been certainly recognized in the vicinity of Odenville, in Cahaba Valley about 18 miles northeast of the north margin of the Vandiver quadrangle, where it is exposed in a borrow pit on the Seaboard Air Line Railway, half a mile east of the town. Here the Mosheim is directly overlain by 400 to 500 feet of Lenoir limestone and is underlain by the Odenville limestone. The Mosheim is also exposed in the west side of the quarry of the cement plant at Leeds and at Newhope Church in Cahaba Valley 7 miles northeast of Pelham. As it is also present 4 miles southeast of Shelby in the Columbiana quadrangle south of this area, it is probably present throughout this region.

Character.—The Mosheim is a pure thick-bedded blue or dove-colored limestone that has conchoidal fracture. It forms a white chalky crust on weathering. In places it is highly fossiliferous. It differs from the Lenoir limestone, which is dark, finely crystalline, and argillaceous and which, in places, in large part has crumbled to small fragments.

Thickness.—At Odenville the thickness of the Mosheim limestone is about 50 feet.

Age and correlation.—The Mosheim is in places full of gastropods of Ordovician types, large high-spired Lophospiras being prominent. At Odenville individuals are numerous, and perhaps a dozen species are present. This fauna is entirely or mostly undescribed, but it is clearly of early Chazy age. Until, however, the fossils have been identified and compared it is not possible to make definite correlations with recognized formations in other parts of the country.

LENOIR LIMESTONE

Name.—The Lenoir limestone was named by Safford and Killebrew in 1876, from Lenoir City, Tenn., which is situated on the outcrop of the formation. It unconformably overlies the Mosheim limestone, which, however, together with the Odenville limestone, is rarely exposed, so that the next lower formation seen is the Newala limestone, from which the Lenoir is sharply distinguished by a conglomerate locally and by a change in lithology and fossils. In Cahaba Valley south of Pelham the Lenoir is limited above by the easily recognized black Athens shale.

Distribution.—The Lenoir crops out in a band 500 to 1,200 feet wide along the west base of Little Oak Ridge for the full length of Cahaba Valley in these quadrangles, and in the Vandiver quadrangle north of Newhope Church a fault has made two belts of outcrop separated by a ridge of Longview limestone and Chepultepec dolomite. The base of the Lenoir can be traced by the conglomerate along the east side of the Louisville & Nashville Railroad the entire distance from Pelham to the south margin of the Bessemer quadrangle.

Character.—The Lenoir is predominantly dark, thick-bedded, rather finely crystalline limestone, but dove-colored compact layers occur. A peculiarity is the network of narrow, veinlike gray bands of about 1 inch mesh on weathered surfaces of the layers. These bands are apparently formed by clayey impurities that have been segregated into intersecting thin layers in the calcareous matter which makes up most of the layer. Between Pelham and Alabaster the lower beds of the Lenoir are conglomeratic, with subangular and well-rounded chert, quartzite, and limestone pebbles the largest of which are half an inch in diameter. These pebbles are largest and most numerous and occur through the greatest thickness of rock at the south margin of the Bessemer quadrangle, where the photograph shown in Plate VII was taken. At the same locality there is, possibly 100 feet below the limestone conglomerate, a mass of coarse conglomerate of unknown but probably small extent, which is composed of quartzite pebbles as much as 3 inches in diameter, with just enough fine material for cement. Southward and northward from this locality the number and size of pebbles in the basal Lenoir decrease, and just north of Pelham only a few small angular fragments, apparently of chert, occur in a 2-foot layer of limestone. The basal beds of the Lenoir are also cherty in places, and a few dark irregular inclusions of chert occur throughout the mass.

Thickness.—The thickness of the Lenoir is about 500 feet in the vicinity of Pelham and Keystone but appears to be as much as 700 or 800 feet in the northern part of the Vandiver quadrangle.

Age and correlation.—*Maclurea magna* is a common fossil throughout the Lenoir limestone in these quadrangles. This fossil occurs along the Appalachian Valley northward to northeastern New York and northwestern Vermont, where it seems to be confined to the part of the Chazy group now known as the Crown Point limestone. This evidence seems sufficient ground for the correlation of the Lenoir with the middle Chazy. It is also correlated with the Pierce and Ridley limestones of the Stones River group of the Nashville basin, Tenn., *Maclurea magna* having been found in the Ridley, according to Safford and Ulrich.

UNCONFORMITY AT TOP OF LENOIR LIMESTONE

Cahaba Valley appears to contain no representative of the Lebanon limestone of the Stones River group of Tennessee, which overlies the Ridley limestone, nor of the Holston marble, both of which, in a complete section, would intervene between the Lenoir and the Athens shale. There is, therefore, between the Lenoir and Athens in Alabama a gap represented by 700 feet or more of limestone that occurs in parts of Tennessee. Furthermore the Athens shale is absent at Pelham and northward, so that the gap between the Lenoir and Little Oak limestones is equivalent to 1,200 feet of shale and limestone or, if the maximum thickness of the Athens in Tennessee—3,000 feet—is regarded, the gap represents a much greater thickness of rocks and a greater length of time.

ATHENS SHALE

Name.—The Athens shale was named by Hayes[12] from Athens, Tenn., where it is strongly developed.

Distribution.—There are but two small areas of the Athens in the quadrangles—one along the west base of Little Oak Ridge from Keystone to the south margin of the Bessemer quadrangle and one on the Page Spring anticline in the southeast corner of the Vandiver quadrangle. The Athens does not extend far north of Keystone, for at Pelham the Little Oak limestone, overlying the Athens, is in contact with the Lenoir limestone.

The only exposure of the Athens seen in this area is at the west base of the Fort Payne chert ridge in the road half a mile southeast of Keystone, in the Bessemer quadrangle. In the Montevallo quadrangle, to the south, it is exposed at a number of places, the nearest to this area being on the Birmingham road about a quarter of a mile south of Alabaster. Just south of the Louisville & Nashville Railroad, about a quarter of a mile south of Siluria, 100 feet or more of dark shale and thin limestone was once exposed but has been covered up in grading the road.

Character.—The Athens shale is mostly black or dark from carbonaceous matter and probably is calcareous. It includes thin layers of dark limestone. Some layers are sufficiently ferruginous to weather brown, and locally there is at the top a layer of green shale a foot or two thick. A very noteworthy feature is the presence of great numbers of graptolites (listed below) that represent a considerable range of species.

Thickness.—At the outcrops just noted a thickness of several hundred feet is indicated. At Simpson Spring, in the Montevallo quadrangle, $2\frac{1}{2}$ miles northwest of Calera, where the opportunities for measurement are best, the Athens is 300 to 500 feet thick.

Age and correlation.—Considerable collections of graptolites have been made from the Athens shale of this region. Although these collections have not been thoroughly studied, the following species have been identified by Ruedemann and Ulrich:

- Climacograptus cf. C. putilus (Hall).
- *Cryptograptus tricornis (Carruthers).
- Dicellograptus smithi Ruedemann.
- Dicellograptus moffatensis var. alabamensis Ruedemann.
- Dicellograptus mensurans Ruedemann.
- *Dicranograptus nicholsoni var. parvangulatus Gurley.
- Dicranograptus near D. contortus Ruedemann.
- *Didymograptus sagitticaulis Hall.
- *Diplograptus foliaceus var. alabamensis Ruedemann.
- *Glossograptus ciliatus Emmons.
- Leptograptus flaccidus.
- Nemagraptus gracilis var. surcularis Hall.
- Retiograptus geinitzianus Hall.

All these species occur in the Normanskill shale of New York, which proves that formation to be of the same age as the Athens shale. The five species prefixed by an asterisk (*) occur also in the Womble shale in Arkansas, with which the Athens is accordingly correlated.

Some of the species listed are of world-wide distribution, being found in the northwestern part of the United States, in England, in Scotland, and in Australia, thus proving that in Athens time these remote parts of the earth were connected by water under conditions favorable to the propagation and migration of graptolites.

Besides graptolites the Athens has yielded a considerable number of species of brachiopods and trilobites, which have not been carefully studied. Probably most of the species are undescribed.

UNCONFORMITY AT BASE OF LITTLE OAK LIMESTONE

As shown in the description of the Athens shale, the Little Oak limestone is unconformable upon the Lenoir limestone in the northern part of Cahaba Valley. The true extent of this unconformity is unknown. It depends upon the age of the Little Oak. If it is older than the Tellico sandstone the unconformity is measured by the Holston marble and Athens shale. If it is younger than the Sevier shale the unconformity is measured by the Holston marble, Athens shale, Tellico sandstone, and Sevier shale, which have a combined thickness of 7,000 feet or more.

LITTLE OAK LIMESTONE

Name.—The Little Oak limestone was named from Little Oak Ridge, a prominent feature of Cahaba Valley north of Pelham, in the Bessemer quadrangle. The limestone crops out on the west side of the ridge and extends to the crest.

Distribution.—The Little Oak limestone is persistent along the west escarpment of Little Oak Ridge from Pelham to the north margin of the Vandiver quadrangle. Immediately north of Pelham its outcrop is repeated by faults, so that there are three long, narrow areas of it. The best exposure is on the point of a prominent synclinal spur $1\frac{1}{2}$ miles southwest of Newhope church, just on the west side of the Vandiver quadrangle. It is also well exposed in the Atlanta, Birmingham & Atlantic Railway cut and adjacent thereto just east of Pelham. The limestone is prominently exposed and apparently of full thickness in the high knobs south of Peavine Creek, half a mile southeast of Pelham. It thins out southward from Pelham by loss of beds from the top, so that at the northern margin of the Montevallo quadrangle, to the south, only the bottom 100 feet or so remains, and farther south, about 1 mile southeast of Siluria, it wedges out, the Frog Mountain sandstone, overlying the Little Oak to the north, being in contact with the Athens shale. Evidently the Little Oak in the area just outlined was beveled off by erosion in the long interval that preceded the deposition of the Frog Mountain sandstone. In the Page Spring anticlinal area, in the southeastern part of the Vandiver quadrangle, chert with Ordovician fossils (*Plectambonites*, *Orthis tricenaria?*, and *Pterygometopus*), mingled with chert with Mississippian fossils (*Platycrinus*), indicates the presence of limestone regarded as probably Little Oak.

Character.—The Little Oak limestone is composed of dark fine-grained thick-bedded cherty and earthy limestone. The chert occurs as irregular plates or nodules, arranged in definite planes. A very characteristic feature is the pattern taken by the earthy impurities on weathering, the exposed surfaces of the limestone beds being covered by a network of gray earthy ridges an inch or two wide, inclosing in their depressed meshes patches of clear blue limestone the largest of which are the size of the hand. (See Pl. XVI.) This character is especially prominent at the top of the limestone, just below the Fort Payne chert, from Pelham northward for 3 miles or more.

Along the west side of the Fort Payne chert ridge south of Pelham and into the Montevallo quadrangle the lower part of the Little Oak is partly made up of highly argillaceous layers, which tend to break up into shaly débris on weathering. It probably also includes layers of shale. Some of the argillaceous limestone is banded with pinkish layers. The character of the lower part of the Little Oak suggests continuous deposition from the Athens, but as the Tellico sandstone of Tennessee, the stratigraphic position of which is probably between the Athens shale and the Little Oak limestone, is not represented in the region, the appearance is deceptive.

Thickness.—The greatest thickness of the Little Oak limestone probably does not exceed 400 feet, which it appears to reach in the northern part of the Vandiver quadrangle. At Pelham its thickness is not over 250 feet.

Age and correlation.—The Little Oak limestone has yielded a considerable number of fossils, and the general character of the fauna is indicated by the subjoined list.

The basal part of the formation is, locally at least, very fossiliferous, and the fossils occur in chert, which is derived perhaps from highly argillaceous or siliceous layers of limestone. The following fossils have been identified:

- Nidulites sp.?
- Receptaculites sp.?
- Christiania near C. trentonensis Ruedemann.
- Christiania, lamellose sp., probably new.
- Orthis crassicosta Butts. Resembles O. panderiana (Hall and Clarke) = O. orthambonites Billings.
- Dalmanella fasciculata Butts.
- Three genera of orthoids suggesting Dalmanella, Hebertella, and Pianodema.
- Plectambonites near P. pisum Ruedemann.
- Rafinesquina sp.
- Strophomena n. sp.?
- Ambonychia sp.?
- Maclurites sp.?
- Tetranota cf. T. obsoleta.
- Twenty or more species of gastropods, including species of Bucania and Trochonema.
- Illaenus sp.?
- Lichas?
- Pterygometopus sp.?
- Sphaerocoryphe sp.?
- Leperditia ovalis Butts.

The fauna of the Little Oak limestone is unique and as yet has yielded but little information beyond the fact that it is probably of latest Lower Ordovician age. So far it has failed to reveal a single species that is certainly identical with any described form. The *Christiania* and *Plectambonites* near *P. pisum* closely resemble *C. trentonensis* and *P. pisum*, respectively, from the Rysedorph conglomerate near Albany, N. Y., but until the Alabama specimens are critically compared with the type specimens and found to be the same it is unsafe to identify them with the species named. Both species have been identified by Ulrich from the Chambersburg limestone of Pennsylvania, but he is not certain that they are really those species or the same as the Alabama species. *Orthis crassicosta* agrees very closely with the figure and description of the form described by Billings under the name *Orthis orthambonites* (=*O. panderiana* Hall and Clarke), a Beekmantown species. A few of these fossils are figured in "Geology of Alabama," recently published by the Alabama Geological Survey.

The Little Oak limestone has been traced northeastward into northwestern Calhoun County, half a mile south of Reads, where it is overlain by red shale known from its fossils to be of Lowville age. This occurrence, in connection with its relations to the Lenoir limestone and Athens shale, definitely fixes its age as upper Chazy and younger than the typical Chazy of New York. As it lies within the same stratigraphic limits as the Tellico sandstone and Sevier shale of the Knoxville region, Tennessee, it is regarded as equivalent to some part of those formations, probably to part of the Sevier.

BIRMINGHAM VALLEY

UNCONFORMITY AT BASE OF CHICKAMAUGA LIMESTONE

In Birmingham Valley the Chepultepec dolomite and the Longview and Newala limestones are absent, so that the Chickamauga limestone, including locally the Attalla conglomerate member at the base, was deposited upon the eroded surface of the Copper Ridge dolomite.

CHICKAMAUGA LIMESTONE

Name.—The name Chickamauga limestone was introduced by Hayes[13] from Chickamauga Creek, east of Chattanooga, Tenn., along which the limestone is typically developed.

Subdivisions.—In the Chickamauga of this area are included three members—the Attalla conglomerate, locally developed at the base; next a shale, also local; followed by the limestone that composes the main mass of the formation. On Red Mountain, at a few points between Birmingham and Bessemer, slabs of a soft ferruginous and calcareous, highly fossiliferous sandstone were collected at the top of the Chickamauga limestone. No exposures of this rock were seen, but there can be only a small thickness and small patches of it, for in some exposed sections it is not present. The fossils collected from this sandstone are of Lorraine age. In northern Alabama the Chickamauga limestone includes still younger beds, of Sequatchie (Richmond) age, but those beds are absent in the Bessemer and Vandiver quadrangles.

Distribution.—The main area of the Chickamauga is the belt extending along the whole length of the west escarpment of Red Mountain. There is a small wedge-shaped area on West End Mountain, west of Bessemer, and a small area of the basal red and purple beds, both shale and limestone, at Interurban Heights on the electric railroad about midway between Birmingham and Bessemer. A single small exposure was seen at the base of one of the small outliers of the Red Mountain formation on Flint Ridge half a mile north of Walnut Grove, in the SE. $\frac{1}{4}$ sec. 14, T. 18 S., R. 4 W. Only a thin layer of Chickamauga limestone can be present here, however. The basal mottled layers are also exposed in the street leading up to Mountain Terrace, Birmingham, where they are in immediate contact with the Copper Ridge dolomite; and at Sloss No. 1 mine, Bessemer, where they are separated from the Copper Ridge by the shale member, there about 100 feet thick. These variegated layers in the base of the limestone mass of the Chickamauga appear to be a constant feature, for they have been observed from Foster Mountain, 15 miles northeast of Birmingham, to a point several miles southwest of Bessemer.

Character.—The Chickamauga is mainly a limestone, the layers of which range from an inch or two to 2 feet or more in thickness. (See Pls. VIII, IX, and X.) Most of the mass is medium grained, but there are layers of lithographic texture. As a rule the color is dove-gray or dark gray, but locally the basal layers are purple or mottled with purple. In some places these layers are highly argillaceous or even become a slightly calcareous and compact red shale or mud rock. Near the top of the formation is a layer of volcanic ash or tuff about 2 feet thick.

The detailed section of the Chickamauga as exposed at Mountain Terrace, in the northeast environs of Birmingham, which is given on page 7, shows its general character. (See also fig. 3, section 1.)

Below the main mass of limestone occurs locally a rock that weathers to the consistency of dry mud and that, in the unweathered condition, is probably a thin-layered calcareous mud rock. This rock, which may be called a shale, carries

[12] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Kingston folio (No. 4), 1894.

[13] Hayes, C. W., Geol. Soc. America Bull., vol. 2, p. 143, 1891 (paper read at meeting of December, 1890); U. S. Geol. Survey Geol. Atlas, Chattanooga folio (No. 6), 1894.

Lingulas as much as 1 inch long and half an inch broad. It is exposed at the intersection of Fourteenth Street and Fourteenth Avenue, South Birmingham, and near Sloss No. 1 mine, Bessemer. At this place 50 feet is exposed, and the bed is probably at least 100 feet thick; below it is the Attalla conglomerate, and above it 50 feet of purple mottled limestone.

Section of Chickamauga limestone at Mountain Terrace, Birmingham, Ala.

	Feet
Red Mountain formation.	
Chickamauga limestone:	
Beds of lower Trenton age (Pl. X):	
Limestone, thick layered, bluish, finely crystalline, full of *Plectambonites curdsvillensis*	2
Limestone, thin layered	8
Limestone, thick layered	2
Limestone, thin layered, finely crystalline, compact, blue; shale partings	8
Limestone, medium thick bedded, coarse and fine grained, compact, bluish, cherty; black chert layers as much as 3 inches thick; trilobites and *Plectambonites* in bottom	3
Limestone, cobbly or nodular, argillaceous matrix; free fossils, *Conradella*, *Bucania*	5
Limestone, evenly thin layered	3
Volcanic ash or tuff (bentonite)	2±
Limestone with large *Plectambonites* and *Heterorthis clytie* Hall; of basal Trenton age	2
Beds of upper Black River age:	
Limestone, medium thick bedded, cherty, coarsely crystalline, weathers chalky, somewhat cobbly or rough surfaced, dove-colored or bluish gray; contains *Orthis tricenaria*, *Pianodema* (*Dalmanella*) *subequata*, *Carabocrinus*, *Chiton*. In this division, too, on Twentieth Street Road 2 miles southwest of Mountain Terrace, *Stromatocerium rugosum* and *Ectomaria prisca*, two good Black River fossils, were collected within 10 feet below the bentonite bed	3
Not exposed	25±
Beds of Lowville age (Pl. IX):	
Limestone, in old quarry, thin bedded	20±
Limestone, in old quarry, thick bedded	30±
Limestone, nodular or cobbly, fossils	1±
Unconformity (Athens shale, Holston marble, Tellico sandstone, and typical Sevier shale absent).	
Beds of Stones River age:	
Limestone, thick bedded	35±
Limestone, shaly, cobbly	5
Limestone, thick bedded; many gastropods	35±
Limestone, thick bedded; mottled purplish, basal layers	5
Copper Ridge dolomite (thick-bedded, densely cherty dolomite).	
	194±

Thickness.—The thickness of the Chickamauga in the Bessemer quadrangle probably does not exceed 250 feet, but exact measurement is difficult. The thickness differs from place to place. The thickness above the bentonite bed is 30 feet at Mountain Terrace and apparently only about 10 feet on Twentieth Street Road, Birmingham. Variations in thickness would result from the unconformities within its mass. At Birmingham a fairly careful measurement gives 194 feet, as shown in the section above, but the basal shale and the Attalla chert conglomerate are absent at the point where this section was measured. In Tennessee beds included in the Chickamauga in places aggregate a much greater thickness.

Attalla chert conglomerate member.—The Attalla chert conglomerate member, named in the Birmingham folio from Attalla, Ala., is composed mostly of rather small angular fragments of chert embedded in a matrix composed of comminuted chert. In places it includes well-rounded quartzite pebbles, the largest of which are 4 or 5 inches in diameter. It occurs in small isolated areas, as in Birmingham, on Cemetery Ridge and at the intersection of Fourteenth Street and Fourteenth Avenue in South Highlands, where it has been exposed in grading a street; near West End, in a conspicuous little knoll about 500 feet southeast of the Alabama Great Southern Railroad; at Woodward and Brighton; and at several places in the Salem Hills, southwest of Bessemer.

The thickness of the Attalla differs considerably from place to place, but in general there is nothing to indicate that it is anywhere more than 20 to 40 feet thick.

The Attalla lies upon the eroded surface of the Copper Ridge and Ketona dolomites and in places upon the edges of their upturned and eroded beds. A mile or so south of Birmingham a low knoll of the Attalla rests on the Conasauga limestone. Nowhere, so far as known, is the conglomerate overlain by rocks older than Chickamauga. It is possible that some areas of the Attalla were deposited in old caves or underground watercourses in the dolomites in the period when the region was above sea level, preceding the deposition of the Chickamauga, or even in Mesozoic time. In places, however, it is a bedded deposit dipping beneath the Chickamauga.

Volcanic ash (*bentonite*).—The presence of a layer of volcanic ash in the uppermost part of the Chickamauga of this region first came to light in sinking the Woodward shaft to the Big seam of iron ore 3 miles southeast of Bessemer. Near the bottom of the shaft a 20-inch layer of gray crumbling rock attracted the attention of J. A. Udden, geologist of the Tennessee Coal, Iron & Railroad Co. Samples were taken and submitted to E. S. Larsen, of the United States Geological Survey, who reported upon the rock as follows:

> The rock is made up very largely of rather coarsely crystalline montmorillonite with several per cent of orthoclase, less of magnetite, quartz, and biotite, and accessory apatite and zircon. It is without doubt an altered rhyolite tuff and is similar to the bentonites of the western United States. The montmorillonite is probably derived from the glass of the original tuff.

The ash bed was later identified by Wilbur A. Nelson, State geologist of Tennessee, on Red Mountain at Birmingham, where on the Twentieth Street Road it appears to be about 10 feet below the top of the Chickamauga. (See Pl. XVII.) He identified it also on Mountain Terrace road, where it is 31 feet below the top of the Chickamauga, as shown in the section at the left and in Plate X. At both these points and in the Woodward shaft it is associated with *Plectambonites curdsvillensis*, which occurs above and below it. Close below it on Mountain Terrace, however, are still other fossils, as listed in the section. *Plectambonites curdsvillensis* is a form peculiar to the limestone in Kentucky known as the Curdsville limestone, of basal Trenton age. The circumstances would seem to indicate that the ash bed was deposited in Alabama in the early part of the Trenton epoch. Volcanic ash in the same stratigraphic relations is now known at points as far north as southern Ohio and central Pennsylvania. Evidently there were active volcanoes in early Trenton time near enough for the ash to be transported into Alabama either by air or by water. In central Pennsylvania thin beds of volcanic ash occur in limestone of Chazy age also, and in Alabama at Ragland such beds have recently been discovered in the Little Oak limestone, also of Chazy age.

Age and correlation.—About the lower half of the Chickamauga limestone in this area represents the Stones River group of middle Tennessee, which is equivalent to part of the Chazy group of New York. The Lenoir limestone of Cahaba Valley is believed to be represented in the lower half of the Chickamauga. The upper part of the formation in the knobs to the southwest of Blount Mountain in the Birmingham quadrangle and at Birmingham contains a good fauna of Black River age, and at the top of the formation in both localities limestone of Trenton age occurs in thicknesses ranging from 10 to 50 feet. (See sections, p. 8.)

The fossils of the following lists, collected mainly in the Birmingham quadrangle and identified by Ulrich, are the basis of the statements made above:

Corynoides n. sp.
Solenopora compacta (Billings).
*Tetradium syringoporoides Ulrich.
*Batostoma libana Safford.
Eridotrypa aff. E. aedilis (Eichwald).
*Escharopora aff. E. ramosa Ulrich.
*Escharopora aff. E. briareus Ulrich.
*Nicholsonella pulchra Ulrich.
*Pachydictya aff. P. robusta Ulrich.
Prasopora aff. P. contigua Ulrich.
Rhynidictya nicholsoni Ulrich.
Rhynidictya trentonensis Ulrich.
Dalmanella aff. D. hamburgensis (Walcott).
Pianodema (Dalmanella) subequata (Hall and Clarke).
Dalmanella aff. D. testudinaria Conrad.
Dinorthis aff. D. germana (Winchell and Schuchert).
*Hebertella aff. H. bellarugosa (Conrad).
Orthis tricenaria Conrad.
*Plectambonites subcarinatus Ulrich MS.?
Rafinesquina incrassata (Hall).
Rafinesquina aff. R. alternata (Emmons).
Rafinesquina minnesotensis var. N. H. Winchell.
Rafinesquina aff. R. deltoidea Conrad.
Rhynchotrema minnesotensis Sardeson.
*Rhynchotrema plena (Hall).
*Cyrtodonta aff. C. billingsi Ulrich.
Bucania aff. B. lindsleyi Safford.
Ectomaria aff. E. dryope Billings.
*Helicotoma tennesseensis Ulrich and Scofield.
*Liospira progne (Billings).
*Liospira subconcava Ulrich.
*Lophospira perangulata (Hall).
Lophospira bicincta (Hall).
Vanuxemia 2 sp.
*Salterella billingsi Safford.
Aparchites trentonensis Ulrich.
Bythocypris aff. B. robusta Ulrich.
*Isochilina aff. I. gregaria (Whitfield).
*Isochilina aff. I. ottawa (Jones).
Krausella aff. K. inequalis Ulrich.
Leperditia fabulites-pinguis Conrad, Ulrich var.
*Leperditella inflata Ulrich.
Bathyurus aff. B. extans (Hall).
Isotelus maximus Locke?
Isotelus aff. I. gigas Dekay.
*Illaenus aff. I. consimilis Billings.
Pterygometopus aff. P. intermedius (Walcott).

The fossils whose names are preceded by an asterisk (*) are known only from beds of Stones River age. Most of the others are probably distinct species whose nearest relatives are the described species named. Ulrich recognizes, through these fossils, representatives of the four lower formations of the Stones River group, namely, in ascending order, the Murfreesboro limestone, Pierce limestone, Ridley limestone, and Lebanon limestone.

In Birmingham Valley in the Bessemer quadrangle and elsewhere there do not appear to be any beds equivalent to the Holston marble, Athens shale, Tellico sandstone, and typical Sevier shale (=Ottosee shale of Ulrich) of Tennessee and the Little Oak limestone of Cahaba Valley, aggregating as a maximum 6,000 to 8,000 feet of strata of late Chazy age. The absence of these strata makes a great unconformity between the Stones River and Black River parts of the Chickamauga limestone of this area. The exact position of this unconformity is not certainly determined, but it is at least about 90 feet below the top of the beds of Black River age and is believed to be at the horizon of the thin rubbly limestone and coral reef shown in Plates VIII and IX. The beds immediately above this rubbly layer are of Lowville age, but it is not yet proved that the immediately underlying limestone is of Stones River age, although that is probable from the different character of the limestone and from the fact that Stones River fossils have been collected at the quarry shown in Plate IX from beds extending from the bottom of the Stones River equivalent upward apparently high enough to include this limestone. The occurrence of coral reefs at this horizon, as shown in Plate VIII, may indicate a break.

The Black River fossils from the upper half of the Chickamauga limestone consist of the following forms:

Solenopora compacta (Billings).
Stromatocerium rugosum Hall.
Camarocladia rugosa Ulrich.
Tetradium cellulosum (Hall).
Cryptophragmus antiquatus Raymond=Beatricia gracilis Ulrich MS.
Anolotichia impolita Ulrich.
Monotrypa magna Ulrich.
Phyllodictya varia Ulrich.
Escharopora confluens Ulrich.
Orthis tricenaria Conrad.
Dalmanella aff. D. hamburgensis Walcott.
Pianodema (Dalmanella) subequata (Hall and Clarke).
Dinorthis deflecta (Conrad).
Rhynchotrema plena (Hall).
Rhynchotrema minnesotensis Sardeson.
Rafinesquina alternata Emmons.
Rafinesquina incrassata Hall.
Cliftonia occidentalis Butts.
Strophomena incurvata (filitexta) (Shepard).
Vanuxemia crassa Ulrich?
Conradella sp.?
Ectomaria prisca (Billings)?
Ctenobolbina subcrassa Ulrich.
Eurychilina subradiata Ulrich.
Eurychilina obesa Ulrich.
Schmidtella crassimarginata Ulrich.
Leperditella germana (Ulrich).
Bathyurus spiniger (Hall).
Bumastus trentonensis Emmons.
Pterygometopus callicephalus (Hall).

According to Ulrich, *Tetradium cellulosum*, *Cryptophragmus antiquatus* (*Beatricia gracilis*), *Escharopora confluens*, *Phyllodictya varia*, *Schmidtella crassimarginata*, *Ctenobolbina subcrassa*, and *Bathyurus spiniger* are known only in beds of early Black River or Lowville age. The *Cliftonia* is a rare representative of a fauna which usually is confined to the eastern belt of the Appalachian Valley from Canada to Alabama.

The 45 feet of granular limestone that forms the top of Foster Mountain, from which came all but one of the following fossils, and 10 to 30 feet of thin-bedded limestone in Red Mountain, at Birmingham, represent the Trenton limestone of New York.

Dendrocrinus acutidactylus Billings.
Pachydictya aff. P. acuta (Hall).
Rhinidictya neglecta? Ulrich.
Dinorthis aff. D. holstoni (Safford).
Dinorthis pectinella (Emmons).
Rafinesquina alternata (Emmons).
Rhynchotrema cf. R. increbescens (Hall).
Plectambonites curdsvillensis Foerste.
Zygospira recurvirostris (Hall).
Isotelus maximus Locke.
Encrinurus vannulus Clarke.

Plectambonites curdsvillensis, according to Ulrich, is characteristic of beds of basal Trenton age in Kentucky and elsewhere. It occurs in the section at Mountain Terrace, Birmingham. The same form associated with *Dalmanella testudinaria* is present in the topmost 8 feet of the Chickamauga in the bottom of the Woodward shaft in Shades Valley 3 miles southeast of Bessemer. The Trenton part of the Chickamauga in the Bessemer quadrangle therefore corresponds to only the base of the Trenton elsewhere.

The slabs of soft ferruginous and calcareous highly fossiliferous sandstone collected at the top of the Chickamauga limestone on Red Mountain, at a few points between Birmingham and Bessemer, contain the fossils listed below, which were identified by Ulrich. These fossils show this sandstone to be of early Lorraine age and to correspond to the Eden shale of Ohio and Kentucky. It is the sole representative of the Cincinnatian series in the district.

Cornulites (Conchicolites) corrugatus (Nicholson).
Dalmanella multisecta (Meek).
Dinorthis cf. D. retrorsa (Salter).
Pholidops cincinnatiensis Hall.
Rafinesquina ulrichi (James).
Calymene callicephala Green.
Isotelus maximus Locke.
Lepidocoleus jamesi Hall and Whitfield.

UNCONFORMITY AT TOP OF THE ORDOVICIAN

In Birmingham Valley there is a great stratigraphic gap between the Chickamauga and the overlying Red Mountain formation, and in Cahaba Valley between the Little Oak limestone and the overlying Frog Mountain sandstone. In Birmingham Valley all the rocks of Trenton age, except a few feet of basal Trenton, and all the rocks of Cincinnatian age, except locally a few feet of early Lorraine (Eden) age, are absent, and in Cahaba Valley, in addition, the entire Silurian system and all of the Devonian system below the Frog Mountain sandstone are absent. In Ohio, New York, and Pennsylvania, where rocks of these ages occur, their aggregate thickness is 5,000 feet.

SILURIAN SYSTEM

The Silurian system is represented in this area only by the Red Mountain formation.

RED MOUNTAIN FORMATION

Name.—The name Red Mountain "group" of Tuomey embraced all the rocks from Cambrian to basal Carboniferous inclusive that crop out in Jones and Opossum valleys. Smith, however, restricted the name Red Mountain to the Silurian formation. These rocks have also been called Clinton formation and Rockwood formation. However, as the fossils show that the part of the Red Mountain above the bottom of the Big seam of iron ore is of Clinton age and the part below the Big seam is of upper Medina age, and as the rocks are lithologically similar throughout, so that it is not desirable to separate them into two formations, Smith's very appropriate name Red Mountain formation is adopted for them.

Distribution.—The formation crops out along the crest of Red Mountain and extends below Shades Valley and the Cahaba coal field eastward to the great Helena fault. This area contains the largest exposures of the formation and also the main known body of workable iron ore. The formation is not present in Cahaba Valley, where its horizon is included in the unconformity between the Little Oak limestone and the Frog Mountain sandstone. There are small outliers of the formation along the crest of Flint Ridge and a narrow strip in the fault block south of Wylam. There is a considerable area in West Red Mountain. As shown by bore holes, the formation extends westward beneath the Warrior coal field for at least 10 miles, but its western limit is not known.

Character.—The Red Mountain formation is composed of sandstone, shale, iron ore, and a very little limestone. Sandstone is the largest constituent. The sandstone above the Big seam of iron ore (Clinton part of the Red Mountain) is thick bedded, fine grained, largely ferruginous, and hence red and hard, but some that contains less iron oxide is yellowish and softer. Most of it is only slightly or not at all fossiliferous. One bed (Hickory Nut ore seam), however, carries abundant *Pentamerus oblongus*.

The sandstone in the Medina part (below the Big seam) occurs partly in thin layers mixed with shale and partly in a thick-bedded stratum 25 feet thick. The thin layers are medium fine grained, brownish, soft, porous, and friable or mealy. Some are highly fossiliferous and ferruginous and dark brown to nearly black. Probably most of the thin layers of sandstone are limy in their natural state, and the porous condition at the outcrop is due to the leaching of the limy cement. The thick-bedded sandstone is fine grained, compact, soft, and slightly ferruginous. It weathers reddish brown on the surface but is yellowish within. The shale throughout the Red Mountain is mostly a hardened laminated yellowish-green clay, but locally it is bleached nearly white on exposure.

The following sections, the graphic sections in Figure 3, and Plates XI–XIII show the character of the formation.

Section of Red Mountain formation and Chickamauga limestone on Twentieth Street in Birmingham, on summit of Red Mountain, at southwest corner of sec. 6, T. 18 S., R. 2 W.

[The measurements of the part below the Big seam were made with a ruler on a clean exposure]

	Ft.	in.
Fort Payne chert:		
Chattanooga shale	1	
Sandstone, yellow, coarse, friable (Frog Mountain sandstone)	10	
Red Mountain formation:		
26. Shale, violet, purple, and gray, with sandstone layers 2 feet in maximum thickness	45±	
25. Not exposed. Shale and sandstone with *Pentamerus* zone (Hickory Nut seam) and Ida seam of iron ore	50±	
24. Sandstone, thick bedded, ferruginous	25±	
23. Iron ore (Big seam)	16	6
22. Shale and sandstone with pebbles	2±	
21. Iron ore (Irondale seam)	6±	
20. Shale and thin sandstone layers	2	
19. Shale mainly; thin sandstone layers near middle	7	6
18. Shale, full of thin sandstone layers 4 inches in maximum thickness	4	
17. Shale mainly; a few thin sandstone layers	8	
16. Shale and thin sandstone layers 2 inches in maximum thickness	4	
15. Shale mainly	6	
14. Ore, lean, fossiliferous, small quartz pebbles	1	
13. Sandstone, ferruginous, dark brown to black, rotten, fossiliferous	7	6
12. Shale, yellow	2	
11. Sandstone, ferruginous, dark brown, rotten, like No. 13	2	
10. Shale, yellow		6
9. Sandstone, thick bedded, ferruginous, yellow; weathers reddish	3	9
8. Shale, yellow	1	
7. Sandstone like No. 9	14	
6. Sandstone, bouldery	5	
5. Shale and thin sandstone	14	
4. Not exposed; like No. 5 (known from section on Mountain Terrace, Birmingham)	20±	
	257±	
Chickamauga limestone:		
3. Limestone; *Plectambonites curdsvillensis* of basal Trenton age)	5–10	
2. Volcanic ash (bentonite)	1	6
1. Limestone: *Stromatocerium rugosum, Ectomaria prisca* ? (of Black River age).		

Section of Red Mountain formation near Sloss No. 1 mine, at Bessemer

	Ft.	in.	Feet
Fort Payne chert.			
Devonian (?) thin.			
Red Mountain formation:			
12. Sandstone, thick bedded, ferruginous, red			30
11. Shale and sandstone			40
10. Sandstone, thick bedded, ferruginous, red			20
9. Shale and sandstone			15
8. Sandstone full of *Pentamerus* (Hickory Nut seam)			10
7. Ore, Ida seam?			4
6. Sandstone, ferruginous, red, cross bedded			20
5. Ore, Big seam:			
Ore; bench mined	14	1	
Sandstone and shale, yellow-green	3	1	
Ore, limy	2	5	
Sandstone, highly ferruginous	5	11	
			25½
4. Shale and thin sandstone layers			40±
3. Sandstone, ferruginous, dark brown, rotten; contains fossils			5±
2. Shale and sandstone like No. 3			20±
1. Not exposed, like No. 2 (?)			20±
Chickamauga limestone.			
			249±

Section of Red Mountain formation and Chickamauga limestone in bore hole at Woodward shaft, 3 miles southeast of Bessemer

[Identifications and measurements by J. A. Udden, except the section of the Chickamauga, which was measured by the author]

	Ft.	in.
Fort Payne chert.		
Chattanooga shale: Shale, chocolate-colored		5
Red Mountain formation:		
Limestone, mottled, argillaceous	1	
Sandstone, dark, argillaceous	1	
Shale, black, pyritiferous	4	7
Limestone, mottled, argillaceous, in places ferruginous	4	
Shale, very sandy, limestone lenses	35	
Sandstone, ferruginous	36	
Shale, sandy	13	
Sandstone, ferruginous	14	2
Sandstone, very calcareous; contains *Pentamerus*	1	
Shale, grayish	2	6
Ore, fine grained, limy streaks (Ida seam)	3	10
Sandstone, argillaceous, reddish	15	6
Ore, Big seam; upper 8 feet 8 inches good ore	21	
Shale, with sandstone layers	87	
Total thickness of Red Mountain formation	239	7
Chickamauga limestone:		
Limestone, *Plectambonites curdsvillensis* (of Trenton age)	3	6
Volcanic ash (bentonite)	1	8
Limestone, *Plectambonites curdsvillensis, Dalmanella testudinaria* (of Trenton age)	6±	

The amount of limestone is insignificant. More is shown in the Woodward shaft than is known elsewhere.

The iron-ore beds are made up largely of fragments of fossil Bryozoa and brachiopods, replaced and cemented by iron oxide and mingled with sand and small quartz pebbles. The unweathered ore preserves much of the calcium carbonate of the fossils, and this may reach 20 per cent of the ore bed.

The sandstone, Nos. 6 to 9, of the section on Twentieth Street in Birmingham does not extend as far south as Bessemer. The dark rotten fossiliferous sandstone, Nos. 11 to 13, persists and is No. 3 of the section at the Sloss No. 1 mine at Bessemer. The limestone in the upper part shown in the section at the Woodward shaft is not known elsewhere in any outcropping sections.

rock") out of which have been made the pebbles between the Irondale and Big seams described above. The absence in the Bessemer quadrangle of the rocks separating the two seams in the vicinity of Irondale and the presence of pebbles made out of some of these rocks indicate a gap or unconformity between the two beds in the Bessemer quadrangle.

Big seam.—The Big seam is the center of interest in the Red Mountain formation because it is the foundation on which rests the industrial greatness of the Birmingham district. It includes about 20 feet of ore and ferruginous sandstone, and in practical continuity below it, in the northern part of the Bessemer quadrangle, is the Irondale seam, which makes the entire mass about 25 feet thick. The upper 10 to 14 feet of the bed is the best, and mining is practically confined to this portion. (See Pl. XIV.)

Ida seam.—The Ida seam, 15 to 50 feet above the Big seam, appears to be persistent, as it is known from Irondale to Bessemer. In places, as in the Sloss No. 1 mine, near Bessemer, the Ida seam is directly beneath the *Pentamerus*-bearing bed; in other places it seems to be 15 to 20 feet below that bed, possibly because *Pentamerus* is not plentiful enough close above the Ida seam at that place to have been observed.

Hickory Nut seam.—The *Pentamerus* zone is persistent and lies 30 to 50 feet above the Big seam. The sandstone in which casts of the brachiopod *Pentamerus oblongus* are abundant and which is strongly impregnated with iron oxide is commonly called an iron ore under the name Hickory Nut seam, suggested by the resemblance of the internal casts of the fossil to the opening hull of a hickory nut. The bed, however, is nowhere, so far as the author knows, an iron ore, and the name is therefore a misnomer.

Potholes in the Red Mountain formation.—At the Ishkooda mine a cylindrical mass of sandstone 20 feet or so in diameter penetrates the ore bed. The sandstone contains *Pentamerus*. A pothole probably had been formed in the ore bed at the time *Pentamerus* was living in the region or later, and this pothole

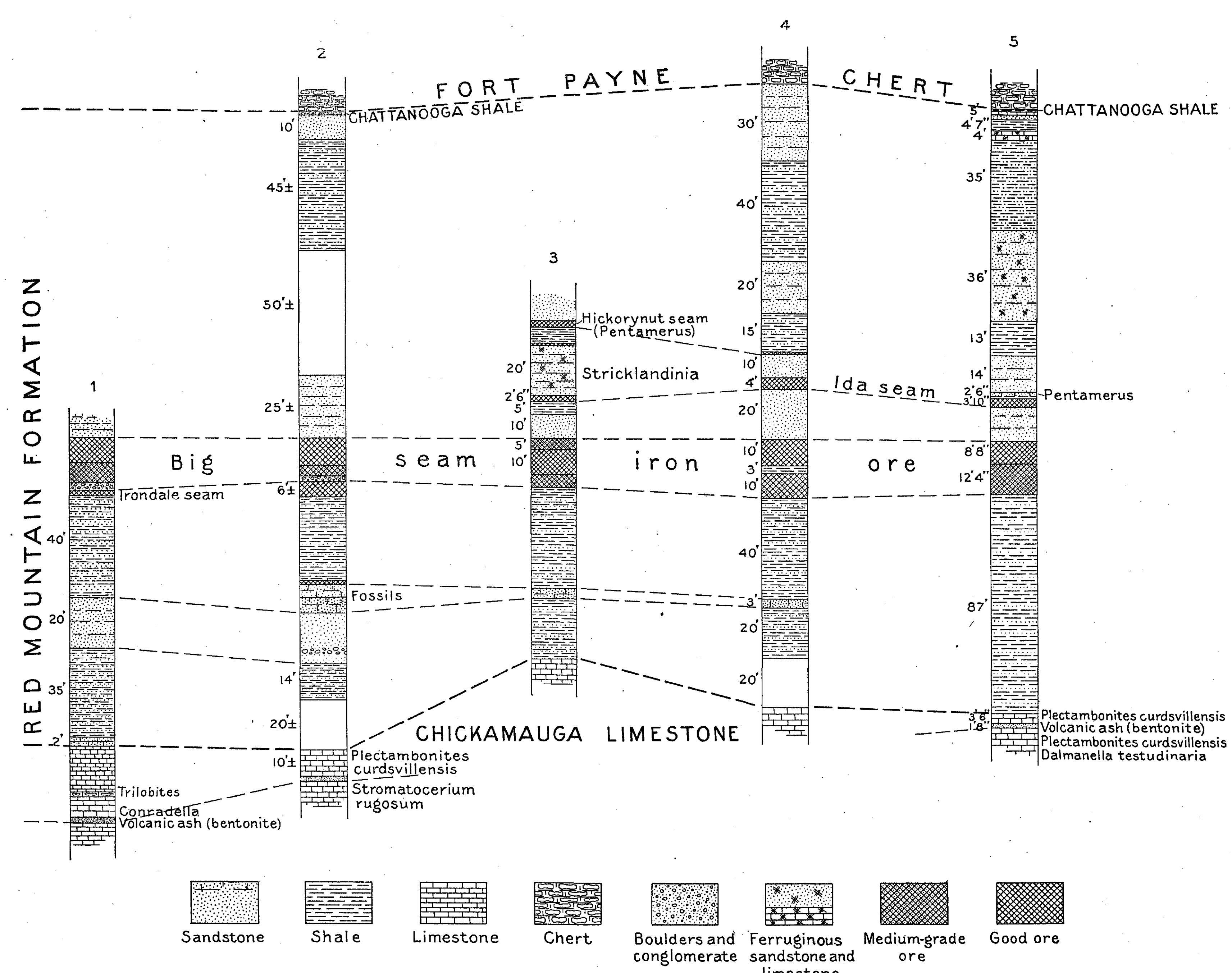

FIGURE 3.—Sections of Red Mountain formation in the Bessemer-Vandiver area, showing the iron-ore seams

1, Helen Bess mine and Mountain Terrace, Birmingham; 2, Twentieth Street road, Birmingham; 3, Spaulding mine, Graces Gap; 4, Sloss No. 1 mine, Bessemer; 5, Woodward shaft, 3 miles southeast of Bessemer

Irondale seam.—The Irondale seam is known as far south as the southeast corner of sec. 20, T. 18 S., R. 3 W. It is everywhere composed of thin layers of ore, shale, and ferruginous sandstone and is 2 to 6 feet thick. It is separated from the Big seam by about 2 feet of shale and thin ferruginous sandstone layers full of discoid waterworn pebbles of limestone as much as 6 or 8 inches in diameter. These layers have been seen from the Helen Bess mine, in the northeast environs of Birmingham, southwest to the Ishkooda mine, in the SE. ¼ sec. 20, T. 18 S., R. 3 W. (See Pls. XV and XVII.)

Relations of the Irondale seam to the Big seam.—At Irondale and vicinity the Irondale seam is separated from the Big seam by as much as 28 feet of shale and sandstone.[14] In that vicinity the Irondale seam is capped by the limestone ("Jack

[14] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala.: U. S. Geol. Survey Bull. 400, pl. 13, *B*, 1910.

seems subsequently to have been filled with sediment. This subject is further considered in the chapter on geologic history, and the ore beds are more fully described under the heading "Economic geology."

Thickness.—As shown in the detailed sections, the Red Mountain formation is 239 to 256 feet thick. The measurement at the Woodward shaft is correct; the others, which are made up from surface measurements, are only approximate except the part below the Big seam in the section in Birmingham. This part is 85 to 97 feet thick. No good measurements of the formation have been made west of Opossum Valley. Only a small thickness has been preserved in the small outliers on Flint Ridge. In a bore hole in Shades Valley near Oxmoor the part of the formation above the Big seam is 91 feet thick, and the ore is 19 feet 6 inches thick. The bore hole went 40 feet below the ore without reaching the bottom of the formation, the whole thickness penetrated being 151 feet. The greatest thickness recorded above the Big seam is 191 feet, which was noted in a drill hole 1,200 feet east of the Sloss No. 1 mine, at Bessemer.

Age and correlation.—By the study of the fossils of the Red Mountain formation Ulrich has arrived at the conclusion that the part below the Big seam of iron ore is of Medina age and that only the Big seam and overlying part of the formation is of Clinton age.

The most diagnostic species from the beds below the Big seam, mainly identified by Ulrich, are listed below:

Favosites venustus Hall.
Enterolasma geometricum (Foerste).
Zaphrentis bilateralis Hall?
Clathropora frondosa Hall.
*Helopora fragilis Hall.
*Phaenopora aff. P. ensiformis Hall.
Chasmatopora (Phylloporina) angulata (Hall).
*Rhinopora verrucosa (Hall).
*Atrypa marginalis (Dalman).
Coelospira cf. C. plicatula (Hall).
Camarotoechia neglecta (Hall).
Leptaena rhomboidalis Wilckens.
Orthis flabellites Foerste.
*Platystrophia daytonensis Foerste.
Rhipidomella hybrida (Sowerby).
Schuchertella subplana (Conrad).
*Stricklandinia triplesiana Foerste.
Strophonella striata (Hall).
Bucanella trilobata (Conrad).
*Cyclonema daytonense Foerste.
Cyclonema sp. undet., common in Brassfield of southern Ohio.
Pterinea cf. P. undata (Hall).
Tetranota cf. T. obsoleta Ulrich and Schofield.
*Calymene vogdesi Foerste.
Pterygometopus cf. P. trisulcatus (Hall).

The starred species, with the exception of the *Helopora*, are unknown except in the Brassfield limestone of Ohio and Kentucky, the Cataract formation of Canada, the Albion sandstone (upper Medina) of New York, and the Rockwood ore of Tennessee. *Rhinopora verrucosa* is, except possibly in a single occurrence, a Medina fossil, and *Helopora fragilis* is most common in beds of that age. As some of these diagnostic forms occur in the Irondale seam of ore, there can be no reasonable doubt of the Medina age of the lower part of the Red Mountain formation in this area.

Of the age of the upper or Clinton part of the Red Mountain formation Ulrich, in an unpublished manuscript, says:

In Alabama, as in Pennsylvania and New York, three Clinton faunas—a lower, a middle, and an upper—are distinguishable. But it is not at all certain that they correspond in time to the divisions recognized in the northern States.

We may accept as established by faunal evidence that the representative of the Clinton in Alabama, beginning with the Big ore seam, corresponds in general to the whole Clinton of Pennsylvania and central New York.

All the Clinton fossils from northeastern Alabama now in the United States National Museum, listed below, indicate only lower Clinton horizons:

*Monograptus clintonensis Hall.
Pasceolus sp.
Cornulites distans Hall.
Pachydictya cf. P. crassa Ulrich.
Orthis flabellites var. Foerste.
Bilobites biloba Linnaeus.
*Platystrophia cf. P. daytonensis Foerste.
*Leptaena rhomboidalis Wilckens.
*Plectambonites cf. P. transversalis (Wahlenberg).
*Chonetes cornutus (Hall).
*Anoplotheca hemispherica (Sowerby).
Rhynchonella? janea Billings.
*Pentamerus oblongus Sowerby.
*Pentamerus ovalis Hall.
Stricklandinia cf. S. salteri Billings.
Stricklandinia cf. S. deformis Meek and Worthen.
Stricklandinia n. sp.
Whitfieldella intermedia (Hall).
Liospira? sp. undet.
Phanerotrema aff. P. occidens (Hall).
Strophostylus (small species).
*Diaphorostoma cf. D. niagarense (Hall).

Of the 22 species in this list those marked with an asterisk (*) occur also in lower Clinton deposits in New York. As compared with the lower Clinton fauna in the Appalachian Valley north of Tennessee, this approximately contemporaneous Alabama fauna proves strikingly different. Two of the most reliable of the Clinton guide fossils (*Chonetes cornutus* and *Anoplotheca hemispherica*) are present; and it is chiefly on their account that these deposits in northeastern Alabama are determined as of lower Clinton age. The horizon of *Pentamerus oblongus* may represent the horizon of the Wolcott limestone member or that of the somewhat older "Reynales" limestone member of the lower Clinton of New York. Nevertheless we miss the extremely common Ostracoda, which are seldom if ever wanting in northern lower Clinton faunas.

In Red Mountain the Big ore seam is extremely rich in fossil Bryozoa, and as Bryozoa are rare elsewhere in the Clinton, this occurrence in Alabama is of special interest because it adds materially to our knowledge of the life of this epoch. At least ten genera are represented: *Fistulipora, Hallopora, Lioclemella, Chasmatopora (Phylloporina), Helopora, Ptilodictya, Clathropora, Phaenopora, Pachydictya,* and *Lichenalia*. If we were not sure that the bed is much older, these Bryozoa would immediately suggest the Rochester or Osgood epoch of the upper Clinton. On the other hand they remind us nearly as much of the late Medina bryozoan fauna, especially that facies of it which is found in the underlying Rockwood of Tennessee.

The second or middle fossil zone in the Clinton of central Alabama is specially marked by *Pentamerus oblongus* and *P. ovalis* and by the absence of the fossils associated with those species in the lower zone in northeast Alabama, as described above. This zone is represented by the ferruginous sandstone known as the Hickory Nut seam. The *Pentamerus* is widely distributed in the southern Appalachian Valley. Apparently it marks a definite zone that is provisionally correlated with the Wolcott limestone of New York.

The upper 50 feet or more of the Red Mountain formation in central Alabama contains a fauna that is readily distinguished from that of either of the underlying Clinton zones. The following list includes the most common species and such of the rarer forms as are valuable for purposes of correlation.

Of this list *Fenestella* cf. *F. elegans*, *Semicoscinium* cf. *S. tenuiceps*, *Atrypina disparilis*, and *Dalmanites limulurus* indicate approximate contemporaneity with the Rochester shale of New York, which is believed to be represented in the upper part of the typical Clinton of central New York.[15]

Zaphrentis bilateralis Hall?
Procteria alabamense Butts.
Large columnals of crinoid or cystid.
Fenestella cf. F. elegans Hall.
Semicoscinium cf. S. tenuiceps Hall.
Ptilodictya gladiola Billings.
Stropheodonta corrugata Conrad?
Orthis flabellites Foerste.
Orthostrophia (Orthis) cf. O. fasciata (Hall).
Plectambonites intermedia.
Chonetes aff. C. cornutus Hall.
Stricklandinia cf. S. deformis Meek and Worthen.
Atrypa reticularis (Linnaeus).
Atrypina disparilis (Hall).
Spirifer radiatus (Sowerby).
Dalmanites limulurus Green.
Encrinurus sp. undet.

UNCONFORMITY AT THE TOP OF THE RED MOUNTAIN FORMATION

In Birmingham Valley the oldest formation present above the Red Mountain is the Frog Mountain sandstone, of Oriskany and Onondaga age. In Pennsylvania there intervenes between the Clinton and the Oriskany 2,000 feet of rocks of Cayugan and Helderbergian age. In Cahaba Valley, where the Frog Mountain sandstone rests upon the Little Oak limestone, the Red Mountain formation and all of the Upper Ordovician are lacking, in addition to the formations that are absent in Birmingham Valley. In other words, there are no rocks in Cahaba Valley that represent the time necessary for the deposition of about 6,000 feet of rocks in Pennsylvania.

DEVONIAN SYSTEM [15a]

The Devonian system is represented in this part of Alabama by the Frog Mountain sandstone (which here is of Oriskany and Onondaga age, as explained beyond) and perhaps by the Chattanooga shale, which is of either Upper Devonian or early Carboniferous age.

FROG MOUNTAIN SANDSTONE

Name.—The Frog Mountain sandstone was so named by Hayes, from Frog Mountain, Cherokee County. As now used the name applies to any sandstone of Devonian age beneath the Fort Payne chert, or the Chattanooga shale.

Distribution.—The Frog Mountain sandstone is known in this area only along the crest of Little Oak Mountain, in the Vandiver quadrangle, and along Red Mountain, in the Bessemer quadrangle. It is exposed in Graces Gap and in the cut at the Twentieth Street crossing of Red Mountain in Birmingham. A few feet of sandstone in Clear Branch Gap, southwest of Bessemer, is probably Frog Mountain, although no fossils have been found in it to prove its age. The Frog Mountain sandstone is also exposed in a cut on the Southern Railway half a mile east of Leeds and in a gap through Little Oak Mountain, 4 miles south of Leeds, in the NE. ¼ sec. 1, T. 18 S., R. 1 W., at the north edge of the Vandiver quadrangle.

Character.—The Frog Mountain sandstone ranges from a coarse-textured friable yellow rock along Red Mountain to a rather fine textured gray or yellowish rock along Little Oak Mountain, where it weathers to a somewhat porous and soft chalky mass. Locally it contains very small quartz pebbles. In Clear Branch Gap it is a hard quartzite. The following sections show the character of the Frog Mountain:

Section in Cahaba Valley, half a mile east of Leeds and 4 miles north of the Vandiver quadrangle

	Feet
Fort Payne chert.	
Chattanooga shale (purple)	2
Frog Mountain sandstone:	
Sandstone, hard, brown pebbly	2
Sandstone, soft, green	2
Sandstone, brown, cherty	5
Chalky rock, with fossils (*Chonetes*); thin layer.	
Sandstone, brown, cherty	1±
Not exposed (sandstone?)	10?
Total thickness of Frog Mountain sandstone	20
Little Oak limestone.	

Section about 4 miles southwest of Leeds, near the boundary between the Vandiver and Birmingham quadrangles

	Feet
Chert (Fort Payne)	90
Concealed (Chattanooga shale?)	4
Frog Mountain sandstone:	
Sandstone, quartzitic, with pebbles and fish bones	10
Not exposed, probably sandstone	10
Limestone (Little Oak).	

Section at Clear Branch Gap, 5 miles south of Bessemer

	Ft.	in.
Fort Payne chert.		
Chattanooga shale:		
Clayey layer stained black		6
Clay, green	1	
Frog Mountain sandstone: Quartzite, distinctive Oriskany fossils (see list)		6
Frog Mountain sandstone (?): Sandstone, coarse, yellow, of Oriskany or Clinton age	10±	

Thickness.—As shown by the sections the Frog Mountain sandstone is from 6 inches to 20 feet thick in this area.

Age and correlation.—The Frog Mountain sandstone has hitherto been classified as of Oriskany age. As a result of recent investigation by the writer it has been discovered that the sandstone occupying the position of the Frog Mountain in different parts of the State ranges in age from Oriskany to probably Hamilton. The facts on which the above assertion is based are stated below.

From the 6 inches of sandstone in Clear Branch Gap (see preceding section) the fossils in the following list were collected:

*Hipparionix proximus Vanuxem.
*Spirifer tribulis Hall.
*Anoplotheca flabellites (Conrad).
*Eatonia peculiaris (Conrad).
*Meristella lata (Hall).

The following forms were collected from the west side of Birmingham Valley, on the Alabama Great Southern Railroad, 2 miles west of Vance and about 16 miles southwest of Clear Branch Gap. The material here is a soft white chalky rock, probably decomposed chert, and was mistaken in the field for the Fort Payne, which crops out at the same point continuously with the Devonian bed.

Stropheodonta sp. undet.
Leptostrophia sp. undet.
*Leptostrophia cf. L. oriskania Clarke.
*Anoplia nucleata (Hall).
Spirifer cf. S. submucronatus Hall.
Spirifer sp. undet.
Anoplotheca flabellites (Conrad).
Beyrichia sp. undet.

The fossils of both lists were identified by E. M. Kindle.

The species marked with an asterisk (*) constitute a distinctly Oriskany fauna, and there can be no reasonable doubt that the rocks from which they were obtained are of Oriskany age, notwithstanding the fact that *Anoplotheca flabellites*, *Anoplia nucleata*, and *Eatonia peculiaris* also range into beds of Onondaga age. The 6 inches of sandstone carrying the fauna of the first list is, however, the only representative of the Oriskany known in this area. The Frog Mountain of the Little Oak Mountain strip is of Middle Devonian age, as shown by the succeeding discussion. No fossils have been obtained from the Frog Mountain sandstone along Little Oak Mountain in this area, but on the same ridge and same outcrop a quarter of a mile east of Leeds and 3½ miles north of the Vandiver quadrangle *Chonetes mucronatus* is common. In the Watkins cut of the Seaboard Air Line Railway through the same ridge 1 mile east of Odenville and 14 miles northeast of Leeds the Frog Mountain section is as follows:

Section 1 mile east of Odenville

	Feet
Fort Payne chert:	
9. Chert	120
Chattanooga shale:	
8. Shale, green and purplish	1½
Frog Mountain sandstone:	
7. Sandstone, rather coarse grained, in layers as much as 1 foot thick	20
6. Partly exposed; some shale showing and probably all shale	8
5. Sandstone, thick bedded, fine grained; some layers so calcareous as to be classed as sandy limestone	20
4. Chert	1
Ordovician, of Lowville age (?):	
3. Sandstone, thick bedded, coarse grained	5
Ordovician, of Lowville age:	
2. Limestone, magnesian, sandy; contains *Tetradium cellulosum*	2
1. Shale, mainly red, with a few layers of coarse sandstone.	

From the middle of bed No. 5 of the above section were collected *Anoplotheca acutiplicata*, *Chonetes mucronatus*, and *Chonostrophia reversa*. About 3 miles northeast of the Watkins cut, in Watson Gap (see topographic map of Springville quadrangle) was collected a piece of very fine grained siliceous rock like some of that in No. 5 of the above section, carrying an undetermined species of *Cypricardella*, a large species of *Paleoneilo*, also apparently undescribed, and *Loxonema* cf. *L. delphicola*. About 7 miles still farther northwest, at Cox Gap, on the same ridge and outcrop, where the Frog Mountain is about 25 feet thick and carries layers of rock like that of the piece found in Watson Gap, the following species were collected 6 to 8 feet below the Chattanooga shale: *Tropidoleptus carinatus*, *Loxonema* cf. *L. delphicola*, and a fragment of the living chamber of a cephalopod which agrees fully with *Orthoceras crotalum*, although the specimen is slightly compressed. Eleven miles to the northeast, at Greensport, where Coosa River cuts through the same ridge, here named Beaver Creek Mountain, the Frog Mountain is lacking and the Chattanooga shale rests directly upon the upper or Clinton part of the Red Mountain formation, which wedges into the section going northward between the Watkins cut and Cox Gap.

Of the fossils occurring along Little Oak and Beaver Creek mountains cited in the preceding paragraphs, *Chonetes mucronatus* ranges through the Onondaga and Marcellus into the Hamilton. It is cited as a common species from both the Columbus and Delaware limestones of Ohio, the former of Onondaga and the latter of Hamilton and Marcellus age. *Chonostrophia reversa* is a common form occurring in the Delaware limestone only and thus known elsewhere only in beds regarded as of Hamilton age. *Tropidoleptus carinatus* is a common Hamilton form, which is also cited by Schuchert from the Marcellus shale and which ranges into Upper Devonian formations but has never, so far as the writer is aware, been cited from beds known on other evidence to be as

[15] For the latest views on the stratigraphy and correlation of the Clinton see the volume on the Silurian of Maryland (Maryland Geol. Survey, 1923).

[15a] In a forthcoming paper the author of this folio will name the sandstone of Oriskany age in Red Mountain the Clear Branch sandstone, the name Frog Mountain will be restricted to the sandstone of Onondaga age in Cahaba Valley, and the sandstone of Hamilton age as described herein, which is not present in these quadrangles, will be named the Ragland sandstone. These changes were adopted after this folio was in page proof.

old as Onondaga. The same is true of *Loxonema delphicola.* It is a common Hamilton form of New York and ranges up into the lower part of the Mississippian series. The *Cypricardella* and *Paleoneilo* are distinctly Hamilton or later types. *Orthoceras crotalum* is also cited by Hall only from the Hamilton. The only other form that elsewhere seems known from the Onondaga is *Anoplotheca acutiplicata.*

The assemblage of fossils cited above is clearly of Middle Devonian age, and as some of the collections were obtained within 10 feet of the bottom of the Frog Mountain and specimens were seen still lower, it is certain that the formation along Little Oak Mountain includes no component of Oriskany age. The case for the post-Oriskany age of the Frog Mountain sandstone of Cahaba Valley and the belt east of the Coosa coal field is made conclusive by the fossils at the base of the sandstone 1½ miles south-southwest of Ragland, which is 7 miles southeast of Cox Gap on Beaver Creek Mountain, described in a preceding paragraph, and about 35 miles northeast of Birmingham. In an abandoned quarry southeast of Ragland the section exposed is as follows:

Section in quarry southeast of Ragland

	Feet
Fort Payne chert:	
6. Chert	75
Frog Mountain sandstone:	
5. Sandstone, thick bedded; some layers coarse grained, others fine grained, with nodular chertlike bands, probably originally calcareous	49
4. Sandstone, ferruginous, brown, rotten, originally calcareous, highly fossiliferous	2
3. Sandstone, fine grained, nodular	1½
Shale, argillaceous, dark	½
2. Limestone, coarsely crystalline, dark, fossiliferous, (corals)	1
Great unconformity.	
Little Oak limestone:	
1. Limestone to bottom of quarry, thick bedded, gray to dark, ribbony or banded on weathering, fossiliferous	100

From beds 2 and 4 of the above section a very rich coral fauna was obtained. Most of the species and individuals were collected from bed 4, where they are associated with brachiopods, bryozoans, and trilobites. Bed 2 also carries an abundance of corals, but they are only sparingly liberated from the matrix of limestone, and a large collection could not be made. They seem, however, to be of the same species as those from bed 4.

The corals have not yet been carefully identified specifically, but it is apparent at a glance that the assemblage bears a strong resemblance to that of the rich Devonian coral fauna at the Falls of the Ohio at Louisville, Ky., which is of Onondaga and Hamilton age. There are species of cyathophylloids, including *Blothrophyllum*, species of *Favosites*, and species of *Cladopora.* Associated with these corals in the same layers are *Coscinium cribriformis, Cystodictya gilberti?, Taeniopora exigua,* species of *Fenestella, Stropheodonta perplana, Chonetes coronatus, C. mucronatus, Spirifer audaculus, S. divaricata, Anoplotheca acutiplicata?, Tropidoleptus carinatus, Aviculopecten princeps, Actinopteria decussata, Tentaculites scalariformis, Orthoceras crotalum,* and *Phacops rana.* These fossils, occurring in the very bottom of the Frog Mountain sandstone at the Ragland locality, give decisive evidence as to the post-Oriskany age of the entire formation at that place. As between the Onondaga or Hamilton age of the beds, however, the testimony of the fossils is conflicting. The corals alone suggest only Onondaga, but even their testimony is not entirely on the side of the Onondaga. For example, apparently both *Blothrophyllum decorticata* and *B. cinctutum* occur, the first an Onondaga and the second a Hamilton form. Doubtless other contradictions will appear among the corals when the collections are fully identified.

The testimony of the other fossils is slightly more favorable to the Hamilton age of the fauna. For example, *Coscinium cribriformis, Tropidoleptus carinatus, Chonetes coronatus, Actinopteria decussata,* and *Orthoceras crotalum* are common Hamilton forms and are not reported from the Onondaga, although *T. carinatus* occurs in the Marcellus shale, which lies between the Onondaga and Hamilton in New York. Nearly all the other forms occur in both the Onondaga and Hamilton, but most of them only sparingly in the former, while they are all so abundant in the latter that any assemblage of which they are a prominent constituent is generally regarded as a Hamilton fauna.

The easternmost outcrop of the Frog Mountain sandstone occurs along a ridge passing about 2 miles west of Piedmont, Calhoun County, Ala., and running northeastward toward Frog Mountain, the type locality of the Frog Mountain sandstone, which is in southeastern Cherokee County, about 6 miles north of Piedmont. In the ridge referred to the Frog Mountain sandstone may be as much as 50 feet thick and so far as exposed consists of coarse sandstone. A few fragments of corals and of finely striated brachiopods were found in this sandstone, and a few incomplete specimens of silicified corals were found on the slope below the sandstone. From some locality on this ridge about 2 miles from Piedmont a good collection of free specimens of silicified fossils has been obtained and is now in the U. S. National Museum. The collection includes, besides a number of well-preserved corals, *Atrypa reticularis, Spirifera duodenaria, Paracyclas elliptica, Pleurotomaria capillaria,* and *Loxonema* cf. *L. delphicola.* This fauna is Middle Devonian and entirely post-Oriskany. Here too the testimony is conflicting as to the Onondaga or Hamilton age of the fauna. *Atrypa reticularis* ranges through the Silurian and Devonian; *Spirifera duodenaria* is reported from the Onondaga only; *Paracyclas elliptica* occurs in both Onondaga and Hamilton; *Pleurotomaria capillaria* and *Loxonema delphicola* seem to be confined to the Hamilton. Owing to lack of precise description of locality and horizon, the exact source of this fauna is unknown, but it may fairly be assumed that the horizon is, like that of the fossils 1½ miles southeast of Ragland, described above, in the bottom of the Frog Mountain sandstone as developed west of Piedmont.

Another facies of the Devonian appears to be present in Frog Mountain, the type locality, and between Duke and Reads, in the northwestern part of Calhoun County. On a knob about midway between Duke and Reads and east of the Louisville & Nashville Railroad is a great quantity of very coarse grained friable sandstone carrying *Spirifer macrothyris* and a large cyathophylloid coral identified as *Aulacophyllum unguloideum.* A fully exposed section in the gap of Ohatchee Creek just south of Reads shows the sandstone to be only 20 feet thick in this vicinity.

Frog Mountain, the type locality of the Frog Mountain sandstone, has not been examined by the writer, but Mr. Ulrich kindly furnishes the following section made by him in 1906:

Section on Frog Mountain

	Feet
Floyd shale:	
4. Shale, dark, with *Archimedes.*	
Frog Mountain sandstone:	
3. Sandstone, coarse, red and fossiliferous at top (*Spirifer macrothyris* and *Amphigenia curta ?*)	150±
2. Sandy, calcareous (magnesian?), and cherty beds with rounded quartz grains scattered through magnesian limestone, the quartz grains increasing toward the bottom. Fossiliferous cherty-looking rock at bottom containing *Chonetes mucronatus*	200
Unconformity.	
Limestone of Beekmantown age, probably Newala:	
1. Limestone, fine grained, with Cryptozoa and gastropods.	

In the coarse red sandstone at or near the top of No. 3 of the above section an *Amphigenia*, apparently *A. curta*, a shell suggesting *Stropheodonta perplana, Spirifer divaricatus,* and *Spirifer macrothyris* occur in association with cyathophylloid corals in a more or less fragmentary condition. No evidence of the rich coral and brachiopod fauna found south of Ragland as described above, with its distinctly Hamilton elements, has been found at Frog Mountain. As *Spirifer macrothyris* and representatives of the genus *Amphigenia*, occurring at the top of Frog Mountain at its type locality, are not recorded from beds younger than Onondaga, and as *Chonetes mucronatus*, occurring in the bottom of the Frog Mountain at its type locality, is not recorded from beds older than Onondaga, it follows that, so far as the known evidence goes, the typical Frog Mountain sandstone is entirely of Onondaga age. It is interesting and significant that the Frog Mountain sandstone at Leeds is identical lithologically with the very base of the Frog Mountain sandstone at Frog Mountain and also carries *Chonetes mucronatus* as at Frog Mountain. This indicates that only the basal part of the formation as developed at the type locality is present in these quadrangles.

The Frog Mountain sandstone extends still farther northeastward into Georgia, where it is present in Lavender Mountain and in Horseleg Mountain, about 1 mile west of Rome, in Floyd County, and was mapped by Hayes in the Armuchee chert. At Horseleg Mountain *Spirifer macrothyris* occurs in coarse soft reddish sandstone. In both Lavender and Horseleg mountains this sandstone is immediately underlain by fossiliferous chert which belongs to the Armuchee chert of Hayes as described in the Rome folio. This chert is well exposed in the railroad cut at the southwest end of Lavender Mountain about half a mile west of the railroad station at Lavender. At this place it is about 50 feet thick. From this chert at the north end of Lavender Mountain *Rhipidomella musculosa, Stropheodonta magnifica, Chonetes hudsonicus, Anoplia nucleolata, Meristella rostellata, Spirifer tribulis,* and *Platystoma ventricosa,* all of Oriskany age, have been collected. A collection of silicified fossils from Catoosa County, Ga., 40 miles north of Rome, contains *Eatonia peculiaris* and a *Spirifer* of the type of *S. murchisoni* or *S. angularis.* Both species of *Spirifer* are Oriskany forms, and the *Eatonia*, although recorded rarely from beds of Onondaga age, is of more common occurrence in older beds, as those of Oriskany or even of still older Helderberg age.

It appears, then, that except for the occurrence of a small thickness of Oriskany in the region southwest of Bessemer, southwest of Vance in Tuscaloosa County, and in the vicinity of Jemison, Chilton County, no Oriskany is known in Alabama. Whether the Oriskany of these Alabama localities and the Oriskany (Armuchee chert) of northwest Georgia are now or ever were connected except by way of the open ocean is entirely unknown. The typical Frog Mountain sandstone and that of Little Oak Mountain, as at Leeds and extending southward into the Bessemer and Vandiver quadrangles, is apparently all of Onondaga age, but in the region between Frog Mountain and Leeds, as 1 mile east of Odenville and at Ragland, where the Devonian sea lingered longest, the Frog Mountain probably includes beds ranging in age from the later part of the Onondaga into the early part of the Hamilton epoch.

UNCONFORMITY AT TOP OF FROG MOUNTAIN SANDSTONE

There is a stratigraphic break between the Frog Mountain sandstone and the succeeding Chattanooga shale, the extent of which is in doubt, owing to the uncertainty as to the age of the Chattanooga. If the Chattanooga is of Genesee age, as it is classified in the earlier reports, the unconformity in this area represents no more than the Marcellus, Hamilton, and Tully formations; if it represents some still younger part of the Upper Devonian the unconformity is correspondingly greater; and if it is basal Carboniferous, as held by some, the break represents a considerable part of the Middle Devonian and all of the Upper Devonian, or about 6,000 feet of rocks not present in this part of Alabama.

DEVONIAN OR CARBONIFEROUS SYSTEM

CHATTANOOGA SHALE

Name.—The Chattanooga shale was named by Hayes[16] from Chattanooga, Tenn. In this region it overlies the Frog Mountain sandstone or, where that is absent, the Red Mountain formation and is immediately succeeded by the Fort Payne chert.

Character and distribution.—The Chattanooga is generally a black fissile shale, the black color being due to the presence of carbonaceous matter. The shale is likely to have reddish layers or blotches or to be purplish or greenish where it has weathered down to a clay. In a cut on the Louisville & Nashville Railroad on Red Mountain, near the Twentieth Street crossing, just southeast of Birmingham, the Chattanooga consists of about 4 inches of green clay above and 12 inches of dark clay below.[17] Similar beds represent the shale throughout the southern part of the Bessemer quadrangle. The Chattanooga, though thin, is persistent along Red Mountain, appearing wherever its horizon is exposed. In Clear Branch Gap only a black stain at the top of the Frog Mountain represents the formation. It has not been observed in Cahaba Valley south of Leeds, 3 miles north of the Vandiver quadrangle. (See section on p. 9.)

Thickness.—In the Bessemer-Vandiver area the Chattanooga is nowhere known to be more than 2 feet thick and is probably only a few inches thick in most of the area.

Age and correlation.—The Chattanooga shale includes all the sediments preserved in this region that were deposited in the time between the Frog Mountain epoch and the Fort Payne epoch. Within this time a maximum of about 8,000 feet of Middle and Upper Devonian and lower Mississippian rocks accumulated in central Pennsylvania.

Whether the Chattanooga was deposited in the Devonian or Mississippian part of this long period has not been determined to the satisfaction of all geologists, owing to the lack of decisive evidence. It has generally been classified as Devonian, but Ulrich and others believe it to be basal Mississippian. Ulrich has obtained from it, at Chattanooga, *Lingula melie* and *Orbiculoidea newberryi*, two fossils of the Sunbury shale of Ohio, and at other places, particularly north of Huntsville, Ala., a large number of species of conodonts characteristic of the Sunbury shale, of early Mississippian age. These conodonts are regarded by Ulrich as decisive evidence of the Mississippian age of the Chattanooga shale in Alabama and southern and Middle Tennessee. However, *Lingula melie*, or a form that can hardly be distinguished from that species occurs also in the Ohio shale in Kentucky, below the Sunbury, and the Ohio shale, as shown by actual tracing by the writer and others across Kentucky, probably includes the greater part of the Chattanooga. The writer has obtained *Barroisella subspatulata* from beds below the middle of the Chattanooga shale at Blount Springs, Ala. This form, associated with *Lingula melie*, occurs in the black shale in Illinois and Indiana, which is also believed to fall within the limits of the Ohio shale. The Ohio shale is classified as Devonian by the United States Geological Survey, but it also is believed by Ulrich to be of Mississippian age, except a small thickness locally at the bottom, which is admittedly of Genesee age, so that even if the Chattanooga shale is of the age of part of the Ohio it is still Mississippian, according to Ulrich. On the other hand, those who, like Keith, maintain that the Chattanooga is Devonian base their belief on the continuity of the Chattanooga with the black shale of undoubted Devonian age in southwestern Virginia, which can be traced without break into the Chattanooga. As the black shale in southwestern Virginia is 500 to 1,100 feet thick and has *Lingula melie* and *Barroisella* in its upper part, that part is regarded as Mississippian by Ulrich, who believes that the

[16] Hayes, C. W., The overthrust faults of the southern Appalachians: Geol. Soc. America Bull., vol. 2, p. 142, 1891.

[17] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175), pl. 7, 1910.

southwestward thinning is effected by the loss of Devonian beds from the bottom, so that only the top part, of Mississippian age, extends into southern Tennessee and Alabama.

UNCONFORMITY AT TOP OF THE CHATTANOOGA SHALE

As already shown, there is throughout most of this area an unconformity between the Chattanooga shale and the basal Mississippian Fort Payne chert, the extent of which depends upon the age of the Chattanooga. In the southeast corner of the Vandiver quadrangle shale of Mississippian age of the Floyd type appears to overlie immediately the Newala limestone, of Lower Ordovician age, so that in that locality there is an unconformity between the Mississippian shale and the Newala limestone equal to a maximum of about 24,000 feet of rocks which occupy that interval in Tennessee, Virginia, and Pennsylvania. The absent rocks include a part of the Lower Ordovician, all of the Middle and Upper Ordovician, all of the Devonian and Silurian, and the lower part of the Mississippian series of the Carboniferous system.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

The Mississippian series in this area includes the Fort Payne chert, the Warsaw limestone, the Gasper formation, the Hartselle sandstone (as restricted), the Bangor limestone (as restricted), or the Floyd shale, which is the equivalent of the last three, and at least the lower part of the Parkwood formation.

The type region of the Mississippian series is in the Mississippi and Ohio valleys. Section 1 in figure 4 shows a sequence of the Mississippian formations in that region which is fairly representative. The other sections in figure 4 show the relations of the Mississippian of Alabama to that of the type region.

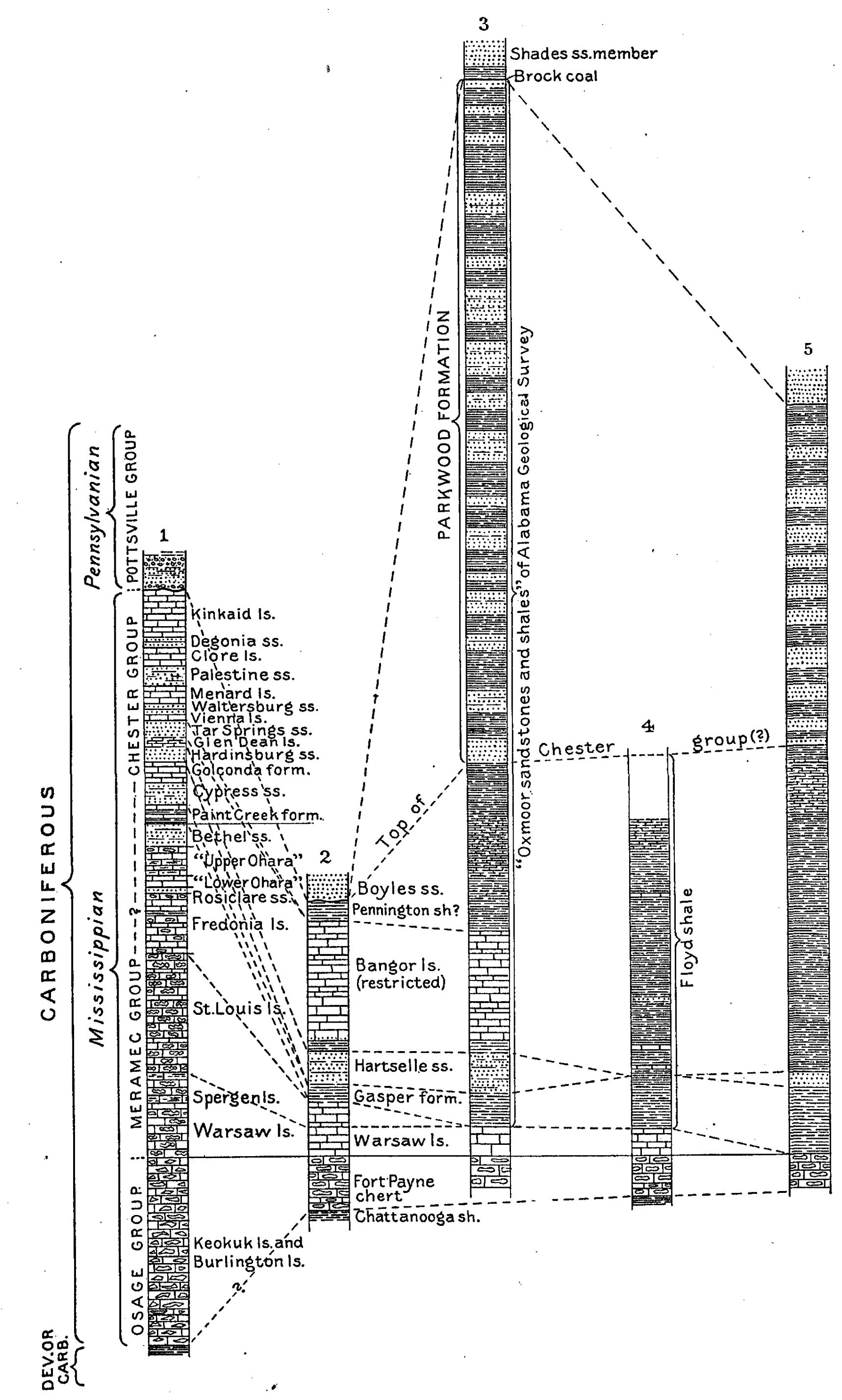

FIGURE 4.—Sections illustrating the succession and relation of the Mississippian formations of Alabama and adjacent region

1, Generalized section for western Kentucky and southern Illinois; 2, section at Blount Springs, in the south end of Sequatchie Valley; 3, section near Irondale, Ala., lower part from drill hole; 4, section of Woodward shaft, 3 miles southeast of Bessemer; 5, section for east side of Cahaba Valley

LOWER FORMATIONS

FORT PAYNE CHERT

Name.—The Fort Payne chert was named from the town of Fort Payne, in Dekalb County, northeastern Alabama. The name was published almost simultaneously by C. W. Hayes, of the United States Geological Survey, and E. A. Smith, State geologist of Alabama. In Hayes's original usage the Fort Payne included all the limestone and chert between the Hartselle sandstone or Floyd shale and the Chattanooga shale. It thus included whatever equivalents of the Tuscumbia limestone of the Alabama Geological Survey are present in northeastern Alabama and also the equivalent of the Warsaw limestone of this folio. In recent years, however, the name has been restricted to the rocks between the Chattanooga shale below and the Tuscumbia limestone (or Warsaw limestone) above, and that is the definition recognized in this folio.

Distribution.—The Fort Payne crops out on West End Mountain, and there is a small patch, a fault block, a mile southwest of Wylam. The formation crops out along the east flanks of Red Mountain, its bottom reaching high up on the east slope or to the crest. In the vicinity of Morgan, in Shades Valley, an area of Fort Payne is brought to outcrop by a fault on the east side. In Cahaba Valley it crops out along the crest and east slope of Little Oak Mountain, this ridge being due to the presence of the resistant chert, which has not been eroded down to the same level as that of the limestone on the west and the soft shale on the east. In the southeast quarter of the Vandiver quadrangle beds that are supposed to be Fort Payne chert crop out around an elliptical area along Page Spring Branch.

Character.—At its outcrop the Fort Payne is made up of layers of chert from a few inches to 2 feet in thickness, generally separated by thin partings of shale. Some of the layers are very even surfaced, as shown in Plates VII and IX in the Birmingham folio. Plate VII shows the thinner, more unevenly bedded chert, which is the prevailing type, and Plate IX the thicker-bedded chert.

The chert is generally yellowish, but weathered pieces are commonly whitish, with small red patches. It is brittle or finely jointed and breaks so easily that it can be blasted out to a depth of 100 feet in a condition to be used for road surfacing without much further preparation.

In places some beds of the chert yield on weathering a light, very fine grained soft, porous rock suitable for use as polishing material. Primarily the chert as a formation is calcareous, as shown by specimens brought up from considerable depths as cores of diamond-drill borings. Some of the chert in such material appears as irregular inclusions in limestone, but this chert is full of crystals of calcite according to C. W. Washburne. The chert is at present fine-grained crystalline quartz, but it probably was not originally in this form.

Thickness.—The thickness of the formation ranges from 90 to 200 feet, or possibly a little more in some sections. Logs of well borings in Shades Valley report 125 to 200 feet of chert and limestone that are included in the Fort Payne. In the Woodward shaft the thickness is 129 feet. The formation is probably not over 125 feet thick along Little Oak Mountain.

Age and correlation.—Extensive collections of fossils from the Fort Payne of the Birmingham quadrangle were studied by G. H. Girty, who expressed the opinion that the formation in that region is younger than the Kinderhook and older than the Warsaw of the Mississippi Valley. Whether both the Burlington and Keokuk are represented, or only one, was not determinable with the material in hand. However, in the writer's opinion, such forms as *Rhipidomella oweni*, *Athyris lamellosa*, *Delthyris novamexicana*, and *Spiriferina subelliptica* indicate a horizon as low as Fern Glen, at the base of the Osage group. In the main, however, the Fort Payne corresponds to the Keokuk, for it can be traced into northern middle Tennessee, where generally it certainly includes only rocks of Keokuk age. A list of fossils as identified by Girty in 1908 follows:

Lingula aff. L. tighti Herrick.	Productus aff. P. semireticulatus Martin.
Rhipidomella oweni Hall and Clarke.	Camarotoechia mutata (Hall).
Rhipidomella aff. R. thiemei (White).	Reticularia aff. R. setigera (Hall).
Chonetes aff. C. geniculatus White.	Spirifer aff. S. forbesi Norwood and Pratten.
Chonetes aff. C. illinoisensis Worthen.	Spirifer increbescens Hall?
Chonetes aff. C. logani Norwood and Pratten.	Spirifer keokuk Hall.
Chonetes aff. C. ornatus Shumard.	Spirifer aff. S. logani Hall.
Chonetes planumbonus Meek and Worthen.	Spirifer leidyi Norwood and Pratten.
Productella aff. P. concentrica (Hall).	Spirifer rostellatus Hall.
Productella aff. P. pyxidata Hall.	Spiriferella aff. S. neglecta (Hall).
Productella spinulicosta (Hall).	Spiriferina aff. S. depressa Herrick.
Productella sp.	Spiriferina subelliptica (McChesney).
Pustula biseriata (Hall)?	Syringothyris aff. S. carteri (Hall).
Pustula aff. P. blairi (Miller).	Ambocoelia? aff. A. lavicula Rowley.
Pustula aff. P. scabricula (Martin).	Cyrtina aff. C. burlingtonensis Rowley.
Pustula aff. P. wallaciana (Derby).	Delthyris novamexicana (Miller).
Productus aff. P. burlingtonensis Hall.	Athyris lamellosa (L'Eveille).
Productus aff. P. ovatus Hall.	Cliothyridina hirsuta (Hall).
Productus aff. P. mesialis Hall.	Cliothyridina sublamellosa (Hall).
Productus aff. P. parvus Meek and Worthen.	Eumetria verneuiliana (Hall).
	Allorisma consanguinatum Herrick.
	Deltopecten aff. D. batesvillensis Girty.
	Acanthopecten? aff. A. coloradoensis Newberry.
	Aviculipecten aff. A. oblongus Meek and Worthen.
	Conocardium aff. C. prattenianum Hall.
	Cypricardinia aff. C. scitula Herrick.

WARSAW LIMESTONE

Name and correlation.—The Warsaw limestone, named by Hall from Warsaw, Ill., has only recently been discriminated in Alabama, although it is a constituent of the Tuscumbia limestone of the Alabama Geological Survey, which occurs in northwestern Alabama and in Little Wills Valley in northeastern Alabama. In Little Wills Valley the Tuscumbia was formerly included by the United States Geological Survey in the Fort Payne chert. The Warsaw was included in the Bangor limestone (broad sense) as mapped by the writer in the Birmingham folio.

Distribution.—The only known exposures of the Warsaw in these quadrangles are in the area mapped in Shades Valley southeast of Bessemer, one a short distance west of the railroad about 1 mile west of Morgan and another at Birons Ford across Shades Creek. The Warsaw was also penetrated in the Woodward shaft to the iron ore east of Bessemer. The only other exposures seen in the general region are on the Louisville & Nashville Railroad 1 mile northwest of Irondale and at Vann's quarry, 2 miles north of Trussville, which is the best development and exposure in the region. (See Pl. XX.) The formation is also well exposed at Blount Springs, Ala., in the new railroad cut. There is no doubt of its persistence from Vann's to Birons Ford, southeast of Bessemer. It crops out along the lowest ground between Red Mountain and Sand Ridge in the northern part of the Bessemer quadrangle.

Character.—The Warsaw is a coarsely crystalline thick-bedded gray limestone. It is highly fossiliferous, being largely made up of crinoidal plates and plates of other echinoderms. It appears to be high in calcium carbonate. In the Woodward shaft it is reported to be 79 feet thick. It is about 90 feet thick at Vann's quarry.

Age and correlation.—The Warsaw of northern Kentucky and that of southern Indiana are satisfactorily correlated with the Warsaw of the type locality. From northern Kentucky the formation can be traced continuously into northern Alabama, where it is included in the Tuscumbia limestone of the Alabama Geological Survey. It is typically developed in the head of Sequatchie Valley in Tennessee and doubtless is continuous from that locality to Blount Springs, in the south end of the same valley. Furthermore, the Warsaw is distinguished by a good number of diagnostic fossils. Of these the following species have been identified by the writer from the localities in Shades Valley, from Vann's to Morgan:

Batocrinus sp.?	Camarotoechia mutata (Hall).
Pentremites conoideus Hall.	Cliothyridina hirsuta Hall.
Platycrinus boonvillensis Miller?	Dielasma formosum (Hall).
Talarocrinus simplex (Shumard).	Spirifer lateralis Hall.
Dichotrypa lyroides Ulrich.	Spirifer bifurcatus Hall.
Brachythyris subcardiformis (Hall).	Spiriferella neglecta (Hall).

This assemblage of fossils is one not known elsewhere outside of the Warsaw and may be accepted as conclusive evidence of the age of this limestone.

UNCONFORMITY AT THE TOP OF THE WARSAW LIMESTONE

In this area the Warsaw limestone is succeeded by the Gasper formation. In western Kentucky there intervene between the Warsaw and the Gasper formation the Spergen limestone, the St. Louis limestone, the Ste. Genevieve limestone, and the Bethel sandstone, amounting to a thickness of 700 feet. There is thus a considerable stratigraphic gap or unconformity between the Warsaw and the Gasper. At Vann's quarry there is beneath the shale of the Gasper formation about 8 feet of oolite, shown in Plate XX, that undoubtedly corresponds to a part of the Gasper oolite to the north.

CHESTER GROUP

SUBDIVISIONS

The Gasper formation, Hartselle sandstone as here restricted, Bangor limestone as here restricted, Floyd shale, and in part at least the Parkwood formation fall within the limits of the Chester group, named from Chester, Ill., in the type region of the Mississippian series; the name has been in common use since 1860.

The Chester rocks in Shades Valley in the Bessemer quadrangle have been called "Oxmoor shales and sandstones" by the Alabama Geological Survey, the top of the "Oxmoor" being somewhere in the Parkwood formation. Owing to the subdivision of the "Oxmoor" of the Alabama Survey, and owing to the fact that the name Oxmoor was used by Hayes for the Hartselle sandstone only, it has been thought best not to endeavor to establish the name Oxmoor in any restricted sense that could be made applicable. Any restriction of Oxmoor has also been made unnecessary by the identification in Alabama of the formations of the typical Chester group of the Mississippi Valley region.

GASPER FORMATION

Name.—The Gasper formation, which in this area succeeds the Warsaw limestone, was named for its exposures on Gasper River, in Warren County, Ky. Its normal position within the Chester group is between the Cypress sandstone above and the Bethel sandstone below. In these quadrangles, however, the Bethel sandstone, the Cypress sandstone, and the overlying Golconda formation are absent, so that the Gasper formation is overlain by the Hartselle sandstone as restricted (equivalent to the Hardinsburg sandstone of the Mississippi Valley section) and is underlain by the Warsaw limestone; the Spergen, St. Louis, and Ste. Genevieve limestones, which normally intervene between the Bethel and the Warsaw, are also absent. It is possible that in the upper part of the Gasper formation as here mapped there may be a thin representative of the Golconda formation. (See Pls. XIX and XX.)

In the section given by Hayes[18] for northeastern Alabama a shale immediately underlying the Hartselle ("Oxmoor")

[18] Hayes, C. W., Report on the geology of northeastern Alabama and adjacent portions of Georgia and Tennessee: Alabama Geol. Survey Bull. 4, p. 32, 1892.

sandstone and corresponding to the Gasper formation is called Floyd shale, being regarded as a basal sheet or tongue of the Floyd extending westward beneath the Hartselle.

Distribution.—The Gasper formation persists throughout the Birmingham quadrangle, to the north, where it was included in the Bangor limestone (broad sense) as mapped in the Birmingham folio. It extends southward along Shades Valley between Sand Ridge and Red Mountain nearly to the latitude of Bessemer, where the Hartselle sandstone thins out and the Gasper merges with the general body of the Floyd shale, of which it forms the basal part. It is partly exposed in Graces Gap and Red Gap. The best exposure, however, is at Vann's quarry in Shades Valley, north of Truesville, in the Birmingham quadrangle, 15 miles northeast of Birmingham.

Character.—In Red Gap, where only the upper half or so of the Gasper formation is exposed, it is a soft blue clay shale, sharply separated from the Hartselle sandstone. At Vann's quarry the shale has all been exposed in stripping. The lower part, which only was examined, is a black fragile indurated clay with many shreds of plants and a thin layer or two of concretionary ferruginous limestone. Below the shale is 7 feet of oolite of Gasper age resting upon the Warsaw limestone, as shown in Plate XVIII. At Blount Springs, where it is fully exposed at the east end of the railroad cut about half a mile east of the station, the formation is composed of shale and thin layers of sandstone in the upper 20 feet and of dark micaceous clay shale below. Here a merging into the Hartselle is indicated. Here also, at the very bottom and attached to the upper surface of the thick-bedded limestone that is supposed to be St. Louis, is a thin argillaceous layer carrying fossils of Chester age.

Thickness.—In the exposures at Blount Springs the Gasper formation is 50 feet thick; at Vann's quarry it is fully 100 feet thick; and in the log of a bore hole in the vicinity of Red Gap it is given as 97 feet thick. (See fig. 4, section 3.)

Age and correlation.—At Blount Springs, in the Birmingham quadrangle, a few species of fossils were obtained from the bottom of the formation. Among these fossils are a single specimen each of two species of *Pentremites*, one apparently *P. biconvexus* and the other, partly inclosed in the matrix, resembling *P. pyriformis*. Another fossil is *Chonetes chesterensis*. These fossils indicate that the age of the bed is the same as that of the upper part of the Gasper oolite of central Kentucky or its partial equivalent, the Paint Creek formation of western Kentucky and southern Illinois. At Vann's quarry *Talarocrinus*, a characteristic Gasper fossil of Alabama, occurs in the oolite at the bottom, mentioned above.

The Gasper formation 2 to 3 miles north of Trussville has yielded a few fossil plants, identified by David White, which are listed below:

Anaemites sp.	Lepidocystis.
Cephalotheca n. sp.	Sphenopteris moravica (Ettingshausen)?
Lepidodendron cf. L. volkmannianum Sternberg.	Taeniocradia? sp.
Lepidophyllum n. sp.	

White says that the genus *Cephalotheca* has not been reported hitherto on this continent. Its known occurrence elsewhere is in rocks regarded as of Devonian age.

Additional fossils collected from the Gasper formation at Red Gap and a short distance west of Trussville in the Birmingham quadrangle are listed below as identified by G. H. Girty:

Archimedes invaginatus Ulrich.	Caneyella wapanuckensis Girty?
Diaphragmus elegans (Norwood and Pratten).	Leda vaseyana (McChesney).
Leiorhynchus sp. (L. laura or L. carboniferum?)	Gastrioceras sp.
Allorisma aff. A. consanguinatum Herrick.	Goniatites aff. G. kentuckyensis (Miller).
	Ostracoda undetermined.

Caneyella is a form known elsewhere apparently only in Arkansas and Oklahoma, where it occurs in the Caney and Moorefield shales.

To the north of these quadrangles the Gasper has been identified at many localities by its fossils and lithology. In the Gasper of that region occur species of the crinoid genus *Talarocrinus*, which are diagnostic of the Gasper, and the coral *Campophyllum gasperense*, which is confined to and highly characteristic of the lower part of the Gasper in Kentucky and Tennessee.

HARTSELLE SANDSTONE (RESTRICTED)

Name.—The Hartselle sandstone was named by E. A. Smith from Hartselle, Ala., which is located upon the formation. As originally defined and used in previous reports, however, the name was applied to all the sandstone beds and associated beds of shale and limestone down to the base of the Bethel sandstone. As here restricted the Hartselle is a definite and widely distributed lithologic unit, the bottom of which crops out at the north end of the railroad cut half a mile or more north of Hartselle and the top of which descends below the railroad level about 3 miles south of Hartselle and 1 mile north of Leesdale. As here redefined the formation occupies the stratigraphic position of the Hardinsburg sandstone of the Mississippi Valley section of the Chester group. In this area, as elsewhere in the State, it is overlain by the Bangor limestone as restricted, the basal part of which corresponds to the Glen Dean limestone of the Mississippi Valley. In northwestern Alabama the Golconda formation underlies the Hartselle sandstone as restricted and is in turn underlain by the Cypress sandstone. In these quadrangles, however, the Golconda and Cypress are absent so far as known, and the Hartselle sandstone rests on the Gasper formation.

Character and distribution.—In the Bessemer-Vandiver district and in the Birmingham quadrangle, on the north, the Hartselle sandstone ranges from a predominantly fine-grained hard rock or almost a quartzite to one that is locally coarse grained and friable. The coarse-grained friable phase is well exhibited at a quarry half a mile west of Irondale, where the rock is utilized for sand, being so soft that it can be pulverized by rubbing with the fingers.

The Hartselle sandstone is one of the most persistent stratigraphic units in the region, being present in Brown Valley, in Murphrees Valley, and along the east side of Shades Valley nearly to Readers Gap. Owing to its resistant character it is a ridge maker, forming, for example, Sand Ridge in Shades Valley, which extends along the east side of Red Mountain from the north edge of Bessemer quadrangle to a point east of Bessemer, where the sandstone and the ridge die out. The Hartselle can not be recognized in Cahaba Valley in the Bessemer-Vandiver district, although east of Leeds, in the Birmingham quadrangle, 4 miles along the strike northeast of the margin of the Vandiver quadrangle, there is a sandstone in its position and correlated with it. There is a good development of both the Hartselle sandstone and the Gasper formation in Watkins Gap, 1 mile east of Odenville and 10 miles or more northeast of Leeds.

Thickness.—The thickness of the Hartselle sandstone penetrated in the bore hole in the vicinity of Irondale, as interpreted by the drillers, is 117 feet. (See fig. 4, section 3.) The sandstone gradually diminishes in thickness southward in Shades Valley until it thins out entirely about the latitude of Bessemer. No sandstone was encountered at its horizon in the Woodward shaft, a little southeast of Bessemer.

Correlation.—The Hartselle sandstone as restricted occupies the stratigraphic position of the Hardinsburg sandstone of Illinois and Kentucky and is correlated with that formation.

BANGOR LIMESTONE (RESTRICTED)

Name.—The Bangor limestone as redefined and restricted is named from Bangor, Ala., in the Birmingham quadrangle, near which it is typically developed and fully exposed. It includes the limestone between the underlying Hartselle sandstone and the overlying Pennington shale, or, as in Shades Valley between the Hartselle and an overlying tongue of Floyd shale, as explained in the description of the Floyd.

The name Bangor limestone was introduced at approximately the same time by Hayes, of the United States Geological Survey, and by Smith, the State geologist of Alabama. Unfortunately the name has never been precisely defined nor consistently applied. The following quotation reveals just what strata Hayes[19] intended the term to include.

> The upper member of the sub-Carboniferous or Mississippian group consists in the main of pure blue limestone. Its greatest development is in the western division of the area, where it rests directly upon the Oxmoor [Hartselle] sandstone; or, where that is wanting, as at Stephenson, Ala., the limestone extends without break down to the Fort Payne chert.

The map accompanying the report from which the above quotation is taken, as well as the maps of the Stevenson and Gadsden folios, show that Hayes included in the Fort Payne chert all the strata of Mississippian age below the "Oxmoor" (Hartselle) sandstone, and of necessity where the "Oxmoor" is absent the Bangor rests upon his Fort Payne.

Smith included in the Bangor in the Tennessee Valley in northwestern Alabama all the limestone and sandstone below the "Coal Measures" (Pottsville formation) and above the top of the siliceous (cherty) limestone, probably there corresponding to the top of the St. Louis limestone. Smith thus included in the Bangor the Ste. Genevieve limestone and Gasper oolite. In Birmingham Valley the Ste. Genevieve is absent and the Gasper consists of 50 to 100 feet of shale underlain, at Vann's quarry, by a thin bed of oolite. (See Pl. XX.) In the Birmingham folio, which covers the area north of the Bessemer-Vandiver district, the writer made the top of the Fort Payne as now limited the bottom of the Bangor, thus including in the basal part of the Bangor, in the south end of Browns Valley, 30 miles due north of Birmingham, about 130 feet of limestone now known to belong to the St. Louis and Warsaw formations. As the Bangor in that usage includes several units of formational rank it seemed best to restrict the name to the limestone unit typically developed at Bangor, which overlies the Hartselle sandstone ("Oxmoor" sandstone of Hayes), and thus to return to Hayes's original usage. The name was thus restricted by the writer in the "Geology of Alabama."[20]

[19] Hayes, C. W., op. cit., p. 48.

[20] Alabama Geol. Survey Special Pub. 14, 1926.

Distribution.—The Bangor limestone in this area crops out only in the northern part of Shades Valley immediately east of Sand Ridge, where it occupies a wedge-shaped area that tapers southward to a point a few miles south of Graces Gap. No natural exposures were observed. One small exposure was seen in an old quarry about half a mile east of Graces Gap. Knowledge of the limestone in this area has been acquired through borings to the iron ore. The Bangor does not extend southward to the latitude of Bessemer, as shown by a shaft and by borings in Shades Valley east of Bessemer.

Character.—Where the Bangor is exposed in the area to the north of this district, as in Browns and Murphrees valleys, in the Birmingham quadrangle, it is a rather thick bedded, prevailingly coarsely crystalline or oolitic bluish to gray limestone, generally crowded with fossils. In Shades Valley, where it is not exposed in outcrop, its character is reported in the logs of borings as follows:

Log of boring in the NE. ¼ SE. ¼ sec. 26, T. 27 S., R. 2 W., in Shades Valley about 4½ miles northeast of Rosedale

	Feet
Soil	8
Shale, black (Floyd)	292
Limestone, hard (top of Bangor)	30
Limestone, gray	37
Sandstone	6
Limestone	97
Limestone, hard	175
Clay (base of Bangor)	5
Sandstone (Hartselle)	115

Log of boring about half a mile southeast of Graces Gap

	Feet
Alluvium	2
Limestone, blue (top of Bangor)	45
Limestone, blue, stratified	67
Shale, blue	20
Limestone, gray (base of Bangor)	48
Sandstone (mostly), Hartselle	135

These logs do not give much information regarding the character of the limestone. If it differs from its character in the region farther north the reasonable supposition is that it has a larger content of clayey matter, which it would have acquired near the area of its lateral passage to the Floyd shale facies described below.

In the vicinity of Bangor a clay or dark shale that has a maximum thickness of about 20 feet and lies directly above the Hartselle sandstone is included in the Bangor. Above the shale is a sandstone as much as 5 feet thick. The best exposures of these beds are in a cut on the abandoned site of the Louisville & Nashville Railroad about half a mile south of Bangor and in an old road in the SE. ¼ sec. 22, 1½ miles east of Bangor, where the sandstone is 5 feet thick.

Thickness.—As shown by borings the Bangor limestone is 365 feet thick in Shades Valley, at the north edge of the Bessemer quadrangle, and at least 133 feet thick at Graces Gap. It may be thicker in that latitude than is shown in the boring, which may have started below the top of the limestone. In the latitude of Bessemer it is absent, as shown by the shaft already mentioned and borings to the bed of iron ore.

Age and correlation.—The age and correlation of the Bangor limestone are explained in connection with the age and correlation of the Floyd shale.

FLOYD SHALE

Name.—The name Floyd shale was introduced by Hayes for a thick mass of rock typically developed in Floyd County, Ga., composed predominantly of green, dark, and black shale but including considerable limestone and some sandstone.

In Shades Valley the Bangor limestone as here restricted passes laterally into shale like that of the Floyd, and to this shale the name Floyd is applied, although it is not strictly equivalent to the typical Floyd, which includes older beds than the Bangor. In Shades Valley the Floyd also extends up to the sandstone that makes Little Shades Mountain, which is taken as the base of the Parkwood formation, and in the northern part of Shades Valley an upper tongue of Floyd shale overlies the Bangor limestone.

Distribution.—There are five areas of Floyd shale, a narrow strip northeast of Dolomite; the Shades Valley area, which expands to a width of 4 miles southeast of Bessemer, where low dips and gentle rolls prevail; the Cahaba Valley belt; the Vandiver-Peavine Creek belt; and the wide area east of the Coosa coal field. In the Coosa area the beds are intensely crumpled and apparently somewhat broadly and irregularly folded, so that the formation, though probably not over 1,200 feet thick, spreads over an area 6 to 7 miles wide in a highly inclined attitude.

Character.—The Floyd is composed predominantly of gray calcareous olive-green and carbonaceous black shale and subordinately of impure limestone and hard fine-grained greenish and gray sandstone. The shale is exceedingly soft and friable and crumbles easily in the hand. There is little or no stiff fissile shale. The limestone and sandstone of the Floyd are lenticular, especially in the region east of the Coosa coal field. On the south side of Bee Mountain, 3 miles southeast of Bessemer, 140 feet above the highway, there is a lens of coarsely crystalline fossiliferous limestone 5 feet thick at the thickest point and about 100 yards long on the outcrop. On the edges it breaks down into nodules, and a little beyond disappears entirely. Limestone lenses of the same character were noted at a few places in the area east of the Coosa field.

The general character of the Floyd in Shades Valley is revealed in a bore hole near the Woodward shaft the log of which is given below as identified by J. A. Udden:

Section of Floyd shale in bore hole near Woodward shaft 3 miles southeast of Bessemer, Ala.

	Feet
Floyd shale:	
Sandstone, shale, and some limestone	63
Shale	160
Limestone, argillaceous	10
Shale, grayish	312
Sandstone, shaly	6
Shale, grayish	113
Limestone, argillaceous	2
Shale	51
Limestone, argillaceous	2
Shale, dark	176
	895
Warsaw limestone	79
Fort Payne chert	129

The absence of the Bangor limestone and Hartselle sandstone as distinct units in this locality is demonstrated by this section.

Thickness.—The best determination of the thickness of the Floyd is afforded by the Woodward shaft, where the thickness penetrated is 895 feet. As the shaft starts about 150 feet below the top of the Floyd, the total thickness is about 1,045 feet. In a boring on Shades Creek, $2\frac{1}{2}$ miles southwest of Oxmoor, in the NE. $\frac{1}{4}$ sec. 8, T. 19 S., R. 3 W., it is about 1,000 feet thick.

Owing to extreme crumpling in the area in Coosa Valley, in the Vandiver quadrangle, no reliable estimate of thickness can be made. It may not exceed 1,100 or 1,200 feet, although owing to the crumpling the formation is highly inclined and its outcrop is 7 miles wide.

Relations of the Floyd shale and Bangor limestone.—At Trussville, in the Birmingham quadrangle, about 20 miles northeast of Oxmoor, the interval between the Hartselle sandstone and the bottom of the Parkwood formation is occupied by the Bangor limestone as here restricted. At Oxmoor or a little to the south, in the Bessemer quadrangle, the corresponding interval is occupied by the Floyd shale. Between the latitude of Oxmoor and that of Trussville the Bangor limestone and that part of the Floyd shale above the Hartselle sandstone pass laterally into each other. About midway between Trussville and Oxmoor a drill hole penetrated first 292 feet of dark shale and below that 365 feet of limestone in going down to the top of the Hartselle sandstone, showing that in the vicinity of Irondale almost the upper half of the Bangor has passed into the shale facies. The equivalence of the Bangor limestone and that part of the Floyd shale above the Hartselle sandstone seems fully established by their stratigraphic and geographic relations just described.

Age and correlation of Floyd shale and Bangor limestone.—The Floyd shale and Bangor limestone as here restricted carry an abundant fauna of Chester species identified by G. H. Girty in 1908 and listed below. The first of the lists given is a composite list of species collected from both the Bangor limestone and Floyd shale at different places in Shades Valley in the Birmingham and Bessemer quadrangles. The fossils in the second list came from the top of the Floyd shale east of the Coosa coal field, at the east end of the tunnel on the Central of Georgia Railway between Dunnavant and Vandiver.

List No. 1

Pentremites godoni DeFrance.
Pentremites pyramidatus Ulrich. (Added by Butts.)
Prismopora serrulata Ulrich. (Added by Butts.)
Archimedes communis Ulrich.
Archimedes meekanus Ulrich.
Archimedes swallovanus Ulrich.
Archimedes terebriformis Ulrich.
Chonetes aff. illinoisensis Worthen=C. chesterensis Weller? (Question by Butts.)
Cliothyridina sublamellosa (Hall).
Cliothyridina hirsuta (Hall)?
Composita subquadrata (Hall).
Diaphragmus elegans (Shumard).
Dielasma formosum (Hall)?
Eumetria verneuiliana (Hall).
Leiorhynchus laura=L. carboniferum? (Question by Butts.)
Lingulodiscina batesvillensis Girty.
Derbya (Orthotetes) kaskaskiensis McChesney.
Productus inflatus McChesney.
Productus aff. P. hirsutiformis.
Productus ovatus Hall.
Productus parvus Meek and Worthen.
Productus aff. P. pyxidiformis DeKoninck.
Productus semireticulatus Martin.
Pustula punctatus (Martin).
Reticularia setigera (Hall).
Spirifer aff. S. cameratus Morton.
Spirifer increbescens Hall.
Spirifer leidyi Norwood and Pratten.
Spiriferina spinosa Norwood and Pratten.
Spiriferina transversa McChesney.
Aviculopecten chesterensis Worthen.
Aviculopecten aff. A. coxanus Meek and Worthen.
Aviculopecten hardinensis Worthen.
Caneyella wapanuckensis Girty.
Deltopecten occidentalis (Shumard).
Edmondia aff. E. glabra Meek.
Leda nasuta Hall?
Leda vaseyana (McChesney).
Lima chesterensis Worthen.
Myalina arkansana Weller.
Myalina batesvillensis Girty.
Myalina monroensis Worthen.
Nucula illinoisensis.
Pteria (Leptodesma?) sp.
Pteria aff. P. sulcata.
Schizodus aff. S. symmetricus Calvin.
Sulcatopinna maxvillensis Whitfield?
Yoldia laevistriata Meek and Worthen.
Conularia aff. C. newberryi Winchell?
Bucanopsis aff. B. textilis (Hall).
Euphemus aff. E. nodocarinatus (Hall).
Straparollus planidorsatus Meek and Worthen.

List No. 2

Pentremites godoni DeFrance?
Pentremites symmetricus Hall?
Archimedes lativolvis Ulrich?
Archimedes terebriformis Ulrich.
Composita subquadrata (Hall).
Eumetria verneuiliana (Hall).
Derbya (Orthotetes) kaskaskiensis McChesney.
Productus semireticulatus Martin.
Reticularia setigera (Hall).
Spirifer leidyi Norwood and Pratten.
Spiriferina spinosa Norwood and Pratten.
Spiriferina transversa McChesney.
Allorisma? sp.
Aviculopecten aff. A. chesterensis Worthen.
Aviculopecten aff. A. magnus Swallow.
Aviculopecten aff. A. monroensis Worthen?
Laevidentalium? sp.
Leda sp.?
Myalina angulata Meek and Worthen.
Pteria (Leptodesma?) sp.

A few plants have been collected from clay just above the Hartselle sandstone exposed in a cut on the old site of the Louisville & Nashville Railroad half a mile south of Bangor in the Birmingham quadrangle (list No. 3), and from the Floyd shale in Shades Valley near the south boundary of the Bessemer quadrangle (list No. 4). These plants are listed below as identified by White.

List No. 3

Asterocalamites scrobiculatus (Schlotheim).
Bothrodendron sp.
Lepidodendron volkmannianum Sternberg.
Lepidophyllum n. sp.
Psilophyton sp.
Sigillaria (Subsigillaria) n. sp.
Sphenopteris cf. S. distans Sternberg.
Sphenopteris (Rhodea) moravica Ettingshausen?
Sphenopteris cf. S. schistorum Zeiller.
Sporocystis sp. cf. S. cardiocarpon rostratum O. Feist.

List No. 4

Rhacopteris sp.
Cardiopteris n. sp.
Sphenopteris n. sp. (West Virginia form).
Sphenopteris goepperti Dunker.
Sphenopteris sp. undet. cf. Rhacopteris machaneki Stur.
Trigonocarpum n. sp.

Nearly all the species of invertebrates in the above lists would be expected in any considerable collection of Chester group fossils from the Mississippi or Ohio valleys. Nevertheless, *Pentremites pyramidatus* is known elsewhere only from the Glen Dean limestone of Kentucky and Tennessee, and *Prismopora serrulata*, which is very common in the Glen Dean, is rare in any other formation. *Chonetes chesterensis* is also common in the Glen Dean in Tennessee and abundant in it in Colbert County, Ala., where it is associated with other characteristic Glen Dean forms. The position of the Bangor as here restricted and of the part of the Floyd shale above the Hartselle sandstone, which is correlated with the Hardinsburg sandstone, is an added evidence of the Glen Dean age of at least the lower part of the Bangor and equivalent beds in the Floyd shale. It is probable, however, that the upper part of the Floyd corresponds to part or all of the Pennington formation of Virginia, Kentucky, and Tennessee and includes the equivalent of the Pennington as recognized in the Birmingham quadrangle (northern part only, not in Shades Valley[21]), although no red shale or other rocks of Pennington type have been observed there. The tongue of Floyd shale overlying the Bangor limestone in Shades Valley was called Pennington in the Birmingham folio.

The occurrence of *Caneyella* in this region is interesting. The genus is characteristic of the Caney shale of Oklahoma and the Moorefield shale of Arkansas and has not, so far as the present writer knows, been found in Chester rocks elsewhere except in Alabama.

The plants are of interest in that fossil plants are rare in the Mississippian formations of the central United States. They exhibit, too, a curious mixture of forms generally accredited to the Devonian (*Psilophyton*), Mississippian (*Sphenopteris moravica* and *S. schistorum*), and Pennsylvanian (the *Asterocalamites* and the *Lepidodendron*).

PARKWOOD FORMATION

Name.—The Parkwood formation was named from the town of Parkwood, in the Bessemer quadrangle, which is located on the formation. It includes the 1,500 to 2,200 feet of gray shale and sandstone lying above the base of the sandstone that makes Little Shades Mountain and Bald Ridge half a mile west of Oxmoor and below the Brock coal bed, which is taken as the base of the Pottsville formation. (See section 3, fig. 4.)

Distribution.—The formation crops out in these quadrangles only on the west sides of the Cahaba and Coosa coal fields, whence it dips eastward beneath the younger rocks. It crops out along both sides of the Vandiver-Peavine Creek valley; and, dipping westward, it is exposed for a short distance along the east side of the Coosa field in the southern part of the Vandiver quadrangle. Along most of the east side of the Coosa field the Parkwood is faulted out. The best outcrops of the Parkwood are in the vicinity of Oxmoor, where it is nearly all exposed, and along the Southern Railway west of Genery Gap, in the Bessemer quadrangle.

Character.—The Parkwood formation in these quadrangles is composed of gray shale and sandstone that bear a close resemblance to the Pottsville rocks, which overlie the Parkwood. The sandstone generally makes thick beds, the maximum being 100 feet. Some of it is hard and quartzose, but most of it is probably more or less feldspathic. Much of it is somewhat ferruginous and weathers to a rusty color. No calcareous matter occurs in the formation, and at only one point was black shale noted. In these respects the Parkwood is entirely different from the underlying Bangor and Floyd in Shades Valley. In its eastern areas of outcrop, however, the Parkwood is scarcely distinguishable from the Floyd, for the upper part of the Floyd, although it contains layers of black shale, is there largely made up of gray shale with gray quartzose sandstone similar to that of the Parkwood.

Thickness.—The thickness of the Parkwood appears to be 2,200 feet just east of Trussville, in the Birmingham quadrangle; 1,500 feet east of Irondale, also in the Birmingham quadrangle, and at Oxmoor in the Bessemer quadrangle; and not over 1,000 feet on the west side of the Coosa coal field. The thickness attains the maximum at Trussville and decreases in all directions as if the formation were beveled by pre-Pottsville erosion.

Age and correlation.—The Parkwood affords very little evidence of its age except that of its position above the Floyd shale, which is of Chester age, and below what is taken as the base of the Pottsville formation. Lithologically, except for the absence of coal beds, the Parkwood is more like the overlying Pennsylvanian than the underlying Mississippian formations. Fossils were found in it in the sandstone that makes Bee Ridge, where it is exposed in a cut on the Southern Railway half a mile north of Genery Gap. These fossils are listed below as identified by G. H. Girty:

Rhombopora? sp.
Schizophoria n. sp.
Derbya crassa Meek and Hayden?
Pustula aff. P. nebraskensis (Owen)?
Marginifera? n. sp.
Dielasma? sp.
Spirifer rockymontanus Marcou.
Composita subtilita (Hall).
Hustedia n. sp.?
Nucula sp.
Parallelodon aff. P. tenuistriatus (Meek and Worthen).
Aviculopecten sp.
Deltopecten occidentalis (Shumard).
Pleurophorus subcostatus Meek and Worthen.
Bucanopsis? sp.
Euphemus sp.
Pleurotomaria sp.
Sphaerodoma sp.

Girty says:

> The Pottsville age of this collection does not rest on certain ground, though it may be regarded as probable. Hardly any of the species listed, and not many of the genera, even if the generic assignments could be vouched for, weigh heavily on the Pennsylvanian side. This fauna, however, shows a conspicuous change from the lower faunas, a change marked by the complete elimination of the diagnostic genera and species that assure their Mississippian age. At the same time it shows a distinct rapprochement with the Pottsville faunas above, the most noteworthy evidence in point being perhaps the *Schizophoria*, which occurs in so many of the Pottsville collections but is entirely lacking in the Mississippian ones. The genera *Marginifera* and *Hustedia*, though they probably are not quite restricted to the Pennsylvanian faunas, suggest the same assignment.

Another collection of fossils, listed below as identified by Girty, is composed of distinctly Mississippian species. The horizon of these fossils is at least 500 feet above the bottom of the Parkwood as somewhat doubtfully located in the vicinity of the place at which the lot was obtained.

Fistulipora sp.
Cystodictya sp.
Rhombopora sp
Fenestella tenax Ulrich.
Archimedes sp.
Polypora sp.
Diaphragmus elegans (Worthen).
Camarotoechia? sp.
Dielasma sp.
Spiriferina sp.
Deltopecten aff. D. batesvillensis Girty.
Leptodesma carboniferum?
Yoldia levistriata Meek and Worthen?

The source of these fossils is a fine-grained friable brownish to yellowish sandstone or sandy shale 20 feet thick and rather unlike most of the Parkwood or Floyd beds, If the horizon of this collection is correctly identified the lower 500 feet of the Parkwood is certainly Mississippian, probably corresponding to part of the Pennington formation of the type region, in southwestern Virginia. The Mississippian-Pennsylvanian boundary would lie, then, between the horizon of this fauna and the horizon of that obtained from the sandstone of Bee Ridge. Such a location of the boundary is just what would be expected, if, as is probable, the Parkwood bridges the gap that elsewhere in the Appalachian region separates the Mississippian and Pennsylvanian. In this folio the Parkwood is tentatively classified as Mississippian.

UNCONFORMITY AT THE TOP OF THE MISSISSIPPIAN

Where the Parkwood is thickest, in Shades Valley, sedimentation was apparently continuous into Pennsylvanian time, but in the Warrior field, where the Parkwood is absent, the Pennsylvanian rocks rest unconformably on the Floyd. This relation is in harmony with the marked unconformity that has been long recognized by geologists as existing between the Mississippian and Pennsylvanian on the west side of the Appalachian Valley province from Alabama to Pennsylvania.

PENNSYLVANIAN SERIES

POTTSVILLE FORMATION

Name.—The Pottsville formation takes its name from Pottsville, in the anthracite coal field of Pennsylvania. It forms the lowest part of the Pennsylvanian series in the Appalachian coal fields and constitutes the top of the Paleozoic section in Alabama.

[21] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Birmingham folio (No. 175), 1910.

Distribution.—As shown on the areal-geology maps, the Pottsville formation occupies three separate areas—the Warrior field, in the northwest corner of the Bessemer quadrangle; the Cahaba field, which lies diagonally across the median part of the two quadrangles, and the Coosa field, which extends diagonally across the Vandiver quadrangle.

Character.—The Pottsville rocks are made up of sandstone and shale containing coal beds. The sandstone consists almost wholly of quartz grains, though it contains a little mica and feldspar and scattered crystals of magnetite and zircon. None of the sandstone contains enough feldspar to be markedly arkosic. In addition to aluminous matter the shale contains a large proportion of very fine quartz grains and of mica shreds in about equal proportion, together with small amounts of the other minerals that occur in the sandstone. Carbon and iron oxide are present in both shale and sandstone as coloring matter. The shale of the Pottsville ranges from a pure clay to a sandy material; the clay is excellent for building brick, especially pressed brick, and the sandy material for vitrified brick for paving and other purposes.

Although most of the rocks are probably of fresh-water origin, yet the presence of marine fossils in certain beds from the bottom to the top of the formation shows that those beds were deposited in the sea.

Coal is the most distinctive and valuable constituent of the formation and is fully described under the heading "Economic geology." The names and vertical succession of the coal beds are shown in the columnar-section sheet and in Figure 5.

The lower part of the formation includes thick and resistant beds of sandstone or conglomerate that persist throughout all its areas and express themselves in prominent ridges, such as Sand Mountain in the Warrior field, Shades Mountain in the Cahaba field, and Double Mountain and others in the Coosa field. These beds are commonly called "Millstone grit." Owing to their stratigraphic significance and topographic prominence several of these sandstones are named and mapped as members of the Pottsville formation.

The part of the formation above that which contains these basal sandstone members is a monotonous repetition of shale and sandstone beds, in which some of the shale beds are as much as 200 feet thick. Nearly all the workable coal beds occur in this upper part—that is, above the "Millstone grit." The coal groups of the Warrior field are generally associated with much sandstone. The coarsest conglomerate in the Bessemer-Vandiver district, the Straven conglomerate, occurs high in the formation. Some of these upper sandstone beds are prominent enough to be mapped as members, as the Razburg sandstone member in the Warrior field, the Rocky Ridge sandstone member and the Straven conglomerate member in the Cahaba field, and the Straight Ridge and Wolf Ridge sandstone members in the Coosa field.

Boyles sandstone member.—At the base of the Pottsville in the Warrior field, immediately above the Bangor limestone or Floyd shale, lies the Boyles sandstone member, named from Boyles Gap through Sand Mountain, 4 miles north of Birmingham. Its only area of outcrop in the Bessemer quadrangle extends from Wylam to a point 1 mile southwest of Dolomite, where it is faulted out. It is nearly vertical along this outcrop, which is marked by a low ridge or a line of low knolls. The sandstone is coarse, thick bedded, quartzose, and in places conglomeratic at the base. Where thickest it changes to a flaggy, finer-grained, and perhaps argillaceous rock toward the top. In the vicinity of Wylam it is slickensided and quartzitic as a result of crushing and slight metamorphism near the great fault bordering the coal field. It is about 100 feet thick and is believed to correspond to the Pine sandstone of the Cahaba field.

Razburg sandstone member.—The highest bed of the Pottsville in this area, in the northwest corner of the Bessemer quadrangle, is a sandstone named the Razburg sandstone member, from Razburg post office, 9 miles west of the Bessemer quadrangle, where it is well developed and exposed. The Razburg sandstone occupies a large part of the surface of the Warrior field in the Bessemer quadrangle and is persistent throughout a large area in the Brookwood quadrangle, to the southwest. It is gray, generally thick bedded, rather coarse, and 20 to 30 feet thick.

Brock coal.—The Brock coal bed, named from Brock Gap, near Parkwood, is regarded as the base of the Pottsville formation in the Cahaba coal field. As it is a persistent bed and is recognizable at a number of points along the northwest margin of the Cahaba field it serves excellently as a boundary.

Shades sandstone member.—The Brock coal is overlain by 40 to 60 feet of shale, above which lies the Shades sandstone member, named from Shades Mountain, which is formed of this sandstone. It crops out along the crest and eastern slope of the mountain, and its basal 40 feet or more crops out as a cliff for long stretches on the western slope of the mountain. The cliff is especially conspicuous on Shades Mountain at Oxmoor. In the Coosa field, where the Shades sandstone member is steeply inclined, its outcrops give rise to such conspicuous ridges as Oak Mountain, Double Mountain, and Double Oak Mountain. The Shades sandstone is thick bedded, rather coarse, and generally somewhat conglomeratic in the lower part, where the pebbles of white quartz are small and pockety in distribution. It is about 200 feet thick in the Cahaba field and even thicker in the Coosa field.

Pine sandstone member.—About 200 feet above the Shades sandstone in the Cahaba field and 1,000 feet above it in the Coosa field lies the Pine sandstone member, named from Pine Ridge, in the Cahaba field. In the Bessemer quadrangle this member crops out along the crest and east slope of Pine Ridge, the sandstone and the ridge persisting the entire length of the Cahaba field. In the Coosa field the Pine sandstone, like the Shades, is more strongly developed than in the Cahaba field. It crops out along the ridges parallel to the outcrop of the Shades sandstone and forms the crest of Pine Mountain. Signal Mountain, the highest point in the quadrangles, is formed of this sandstone. The Pine sandstone member is quartzose, coarse, and thick bedded at the base but finer grained and more flaggy at the top and is 250 feet thick. It is correlated with the Boyles sandstone member of the Warrior field.

Chestnut sandstone member.—Above the Pine sandstone lies about 500 feet of beds that are mostly shale, and above this shale lies a persistent quartzose sandstone 100 feet thick, which makes Chestnut Ridge, an easily recognizable feature along almost the whole length of the Cahaba field. This sandstone is named the Chestnut sandstone member.

Rocky Ridge sandstone member.—The Rocky Ridge sandstone member is named from the fact that it forms Rocky Ridge, to the east and northeast of the Cahaba pumping station, in the northwestern part of the Vandiver quadrangle. This member has been recognized only in the Little Cahaba syncline, where it crops out in two separate areas, the narrow syncline east and northeast of the pumping station and the somewhat more complexly folded area $2\frac{1}{2}$ to 5 miles south of the pumping station and east of Caldwell ford. It is best displayed and apparently best developed around the south end of the syncline east of the pumping station. As shown in that locality it is a thick-bedded conglomeratic quartzose sandstone, apparently 50 to 100 feet thick. It is sufficiently prominent in the southern area described to be traceable with a good degree of certainty and has served as a key to the complex structure of that area.

Straven conglomerate member.—The Straven member, named from Straven, in the Montevallo quadrangle, lies about 500 feet below the top of the Pottsville of this area. It extends across the quadrangles and is present in each of the subordinate basins on the east side of the Cahaba field. The Straven is a very coarse conglomerate 40 feet thick or thereabouts. It is composed of quartzite and chert pebbles 4 inches or less in diameter, with just enough fine material to cement the pebbles together. The pebbles diminish in number and size northward, and in the area southwest of Henryellen in the Birmingham quadrangle the bed is a sandstone that has a few small pebbles scattered through it. The Straven conglomerate is the basal bed of a conglomerate series of the same kind, which reaches a thickness of 2,000 feet, making the uppermost part of the Pottsville formation in the southeastern part of the Cahaba field west of Montevallo. The source of the material was probably still farther southeast.

Wolf Ridge sandstone member.—In the Yellowleaf basin of the Coosa coal field there is a persistent hard quartzitic sandstone 50 to 100 feet thick, which lies about 1,200 feet above the Pine sandstone and which makes a ridge known as Wolf Ridge, from which the sandstone is named. The Wolf Ridge sandstone is especially well developed to the east of Pine Mountain, in the northeastern part of the Vandiver quadrangle, where it makes a persistent and prominent narrow ridge, in the gaps of which, as at Rattlesnake Gap, the hard white sandstone is well exposed. It also makes a well-marked ridge to the north of Locust Ridge and northwest of Thomas Gap, in the southwest corner of the Vandiver quadrangle. The Wolf Ridge sandstone is correlated with the Chestnut sandstone of the Cahaba field.

Straight Ridge sandstone member.—The name Straight Ridge sandstone is given to a resistant bed 50 to 100 feet thick that makes the ridge of that name which extends along the west side and south end of the Yellowleaf basin. It lies about 800 feet above the Wolf Ridge sandstone.

Red shale.—The upper 2,000 feet of the Pottsville of the Coosa coal field is composed of shale with thin sandstone layers. In this mass red shale occurs at 1,500 feet and 1,000 feet below the top. At each level this shale appears to occur as lentils here and there through beds 50 to 100 feet in thickness. These red shales are notable from the fact that they are the only such shales in the Pottsville of Alabama.

Thickness.—The thickness of the Pottsville in the Warrior field in this area is about 2,300 feet, in the Cahaba field 5,500 feet, and in the Coosa coal field 7,400 feet.

Age and correlation. — Considerable collections of fossil plants and invertebrates have been made from the Pottsville formation in the course of several seasons' work in the Birmingham district. The collections of invertebrates were obtained at points in the Warrior and Cahaba coal fields as widely separated as Cleveland, in the northeastern part of the Birmingham quadrangle; Henryellen, in the eastern part of the Birmingham quadrangle; and the mouth of North River, in the southwestern part of the Brookwood quadrangle, about 3 miles north of Tuscaloosa. The collections range through nearly the full thickness of the Pottsville, occurring in at least five thin zones or layers in the Warrior field, the lowest of which is only about 100 feet above the bottom and the highest near the horizon of the Brookwood coal, near the top of the formation. In the Cahaba field two fossil-bearing zones are known, one about the middle and the other well up toward the top of the formation.

The abundance of invertebrate fossils in the Pottsville of Alabama is remarkable in view of their scarcity in the Pottsville farther to the northeast in the Appalachian coal field. Because of that scarcity these invertebrates can not be used to any extent in correlating the Pottsville of Alabama with that of other parts of the Appalachian region, and because of their great similarity through the full thickness of the Alabama Pottsville, they are not serviceable for identifying horizons or for correlating the beds of the Warrior and Cahaba coal fields. They do, however, throw much light on the history of the Alabama region in Pottsville time, as brought out under the heading "Geologic history."

The invertebrate fossils from the Pottsville formation of the Birmingham district, Ala., shown in the following list were identified by G. H. Girty in 1908:

Lophophyllum profundum Edwards and Haime.
Glyptopora? sp.
Lingula aff. L. carbonaria Shumard.
Lingulidiscina convexa Shumard.
Schizophoria n. sp.
Derbya aff. D. bennetti Hall and Clarke.
Derbya crassa Meek and Hayden.
Derbya robusta Hall?
Chonetes n. sp.
Productus cora D'Orbigny.
Productus nebrascensis Owen.
Productus semireticulatus Martin (fine variety).
Productus aff. P. symmetricus McChesney.
Marginifera muricata Norwood and Pratten.
Spirifer rockymontanus Marcou.
Ambocoelia planiconvexa Shumard.
Spiriferina kentuckyensis Shumard.
Spiriferina spinosa Norwood and Pratten?
Composita subtilita (Hall).
Cliothyridina missouriensis Swallow.
Hustedia mormoni Marcou.
Solenomya sp.
Solenopsis solenoides Geinitz.
Edmondia gibbosa Swallow.
Edmondia aff. E. subtruncata Meek.
Sedgwickia n. sp.
Nucula ventricosa Hall?
Leda bellistriata Stevens.
Yoldia oweni McChesney?
Parallelodon tenuistriatus (Meek and Worthen).
Aviculopecten peracuta Shumard.
Myalina aff. M. kansasensis Shumard.
Myalina swallowi McChesney.
Schizodus aff. S. symmetricus Calvin.
Aviculopecten herzeri Meek.
Aviculopecten aff. A. providencensis Cox.
Aviculopecten rectilaterarius Cox.
Deltopecten aff. D. occidentalis (Shumard).
Lima retifera Shumard.
Modiola subelliptica Meek.
Allorisma terminale Hall.
Astartella vera Hall.
Euomphalus catiloides (Conrad)?
Pleurotomaria, several species.
Phillipsia aff. P. major Shumard.
Phillipsia aff. P. scitula Meek and Worthen.
Estheria dawsoni Jones.

General correlation of the coal beds.—As there is no direct connection between the different coal fields of Alabama, the fossil plants must serve for correlating the coal beds. An incomplete study of the considerable collections of fossil plants has enabled David White to correlate tentatively the Rosa coal in Berry Mountain, the Swansea or Inland coal of the Blount Mountain field, and the Black Creek, Mary Lee, and Pratt coal beds of the Warrior field with the Gould, Harkness, Wadsworth, and Clark (Little Pittsburgh?) beds, respectively, of the Cahaba field, as shown in Figure 5. On stratigraphic grounds the Nivens and Howard coals of the Coosa basin are correlated by the writer with the Gould coals of the Cahaba basin, as the Gould coals lie in the interval between the Pine and Chestnut sandstones and the Nivens and Howard coals between the Pine and the Wolf Ridge sandstones, the Wolf Ridge being correlated with the Chestnut. The higher coals of the Coosa basin are tentatively correlated in a general way with the beds shown opposite them in the section of the Cahaba field in Figure 5. As fossil plants are rare in the south end of the Coosa basin, this means of correlation is not at present available.

White divides the Pottsville formation into lower, middle, and upper Pottsville. The lower Pottsville extends from the bottom of the Pottsville to the top of the Lee formation of Virginia and Tennessee or to the top of the sandstone in east Tennessee named Emory by Safford and Killebrew and Rockcastle by Campbell. It includes the Pocahontas coals of Virginia and West Virginia. The middle Pottsville includes the beds that carry the Sewell and Quinnimont coals of West Virginia, and the upper Pottsville includes the Kanawha coals of West Virginia. The corresponding divisions in the Alabama coal field are indicated in Figure 5.

According to White, the Mary Lee bed of the Warrior Field lies at nearly the same horizon as the Soddy coal, a bed that is close above the Lookout sandstone of Hayes in northern Alabama, which is about 700 feet below the top of the lower Pottsville. The same horizon is therefore approximately represented by the Soddy coal of Tennessee, the Mary Lee and Newcastle coals of the Warrior field, and the Wadsworth bed of the Cahaba field, which are thus several hundred feet below the top of the lower Pottsville. The still higher part of the coal measures of the Warrior field falls in the middle Pottsville, no upper Pottsville being present, in that field. In the Cahaba field the upper Pottsville is represented by the Montevallo and higher coal beds, the boundary between the middle and upper Pottsville lying near the Helena or Yeshic coal.

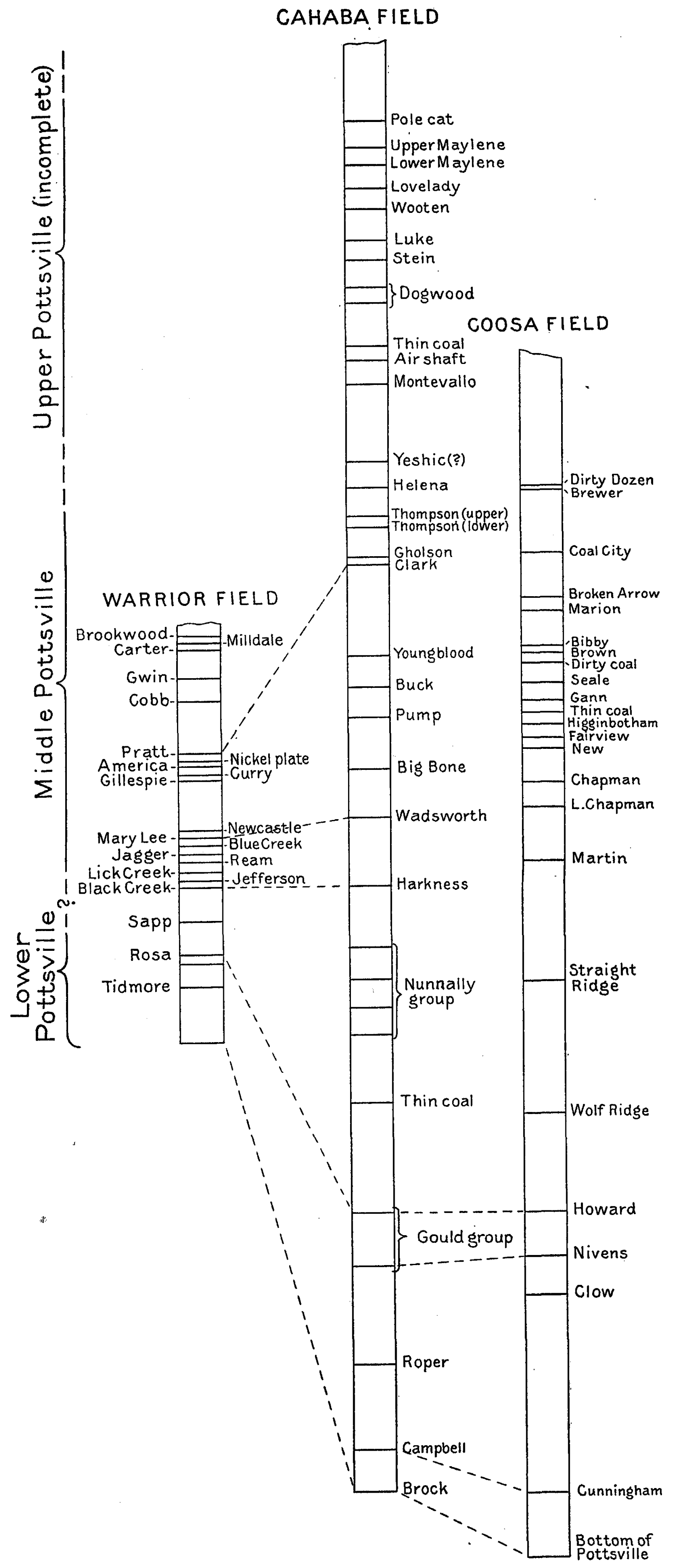

FIGURE 5.—Sections showing coal beds in the three coal fields of Alabama and provisional correlation of the coals
Scale: 1 inch=1,000 feet

A list of the plants identified by White, upon which he bases the correlations just stated, is given below:

Alethopteris helenae Lesquereux.
Alethopteris lacoei White.
Alethopteris lonchitica var. White.
Aneimites cf. A. tenuifolius (Goeppert) White
Annularia acicularis (Dawson) Renault.
Asterophyllites gracilis Lesquereux.
Asterophyllites minutus Andrews.
Calamites suckowii Brongniart.
Calamostachys lanceolata Lesquereux.
Cheilanthites cf. C. cheathami (Lesquereux).
Cheilanthites microphyllus (Lesquereux).
Lepidodendron alabamense White.
Lepidodendron clypeatum Lesquereux.
Lepidodendron obovatum Sternberg.
Lepidophyllum alabamense White MS.
Lepidostrobus pennsylvanicus White.
Mariopteris dimorpha (Lesquereux) White.
Mariopteris inflata var. White.
Mariopteris cf. M. muricata (Schlotheim) Zeiller.
Mariopteris pottsvillea White.
Neuropteris acutimontana White.
Neuropteris biformis Lesquereux.
Neuropteris elrodi Lesquereux.
Neuropteris cf. N. gigantea (Sternberg) Sternberg.
Neuropteris pottsvillea White MS.
Neuropteris schlehani Stur.
Neuropteris smithii Lesquereux.
Rhabdocarpus alabamensis White MS.
Sphenophyllum bifurcatum Lesquereux.
Sphenophyllum tenerrimum Ettingshausen.
Sphenopteris asplenoides Hector.
Sphenopteris cf. S. divaricata (Goeppert) Geinitz and Gutbier.
Sphenopteris flexicaulis (Lesquereux) Lesquereux.
Sphenopteris larischii (Stur) Lesquereux.
Sphenopteris microcarpa Lesquereux.
Sphenopteris obovata Lindley and Hutton.
Sphenopteris palmatiloba White.
Sphenopteris patentissima (Ettingshausen) Schimper.
Sphenopteris quercifolia (Goeppert).
Stigmaria verrucosa (Martin) [Sternberg].
Trigonocarpon ampulaeforme var. spectabile White.
Trigonocarpon alabamense White MS.
Whittleseya campbelli White.
Whittleseya microphylla var. White.

QUATERNARY SYSTEM

The deposits of the Quaternary system consist of the alluvium in the present valleys and are of recent age. They rest directly upon the surface of the Paleozoic rocks, no Mesozoic or Tertiary rocks being known in the Bessemer-Vandiver area. The alluvium consists of fine gravel and silt that has been laid down by the existing streams as they have overflowed their banks. It is confined to strips along the streams, and these strips with few exceptions are narrow. Its total area is only a few square miles, and its thickness is only a few feet.

STRUCTURE

DEFINITION

The term structure is here used to indicate the attitude or "lay" of the strata, which are in reality extensive sheets of rock piled one upon another. Definitions of the terms used in describing structural features are given on the inside of the cover pages of this folio.

METHODS OF REPRESENTING STRUCTURE

The structure of the Bessemer-Vandiver area is shown by structure sections and by structure contours. A structure section shows the lay of the strata as it would appear in a deep trench cut across the region at right angles to the general strike of the rocks. Structure contours show the structure by lines resembling those that represent surface contours, drawn on the map through points at which the surface of a bed taken as the reference stratum lies at a given distance above or below sea level. As for example a line passing through all points on the top of the Pratt coal bed 500 feet above sea level, another through all points 550 feet, a third through all points 600 feet above sea level, and so on. In the Bessemer-Vandiver district the structure is represented by contours only in the small area of the Warrior coal field, in the northwest corner of the Bessemer quadrangle.

The details of structure are shown on the map by strike and dip symbols, by the lines that represent the position of the faults and axes of the folds, and by the structure sections. A few comments on general and special features follow.

GENERAL FEATURES

The general structure of this district is that characteristic of the Appalachian Valley province from Canada to Alabama. The originally horizontal strata have been folded as a result of lateral compression, so that now the major features of the structure are comparable to a succession of great waves that cross the quadrangles in a northeasterly direction, the crests of the waves corresponding to the great anticlines, such as the Birmingham anticline, and the troughs of the waves to the great synclines, such as the Cahaba and Coosa coal fields. However, as the crests of the great anticlines have been eroded off, the undulating structure can be visualized only when the arches are restored in imagination. These major structural features are themselves affected by minor anticlines and synclines, which are mapped and named. Great overthrust faults form the eastern boundaries of the synclinal troughs occupied by the coal fields.

From the Birmingham anticline the rocks dip southeastward into the Cahaba trough. The Red Mountain formation, which crops out at 1,000 feet above sea level on the crest of Red Mountain, descends eastward to 7,000 feet or more below sea level in the Acton basin. The general southeastward dip is interrupted by minor folds like the Tacoa and Dolly Ridge anticlines and the corresponding Belle Ellen and Little Valley synclines. Along the southeast margin of the Cahaba field lie the subordinate basins—the Eureka, Helena, Acton, and Little Cahaba basins. Between the Little Cahaba and Acton basins is an area of complicated folding which has not been fully worked out, though its general character is indicated by the mapping and by structure section C–C′ of the Vandiver quadrangle.

In the same manner the rocks on the southeast limb of another anticline dip from Cahaba Valley southeastward into the Coosa trough but are interrupted by minor folds like the Vandiver anticline and the other minor folds mapped. The Vandiver anticline separates the Yellowleaf basin from the main area of the Coosa coal field. The Yellowleaf basin is a canoe-shaped syncline with the east side faulted out but with both ends partly preserved. From the east side of the Coosa field the rocks seem to dip eastward in general to the Columbiana syncline, which crosses the southeast corner of the Vandiver quadrangle. The former existence of an anticline near the Coosa field is indicated. The surface rocks east of the Coosa field are minutely crumpled, as noted in the description of the Floyd shale (p. 13).

An interesting question in connection with the plicated Floyd shale of Coosa Valley is discussed under the heading "Geologic history."

The east limbs of the great anticlines have been briefly described, but a complete exposition of the structure of the region demands attention to other structural features.

In the development of the folds through pressure on the southeast, which produced a movement of the great body of rocks to the northwest, the crests of the major anticlines were naturally thrust farther to the northwest than the bottoms of the synclines, so that the northwest limbs of the anticlines (or the southeast limbs of the synclines, as they may equally well be designated), which had at the beginning a northwestward dip, became vertical and then overturned with a southeastward dip, and finally in a few places the beds were completely overfolded, so that the beds in these limbs were upside down. These limbs were weakened by stretching and crushing till they finally gave way, and the overlying masses slid forward along the planes of the breaks to such an extent that the older rocks, which were buried deep in the center of the overturned arches, were thrust upward stratigraphically into a position above the upper rocks involved in the folding. In time the overturned and overthrust masses were eroded away and the surface was reduced to the present condition, in which no trace of the faulting is preserved in the topography. Thus were formed the great faults that border the coal fields—the Opossum Valley, Helena, and Coosa faults—and thus the common limbs of the folds (that is, the northwest limbs of the anticlines and the southeast limbs of the synclines) were destroyed or buried. The total northwestward movement along each of these faults was at least as much as the thickness of rocks displaced, which in the Opossum Valley fault is at least 2 miles and in the Helena fault at least 3 miles in places. The actual horizontal movement may have been much greater. The combined effect of all these faults is an overlapping or "weatherboard" structure for the whole area.

DIP OF FAULT PLANES

The dip of the fault planes is unknown for most of their length, but at Aldrich, in the Montevallo quadrangle, data obtained in mining show a dip of 35° E. for the Helena fault at that place.

METAMORPHISM

Notwithstanding the great movement, with attendant friction and crushing near the fault planes, there has been but slight metamorphism of the rocks. The Montevallo coal bed, which has been mined up to the fault, is said to show no change that would indicate any difference from its ordinary chemical composition.

As already described, the Floyd shale is very minutely crumpled, and the beds everywhere dip steeply. They have also been fractured minutely, and the fractures have been filled with quartz, which forms veins, mostly a quarter to half an inch thick.

GEOLOGIC HISTORY

In the earliest time of which there is record in the sedimentary rocks of the Appalachian Highlands, perhaps a hundred million years ago, along the site of the Appalachian Valley lay a strait between still more ancient lands on the east and on the west. This strait was on the eastern border of a great area, extending to the region of the present Great Lakes, that was slowly but intermittently subsiding during all of Paleozoic time. The Appalachian Strait widened into the Appalachian Gulf. The filling up of this subsiding earth basin by sediments derived from the bordering lands constitutes the part of this history which properly begins with the Paleozoic era. The vast lapse of time which had preceded the deposition of these sediments is recorded in the rocks of the Blue Ridge and Piedmont provinces. These rocks, which extend beneath the Appalachian Valley and Appalachian Plateaus, are the foundation upon which the Paleozoic rocks rest.

PALEOZOIC ERA

CAMBRIAN PERIOD

From the bordering land areas great quantities of fine mud were discharged into the Appalachian Strait by the rivers of Talladega time (Algonkian? and Paleozoic). At times coarse sand mixed with small quartz pebbles was deposited and forms the few thin beds of quartzite in the Talladega slate.[22] There was also a short period of limestone deposition, when the Sawyer limestone member was laid down. Fine clayey material greatly predominated, however, which indicates that the material was derived from land of low relief or was deposited in water distant from shore so that only the finer sediment was transported to it.

As most of the Talladega rocks were originally finely stratified clay they were evidently deposited in water, seemingly under conditions favorable to Cambrian types of life. Except for the rare occurrence of calcareous algae in the Sawyer limestone, however, no organic remains have ever been discovered in them or in their equivalent in Georgia and Tennessee and it is believed that the Talladega sea was destitute of life during most of the time of its existence. In this lack of life the lower two-thirds of the Talladega rocks accord with known pre-Cambrian rocks elsewhere, and the weight of evidence seems to the writer to favor their pre-Cambrian age in part.

[22] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Montevallo-Columbiana folio (in preparation). Butts, Charles, and others, Geology of Alabama: Alabama Geol. Survey Special Pub. 14, 1926.

In the succeeding Weisner epoch much coarse sand with fine gravel was deposited in alternation with fine material like that of the Talladega.[22] The Weisner epoch was certainly Cambrian, for Lower Cambrian fossils occur, though rarely, in the Weisner formation.

The Weisner epoch was succeeded by that in which the Shady limestone was laid down.[22] This indicates a great change in geographic or meteorologic conditions, for obviously pure limestone can not be deposited except in water free from earthy sediment. A few forms of life are known to have existed in the sea of the Appalachian region in Shady time but so far as known life was scarce.

The deposition of earthy sediment was resumed in the succeeding Rome epoch, and a notable feature of the deposits then formed is the red shale, which denotes perhaps an accumulation of soil stained red by iron oxide on a tributary land during an arid time in which the Shady limestone was laid down, the lack of water for the transportation of sediment being the cause of the clear sea of Shady time. At rare intervals the Rome sea was invaded by swarms of trilobites and brachiopods whose remains are now entombed in the deposits laid down during the time of their invasion.

In the Conasauga epoch, which followed the Rome epoch, the conditions again favored the formation of limestone in Alabama. The land area west of the Appalachian Strait was submerged, for limestone or sandstone of Conasauga (Upper Cambrian) age is widely distributed over the Middle West, where the older Cambrian rocks are absent, so that the Upper Cambrian rocks rest upon pre-Cambrian crystalline or metamorphic rocks. Life flourished throughout the Conasauga epoch. There were many species of trilobites and a great abundance of individuals. Brachiopods were also plentiful but of few species.

Probably in Conasauga time a persistent land barrier was raised between Cahaba and Birmingham valleys, for, as shown under the heading "Descriptive geology," the Conasauga is absent along the eastern margin of the Cahaba coal field and probably was not deposited there because of an island in that part of the Conasauga sea. This Cahaba barrier marks an area in which there was a decided tendency to uplift, technically called a positive area, as shown below, and to this tendency is due the peculiarities of distribution of the Ordovician limestones in the two valleys as noted under the heading "Stratigraphy" (p. 3) and hereinafter mentioned.

CAMBRIAN OR ORDOVICIAN PERIOD

The period succeeding the deposition of the Conasauga limestone and ending with the deposition of the Chepultepec dolomite was one of the most notable periods for the deposition of dolomite in the history of the earth. After the Conasauga limestone was laid down Birmingham Valley and Cahaba Valley were elevated above sea level, and the resulting erosion produced the unconformity described on page 3. After the deposition of the Brierfield dolomite in the Montevallo region[22] there followed a resubmergence, including that of the Cahaba barrier, except south of Bessemer (p. 3), and the Ketona dolomite was laid down in both Birmingham and Cahaba valleys. The deposition of the Ketona was succeeded by another uplift of about the same region as before while the Bibb dolomite of the Montevallo region was deposited, after which the sea spread over all of the southern Appalachian region and so remained while the great mass of the Copper Ridge dolomite was deposited. In Alabama, northwestern Georgia, and probably southern Tennessee this submergence continued during Chepultepec time, but in the Birmingham Valley local uplifts precluded the deposition of the Chepultepec and succeeding Longview and Newala limestone.

The seas of this dolomite period were nearly devoid of living organisms that possessed parts capable of fossilization except in Chepultepec time, when some forms, principally gastropods, were common but not abundant.

It is the common belief that dolomite is not deposited as dolomite but that limestone is first deposited and subsequently changed into dolomite by the substitution of magnesium for part of its calcium. So far as known limestone at present is being precipitated from solution in water by organic agencies such as mollusks, corals, and lime-secreting plants, among which bacteria play a noteworthy part. As the dolomites of this period are nearly destitute of fossil shells and other parts of organisms, which would have been preserved, it is evident that the limestones from which the dolomites have been derived were not deposited by shell-bearing animals or corals. It seems necessary, then, to assume that the plants, bacteria, and similar organisms were the principal agents, and that, being perishable, they have left no remains. The great mass of limestone may have been converted into compact dolomite contemporaneously with its deposition in sea water charged with magnesium salts.

ORDOVICIAN PERIOD

The Ordovician period was one of notable oscillation in the Appalachian Valley province, leading to repeated emergence and submergence of certain areas and corresponding gaps in the sedimentary sequence and causing a patchy distribution of the rocks of different ages in some areas as described under the heading "Stratigraphy." The theory of oscillations as affecting the distribution of formations in Birmingham and Cahaba valleys is illustrated in Figure 6.

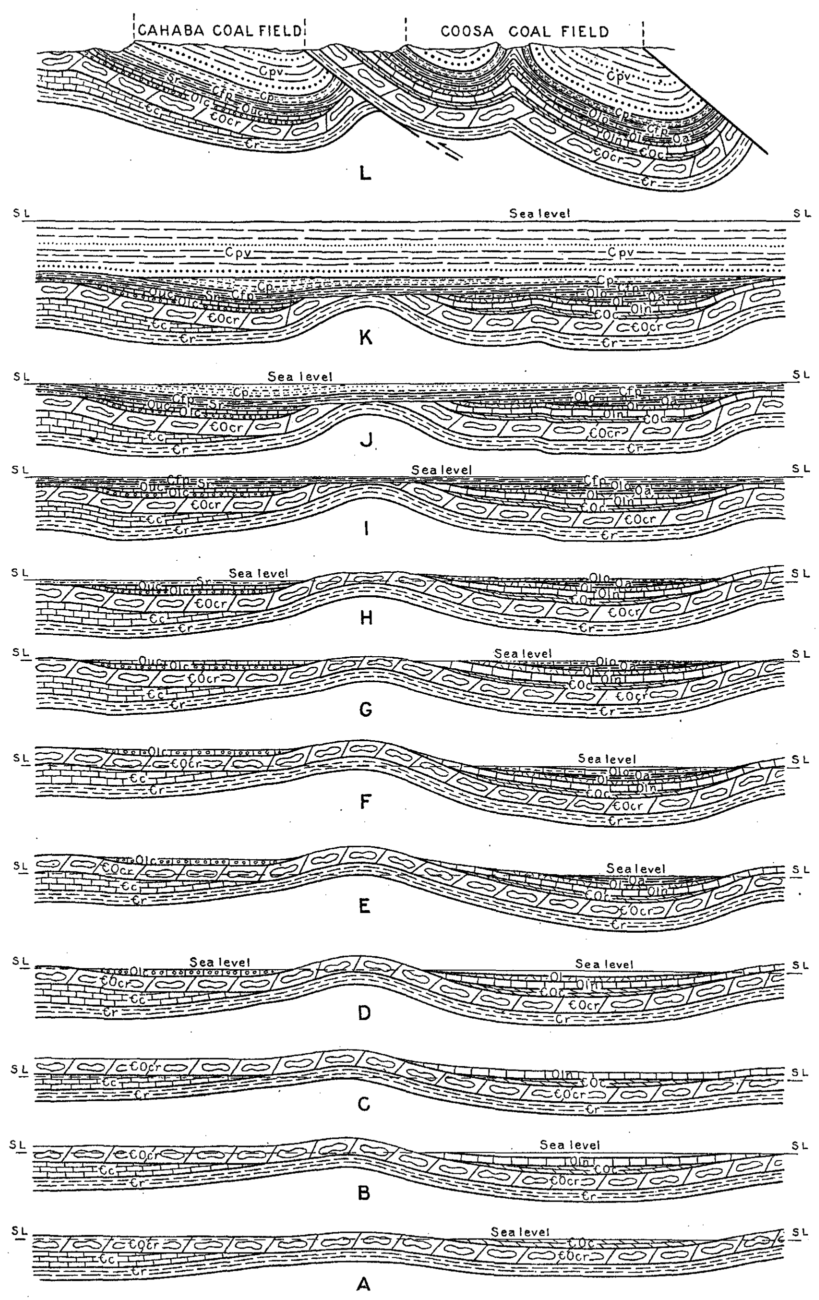

FIGURE 6.—Ideal sections illustrating theoretical conditions at successive stages under which the Paleozoic sediments in northeastern Alabama were deposited in oscillating basins

A, Chepultepec time; B, Longview and Newala time; C, Upper Beekmantown and St. Peters time; D, lower Chickamauga (Lenoir and Mosheim) time; E, Athens time; F, Little Oak time; G, upper Chickamauga (Black River) time and nearly the same conditions through Mohawkian and Cincinnatian time; H, Red Mountain time and nearly the same conditions through the remainder of Silurian time and through Devonian time; I, end of Chester time; J, Parkwood time; K, Pottsville time; L, present time; the fault is located on an old anticline or barrier forming a natural line of weakness owing to less thickness of strata. Єr, Rome formation; Єc, Conasauga formation; ЄOcr, Copper Ridge and Ketona dolomites; ЄOc, Chepultepec dolomite; Oln, Longview, Newala, and Odenville limestones; Ol, Lenoir and Mosheim limestones; Oa, Athens shale; Olo, Little Oak limestone; Olc, lower Chickamauga (Stones River) limestone; Ouc, upper Chickamauga (Black River) limestone; Sr, Red Mountain formation, Frog Mountain sandstone, and Chattanooga shale; Cfp, Fort Payne chert to Floyd shale; Cp, Parkwood formation; Cpv, Pottsville formation. SL, Sea level

The Cahaba barrier seems to have been continuously effective and part of the time to have extended over Cahaba Valley. After a short emergence during Stonehenge time (p. 4) the Cahaba Valley was resubmerged, and Ordovician deposition began with the Longview limestone and continued apparently without interruption through Newala and Odenville time, after which Cahaba Valley emerged during early Chazy time, in which the St. Peter sandstone and possibly limestone of early Stones River age were deposited elsewhere. The Birmingham Valley seems to have been land during most of the time from the end of the Copper Ridge epoch to the beginning of the Chickamauga epoch. When it was again submerged the advancing sea first occupied the lowlands and valleys, in which were accumulations of chert fragments and sand such as exist along the present streams. These accumulations formed the Attalla conglomerate member (p. 7), and above this was laid down mud washed in from the higher unsubmerged areas to form the basal shale member of the Chickamauga (p. 6). In places the mud was red, being such as would be derived from the red soil of the dolomite areas of the present day. Finally, as most of the region became submerged, limestone deposition began, and the basal layers of limestone were in places stained red by a small amount of red clay, which was still being washed into the water. In Cahaba Valley the deposition of limestone, which seems to have begun at about the same time as in Birmingham Valley with the deposition of the Mosheim limestone, was interrupted while the Athens shale was being deposited in the south end of the valley. Dry land probably existed in the north end of the valley during Athens time. On resubmergence of the entire valley the Little Oak limestone (late Chazyan) was deposited, after which the valley area was elevated above sea level and so remained until it was temporarily submerged again in Frog Mountain time.

Limestone deposits were laid down almost continuously during Ordovician time, the only interruption being the Athens episode, during which fine black calcareous mud was deposited in Cahaba Valley. In Athens time this Alabama region had oceanic connection with other parts of the earth generally, as denoted by the world-wide distribution of the Athens graptolites (p. 6).

In Chickamauga time the waters of the region abounded in brachiopods, bryozoans, gastropods, and other marine forms, whose fossilized remains now fill the Chickamauga limestone and are present less abundantly in the Lenoir and Little Oak limestones.

The distinct faunas of Birmingham and Cahaba valleys during Ordovician time developed through the complete separation of the two seas by the Cahaba barrier.

Some remarkable episodes of the Ordovician period were volcanic eruptions that occurred from late Chazy to early Trenton time. The sites of the volcanoes are unknown, but the one active in Trenton time was so located that the ejected rock dust was distributed, probably by the winds, over an area extending from Alabama to southern Ohio. Thus originated the bed of volcanic ash in the upper part of the Chickamauga limestone, described on page 7. The rarity of volcanic action in the Ordovician period in eastern North America is in strong contrast with conditions just across the Atlantic, where, in Wales and western England, volcanoes were active throughout Ordovician time and volcanic ash makes a large proportion of the Ordovician rocks, the ash beds or tuff aggregating several thousand feet in thickness.

SILURIAN PERIOD

Crustal oscillation continued through the Silurian period. The elevation of the Cahaba Valley area above sea level prevented the deposition or resulted in the removal of any Silurian deposits that may have been laid down in that region. Birmingham Valley and the site of the Cahaba coal field, on the other hand, were submerged at the beginning of the period and so remained while the Red Mountain formation was laid down. After about 100 feet of shale and sandstone had accumulated the Irondale ore seam was deposited, and above that seam 25 feet or more of shale and sandstone. Then there was uplift, and the beds down to the Irondale seam were eroded, and probably the Irondale seam itself in the vicinity of Bessemer. The local proximity of the Irondale to the Big seam, as on Red Mountain east of Birmingham, and the intervening shale and conglomerate (p. 8 and Pl. XV) were the results of this uplift and erosion.

Next followed perhaps the most notable event in the history of the region. A slight submergence ensued, and in the shallow sea or a sheltered lagoon the Big seam of ore was accumulated. Animals swarmed in the hospitable water, and their accumulated skeletons formed a coquina-like limestone. In Cahaba Valley and eastward, where the Silurian is absent, lay an ancient land deeply covered with the ferruginous soil that had been formed through the decay of a vast thickness of dolomite and limestone, just such as now covers large areas in the Birmingham region. The rivers that drained this area and emptied into the Silurian lagoon bore supplies of iron compounds in solution, just like modern rivers. Through the constant evaporation of the waters of the lagoon and the constant addition of the iron-bearing solutions the iron became concentrated and was deposited in the coquina, in time replacing part of the lime carbonate of the skeletal remains. Thus the Big seam of ore was formed, and on renewed subsidence it was buried beneath the superincumbent sandstone and shale. By a repetition of the same conditions the Ida seam was formed. In the vicinity of Ishkooda an area was probably uplifted and eroded and a pothole was formed that penetrated the Big seam (p. 8). This pothole was formed during or after the time when *Pentamerus* lived in the region, for casts of *Pentamerus* shells occur in the material that fills the pothole. Of the Cayuga epoch, which lasted during the remainder of the Silurian period, no record remains in Alabama except in the extreme northwest corner of the State, where rocks of this age are believed to be present but are not exposed.

DEVONIAN PERIOD

The gap in the record at the end of the Silurian period covers also the early part of the Devonian period. Then the region was again submerged, the submergence beginning in Oriskany time and continuing into Onondaga time. A few characteristic Oriskany animals made their way into the southern part of the region and a few Onondaga forms invaded the Cahaba Valley belt. The remainder of the Devonian period, an immensely long time, is, however, a blank in this region, except in so far as the Chattanooga shale, regarded by the writer as more probably of Mississippian age, may constitute a meager record that is not susceptible of certain interpretation. The range of possible interpretations is so great and the subject so speculative that limits of space preclude further discussion here. Evidence is accumulating, however, that the Devonian sea persisted into Hamilton time in a considerable area at least in parts of St. Clair and Calhoun counties lying to the northeast of these quadrangles.

CARBONIFEROUS PERIOD

The events of the early part of Carboniferous time (Kinderhook epoch) are not recorded in the Birmingham district unless in the Chattanooga shale, and the succeeding Fern Glen

[22] See footnote 22 on p. 15.

and Burlington epochs are represented only in the lower beds of the Fort Payne chert. The region was entirely submerged, however, during Keokuk (Fort Payne) and Warsaw time but was raised again above sea level during all or parts of St. Louis and Ste. Genevieve time and the early part of the succeeding Chester time. Then it was resubmerged and so continued during the rest of Chester time, and, except in the northern part of the Bessemer quadrangle, where the Bangor limestone was deposited, prevailingly earthy sediment accumulated to form the Gasper formation, Hartselle sandstone, Floyd shale, and Parkwood formation. The deposition of the Parkwood seems to have been followed soon by the deposition of the Brock coal and the basal sandstone of the Pottsville of the Cahaba and Coosa fields, but the area of the Warrior coal field was above sea level during all or part of Parkwood and early Pottsville time, as shown by the unconformity between the Floyd shale and the Pottsville in that area. The deposits of Pottsville time were mud, clay, sand, and vegetal matter, which formed the Pottsville shales, sandstones, and coal beds. The pebbles of chert in the great masses of coarse conglomerate, beginning with the Straven conglomerate member, were doubtless derived from areas of Copper Ridge dolomite, and the pebbles of quartzite and here and there one of conglomerate were probably derived from the Weisner and Talladega formations, for in Carboniferous time areas of all these formations were raised into land to the east and southeast of the coal fields.

The most interesting and valuable deposit of the Pottsville is coal. Land vegetation became abundant and grew luxuriantly in swamps of vast extent near sea level, in which thick deposits of vegetal débris accumulated as in a modern peat bog. These deposits were covered by sediment and in time converted by pressure and loss of moisture and gaseous constituents into bituminous coal. The process was repeated many times, giving rise to many coal beds, thick and thin. That the coal swamps were near sea level is proved by the occurrence of marine fossils over extensive areas of the coal fields at several horizons from top to bottom of the Pottsville (p. 14). As the plants grew in the air and the animals lived only in the sea there must have been alternate emergence and submergence, such as would most likely take place if the land stood continuously near sea level so that a slight sinking would permit flooding by the sea. As the Pottsville accumulated near sea level and is about 9,000 feet thick in the southern part of the Cahaba field, there must have been constant although, as shown by the coal beds, intermittent subsidence of the earth's crust during the long time of its accumulation. The luxuriant vegetation of the Carboniferous period consisted largely of great trees allied to modern club mosses and of smaller plants allied to modern ferns. No flowering plants had yet appeared.

As a bed of peat about 5 feet thick is necessary to make 1 foot of bituminous coal it is easily seen that at the highest imaginable rate of growth a very long time was required to accumulate the coal beds of Alabama, which in the Cahaba field, for example, aggregate not less than 100 feet in thickness and thus required an amount of vegetal matter equal to a bed of peat 500 feet thick.

No record of events during the rest of the Carboniferous period exists in Alabama. In this unrecorded time the Pennsylvanian coal measures of upper Pottsville, Allegheny, Conemaugh, and Monongahela age were laid down in western Pennsylvania, Ohio, Indiana, and Illinois, and above them the Permian series of the Carboniferous, the last of the deposits of the Paleozoic era.

APPALACHIAN REVOLUTION

The Paleozoic era was one of subsidence and deposition in the Appalachian Gulf region. It was a constructive era, in which rock formations were built up. At the end of the Paleozoic a reverse movement—uplift of the formerly subsiding area—began, and it has continued ever since. The region became dry land. As the land emerged from the water it was attacked by the agents of erosion, which have been active during all subsequent time. This great change in the operations of nature in this part of the earth is known as the Appalachian revolution. Besides the direct uplift that affected the region there was a lateral westward movement of the crust, the effects of which are most conspicuous along the Appalachian Valley (p. 15), where the strata were folded, crumpled, and faulted and changed from their original horizontal to their present inclined attitudes, as already described and as shown in the structure sections. Probably these movements were very slow and continued long into the Mesozoic era. They must have been accompanied by violent earthquakes, to judge from the earthquake results of such comparatively slight movements as that which produced the San Francisco earthquake and that on the Red Gap fault, which produced the earthquake in the Birmingham region a few years ago.

MESOZOIC AND CENOZOIC ERAS

The Mesozoic and Cenozoic were eras of destruction, and almost no records of them exist in the Birmingham district. Like all land areas the region was subjected to erosion during the whole time; a great thickness of solid rock has been removed—10,000 feet, for example, in the vicinity of Birmingham—and, as a result, the present hills, ridges, and valleys have been carved in the surface of the region.

Cumberland peneplain.—Although erosion has been constant the upward movements of the crust in the Appalachian Highlands seem to have been intermittent. Some of the pauses were so long that extensive areas were worn down nearly to a plain (peneplain) near sea level. The peneplain of which there is the best evidence seems to have attained its complete development in early Cretaceous time, for its marginal parts, slightly submerged by a tilting movement, were covered by early Cretaceous deposits on the Coastal Plain. Farther north, however, the peneplain was more elevated, and in the Cumberland Plateau it is now represented by an extensive fairly even surface, approximately 2,000 feet above sea level. Thence it slopes southward, connecting approximately with the surface of Sand Mountain in northern Alabama and that of Blount Mountain, 1,300 feet high, farther south. Possibly the crest of Red Mountain and Higher summits of the Warrior and Cahaba coal fields nearly coincide with the old peneplain, but it is too obscurely preserved in these southern latitudes to be surely identified. Because this old peneplain of supposed Cretaceous age is excellently preserved in the Cumberland Plateau it is named the Cumberland peneplain. It may be the same as the Schooley peneplain of New Jersey, which is also thought to dip beneath the Cretaceous deposits of that area.

Peneplains of later date and lower altitude are preserved in the Highland Rim of middle Tennessee and in the Coosa Valley of Alabama. The Highland Rim and Cumberland peneplains probably converge southward and become indistinguishable in the Warrior coal field. The surface of this peneplain is shown in one of the illustrations of the Montevallo-Columbiana folio.

Life of the Mesozoic and Cenozoic eras in Alabama.—There can be no doubt that the land of the southern Appalachian region supported the succession of plant and animal life peculiar to each period of the Mesozoic and Cenozoic eras, although but scanty remains of this life have been preserved or yet discovered. The leaves of several modern genera of forest trees have been found in the Cretaceous deposits of Alabama, and the trees must have grown on the land bordering the Cretaceous sea. Among these genera are the fan palm, the sequoia ("big trees" of California), pine, tulip ("yellow poplar"), magnolia, sycamore, sassafras, holly, poplar, willow, cinnamon, fig, and walnut. The oak was living at this time in the Carolinas, but no specimens have been reported from Alabama. In Cenozoic time a number of other genera of trees such as hickory, pawpaw, cassia (senna), redbud, dogwood, and ash, made their appearance, and their remains are preserved in the Eocene (lower Tertiary) deposits of Alabama. Two living genera of ferns, *Lygodium* (climbing fern) and *Asplenium* (spleenwort), are also recorded from the Alabama Eocene.

Among the animals modern types of clams and fishes probably inhabited the rivers of Alabama throughout the Mesozoic era and the Tertiary period of the Cenozoic era, as they did the rivers of other regions during those times. The great reptiles, the dinosaurs and others that inhabited the Rocky Mountain region, also probably roamed through the forests and over the plains of Alabama, although any morasses in which any of them may have been mired and preserved were removed in the general course of erosion. The strange mammals that are so well known from remains found in the Tertiary deposits of the West, also doubtless lived in Alabama, but like the dinosaurs and for the same reason they have left no traces. In early Quaternary time, while the northern part of North America was buried in the ice of the glacial epoch, the mastodon, megatherium, cave bear, saber-toothed tiger, and a host of other recently extinct animals inhabited the Alabama region, and we may believe that the first human being to tread the soil of Alabama was a contemporary of these extinct animals.

It will be dimly perceived perhaps from this brief history that the present is only a stage in the unceasing evolution of the earth and its inhabitants and is genetically connected with a remote past as well as with an equally remote future. The beginning of this mighty train of events we can not know, and its end we can not foresee.

ECONOMIC GEOLOGY

The mineral resources of the Bessemer-Vandiver area consist of coal, iron, dolomite and limestone, shale and clay, road metal, chert, building stone, sand, lime and cement materials, soil, and water. The most valuable of these resources are coal, iron, and dolomite, for these are the raw materials of iron making, the principal mineral industry of the region. A necessary condition for the profitable operation of the iron-making industry in Alabama is the proximity of the deposits of coking coal, iron ore, and dolomite or limestone to one another. Red Mountain forms the western edge of the ore-bearing area; the eastern edge of the Warrior coal field is 5 miles distant; and in the valley between is the dolomite. The raw materials for iron smelting are therefore cheaply assembled in this region.

COAL

GENERAL FEATURES

As shown on the map (fig. 7), the coal measures of Alabama lie in four different fields—the Plateau, Warrior, Cahaba, and Coosa fields. The Bessemer-Vandiver area includes parts of the last three fields mentioned. The number, names,

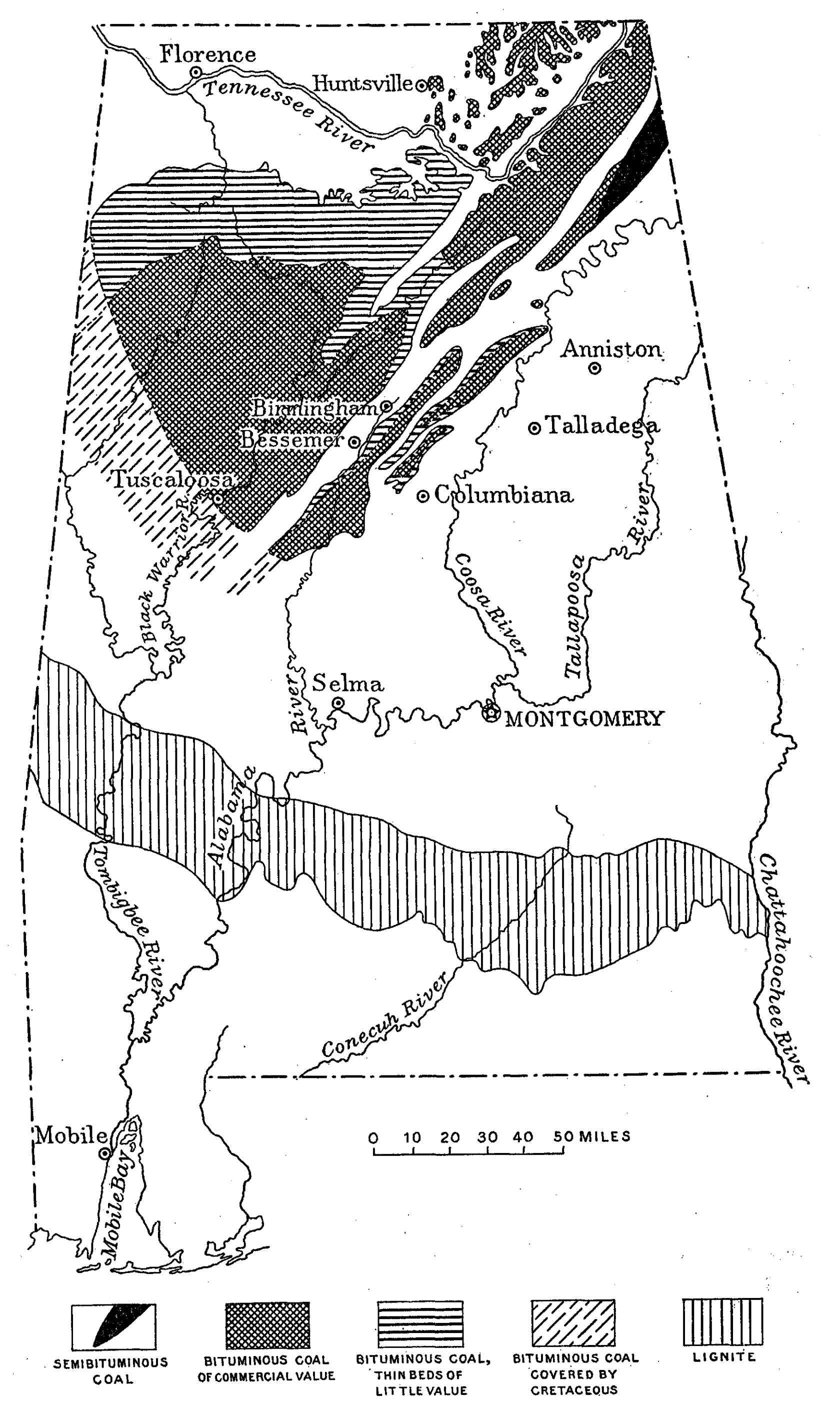

FIGURE 7.—Sketch map showing the location and extent of the Alabama coal fields

sequence, grouping, and correlation of the coal beds are shown in Figure 5. The coal of this district is a high-grade bituminous coal, all of it being excellent for making steam and for domestic use and much of it for making coke and gas. The coal along the east side of the Warrior field is regarded as the best coking coal in the State. Analyses of 19 samples of these coals, as they come from the mine, are given in the table on page 20; the average composition is approximately 3.0 per cent moisture, 29.9 per cent volatile matter, 61.0 per cent fixed carbon, 6.4 per cent ash, and 1.19 per cent sulphur.

COALS OF THE WARRIOR FIELD

The Bessemer quadrangle includes in the northwest corner a small part of the Warrior coal field.

The coals of the Warrior field are more or less distinctly separated into groups, which were named by McCalley, in ascending order, the Black Creek coal group, including the Black Creek, Jefferson, and Lick Creek coals; the Mary Lee coal group, including the Ream, Jagger, Blue Creek, Mary Lee, and Newcastle coals; the Pratt coal group, including the Gillespie, Curry, America, Nickel Plate, and Pratt coals; the Cobb coal group, including the Cobb upper and Cobb lower coal; the Gwin coal group, including the Thompson Mill and Gwin beds; and the Brookwood coal group, including the Carter, Milldale, and Brookwood coals. The beds of the last two groups do not occur in the Bessemer-Vandiver area.

BLACK CREEK COAL GROUP

The Black Creek coal group does not crop out in the Bessemer quadrangle owing to the Wylam and Opossum Valley faults, as shown in section B–B′ of the Bessemer quadrangle. A coal identified as Black Creek is exposed on the electric railroad between Thomas and Pratt City, 2 miles northeast of Wylam, and the same bed is exposed at a number of places near Valley Creek, 6 miles southwest of Pleasant Hill Church. At both places a workable bed, 2 feet thick or more, is indicated. It is probably a workable bed in the Bessemer quadrangle. Nothing is known of the other coals of the group in this area.

MARY LEE COAL GROUP

The Mary Lee coal group probably crops out a short distance west of the Boyles sandstone for a mile or two northeast and southwest of Dolomite, thin coals being exposed at several places along this strip. The only coals observed, however, are made up of thin layers a few inches thick separated by shale bands as much as 5 feet thick. Borings that penetrate the Mary Lee group in this territory show that the different beds of the group can be recognized but are greatly split up and that workable benches occur only in the Jagger and Blue Creek beds. The same split-up condition that is characteristic of the beds of the Mary Lee group throughout the eastern part and probably through the whole Warrior field persists in stronger development in this part of the field. The comparatively thin layers of clay or shale in the Mary Lee bed elsewhere are represented here by layers of shale as much as 5 feet thick, which separate the thin layers of coal so widely that the bed is worthless. A section obtained 1 mile northeast of Dolomite is an example. (See fig. 8, section 1.) In the Bessemer quadrangle the Jagger and Blue Creek beds are in better condition than the Mary Lee, each having a workable bench 2 feet 6 inches thick, with which are associated thinner layers that are separated by a greater or less thickness of clay or shale.

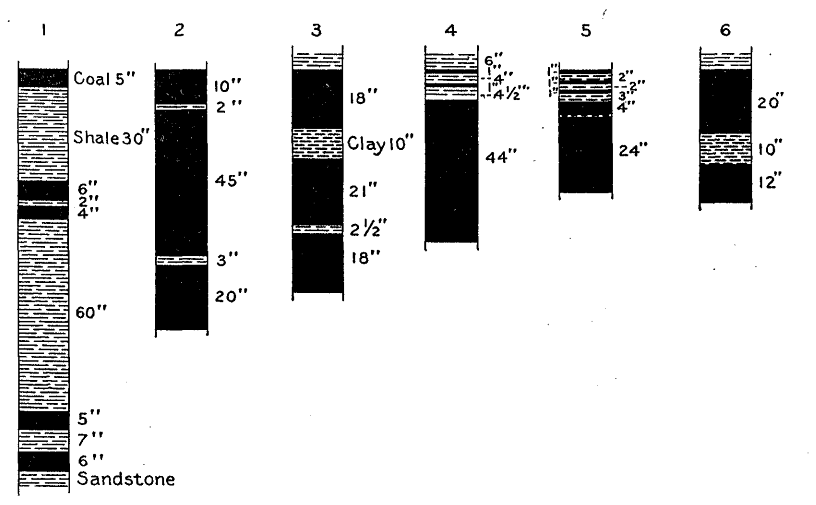
FIGURE 8.—Section of Mary Lee, Pratt, and Nunnally coal beds

1, Mary Lee coal 1 mile northeast of Dolomite; 2, Pratt coal at No. 2 mine, Dolomite; 3, Lower Nunnally coal on Patton Creek near center of sec. 23, T. 19 S., R. 3 W.; 4, Lower Nunnally coal at Acton Ford; 5, Lower Nunnally coal 1 mile northeast of Acton Ford, SE. ¼ sec. 8, T. 19 S., R. 2 W.; 6, Lower Nunnally coal half a mile south of pumping station, Birmingham waterworks. Scale: 1 inch=5 feet

PRATT COAL GROUP

The Pratt coal group crops out from Wylam to a place 2 miles southwest of Dolomite, where its outcrop is cut off by the Opossum Valley fault. As the other beds of the group are deeply covered by rock waste, none of them are known on the outcrop except the Pratt, and that one only where it has been opened in mines. They dip steeply to the northwest along their outcrops.

Gillespie and Curry coal beds.—Borings show that a number of thin layers of coal occur through a wide zone that may be broadly correlated with the Gillespie bed. Still higher there are a number of benches that correspond in a general way to the Curry bed. One of these benches, 220 feet below the Pratt coal, is 2 feet 6 inches thick.

America (Double) and Nickel Plate (Cardiff) coal beds.—The America bed, or at least its main bench, is 123 feet below the Pratt bed at the top of the Pratt group. This bed has been exposed in Wylam and Ensley, and sections measured at these places are published in the Birmingham folio (p. 18). In the Bessemer quadrangle, as revealed by borings, there are a number of layers separated by shale that may be assigned to this general horizon. One main bench, however, 123 feet below the Pratt is 3 feet 11 inches thick and has a 3-inch parting in the middle. A thin bed 28 feet below the Pratt is regarded as the Nickel Plate. It is not known to be minable in the Bessemer quadrangle, but either the Nickel Plate or America bed is minable at the Virginia mine, 5 miles southwest of Pleasant Hill Church.

Pratt coal bed.—The Pratt is a valuable bed throughout the part of the Warrior field in the Bessemer quadrangle and is extensively mined by the Woodward Iron Co. at the Dolomite mines. At both mines it is over 6 feet thick, including partings. (See fig. 8, section 2.) The quality of the coal in this locality is of the very best, as shown by analyses 3579 and 3580 in the table on page 20. The low content of sulphur and ash permits coking without previous washing.

COALS OF THE CAHABA FIELD

The Cahaba coals have been fully described by Squire and by the writer.[23] In this field there are ten coal beds workable in large enough areas to be of commercial importance. In ascending order these beds are the Gould, Lower Nunnally, Middle Nunnally, Harkness, Wadsworth, Buck (Atkins), Youngblood (Black shale), Clark, Thompson, and Helena.

GOULD COAL GROUP

There appears to be more than one bed at the general horizon of the Gould coal, but only one workable bed is known in any section. At the entrance to the Bamford mine the bed worked is 20 inches thick. It is reported to range in thickness from 1 foot 6 inches to 3 feet and to have an average of 2 feet of clear coal. The site of the original mine on this bed, operated many years ago by William Gould, from whom the bed was named, is said to be 4 miles northeast of the Bamford mine. This mine in 1906 was called the Star Cahaba No. 1, but later the name was changed to Elvira. At last accounts it was not operating. At this mine the bed differs much in thickness, as shown by an increase from 1 foot 6 inches at the entrance to 4 feet at a place 200 feet down the slope. The composition of the coal at this mine is shown by analysis 3646 (p. 20). Just north of the Louisville & Nashville Railroad at Elvira two of the beds of this group have been exposed in prospect pits and grading operations. The upper bed is 2 feet and the lower bed 1 foot 6 inches thick. Half a mile south of Rocky Ridge Church a thickness of 3 feet is reported for one of these beds. Across the northwestern part of the Vandiver quadrangle the coal beds of this group, if present, are practically unknown. In Little Valley Mountain the bed is not known to be workable. It is a fair conclusion that the Gould group contains the equivalent of a bed 2 feet thick on its outcrop across the Bessemer quadrangle.

NUNNALLY COAL GROUP

General features.—The Nunnally group of coals, named by Squire from the Nunnally farm, 1 mile northwest of Sydenton, is also called by the same author the Five group in an area southwest of the type locality where five thin coal beds comprise the group. Locally, as to the north of Greenlee Ford and northeast of the Cahaba pumping station in the Vandiver quadrangle, the group carries one to three workable beds of coal. Near the south margin of the Bessemer quadrangle there are apparently two beds identified as belonging to this group. At two places, one in the eastern part of sec. 34, and the other in the southern part of sec. 25, T. 20 S., R. 4 W., a thickness of 24 and 27 inches respectively is reported for the upper bed, and in the western part of sec. 35, in the same locality, a thickness of 40 inches is reported for the lower bed.

Lower Nunnally coal bed.—Between the locality just described and sec. 23, T. 19 S., R. 3 W., no workable beds are known in this group. Near the center of sec. 23 a bed regarded as the Lower Nunnally is 3 feet 9½ inches thick. (See fig. 8, section 3.) Just east of Acton Ford, in the northwest corner of sec. 17, T. 19 S., R. 2 W., the bed is 4 feet 6½ inches thick. (See fig. 8, section 4.)

About 1 mile northeast of Acton Ford, the bed is 3 feet 3 inches thick and has more partings at the top. (See fig. 8, section 5.)

The outcrop of the bed is traceable northward for several miles, and openings have been made on it at several places, but its thickness and character could not be determined. Near the center of sec. 26, T. 18 S., R. 2 W., 1 mile south of the pumping station, the bed is 2 feet thick, and half a mile to the north, in the southern part of sec. 23 of the same township, the bed is 3 feet 6 inches thick. (See fig. 8, section 6.)

For 2 miles north of the locality last described practically nothing is known of the Nunnally coals. In this strip there is reason to suspect that the rocks have been subjected to considerable disturbance in which a segment of the crust including the coal beds has perhaps been faulted out at the surface. In the NW. ¼ sec. 13, T. 18 S., R. 2 W., however, and northward, the outcrop of the Lower Nunnally seems to be certainly identifiable, and the bed is from 2 feet 6 inches to 4 feet 4 inches thick. The greatest thickness is shown in an opening in the SE. ¼ sec. 1, T. 18 S., R. 2 W. (See fig. 9, section 1.)

North of the last-named locality the bed deteriorates, as shown in the SW. ¼ sec. 32, T. 17 S., R. 1 W. (See fig. 9, section 2.)

Middle Nunnally coal bed.—In the S. ½ sec. 18, T. 19 S., R. 2 W., about 2 miles south of Rocky Ridge Church, a thick bed of coal has been prospected at two places half a mile apart. It is called the Middle Nunnally, because it is the middle one of three beds of good thickness in this locality. At one opening the bed is 9 feet 7½ inches thick. (See fig. 9, section 3.) No bed of such thickness in this position was found south of this locality nor to the northwest for a distance of 9 miles. At an opening in the SW. ¼ sec. 12, T. 18 S., R. 2 W., a bed regarded as Middle Nunnally is 1 foot 9 inches thick. (See fig. 9, section 4.) On the river bank in the NE. ¼ of the same section the bed is much thicker. (See fig. 9, section 5.) Just north of the margin of the quadrangle the bed is 6 feet thick and has 1 foot of bone near the middle. (See fig. 9, section 6.)

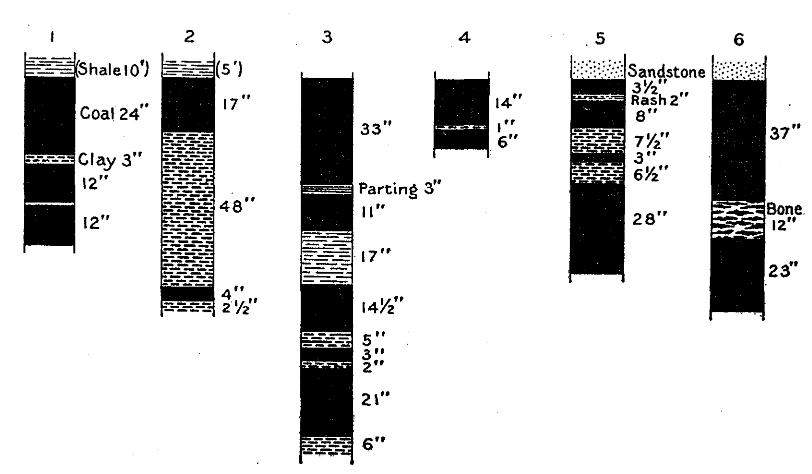
FIGURE 9.—Sections of Nunnally coal beds

1, Lower Nunnally coal in SE. ¼ sec. 1, T. 18 S., R. 2 W.; 2, Lower Nunnally coal in SW. ¼ sec. 32, T. 17 S., R. 1 W.; 3, Middle Nunnally coal in S. ½ sec. 18, T. 19 S., R. 2 W.; 4, Middle Nunnally coal in SW. ¼ sec. 12, T. 18 S., R. 2 W.; 5, Middle Nunnally coal in NE. ¼ sec. 12, T. 18 S., R. 2 W.; 6, Middle Nunnally coal in SW. ¼ sec. 32, T. 17 S., R. 1 W. Scale: 1 inch=5 feet

The facts set forth above indicate that the Middle Nunnally is locally valuable. Possibly more thorough prospecting would show it to be of workable thickness and quality throughout still larger areas.

Upper Nunnally coal bed.—The Upper Nunnally coal bed was seen in the SE. ¼ sec. 18, T. 19 S., R. 2 W., where it is 2 feet thick and lies between beds of sandstone. Some indications of a bed of workable thickness were also seen in sec. 12, T. 18 S., R. 2 W., and thence northward along the river to the north margin of the quadrangle.

HARKNESS COAL BED

The Harkness bed is not well known in the Bessemer quadrangle. At the Harkness farm, on the Louisville & Nashville Railroad in the SW. ¼ sec. 4, T. 20 S., R. 3 W., which is said by Squire to be the type locality of the bed, there is a thin worthless coal, but there is some doubt whether it is the bed named Harkness in the northern part of the Cahaba field.[24] Near the center of sec. 17, T. 20 S., R. 3 W., on the west limb of the Tacoa anticline, a thick bed of black shale and bony coal regarded as the Harkness is exposed in a cut of the Atlanta, Birmingham & Atlantic Railway.

From the Harkness farm northward to and beyond the Cahaba pumping station, in the Vandiver quadrangle, practically nothing is known of this bed. North of the pumping station, from the SW. ¼ sec. 13, T. 18 S., R. 1 E., to the north margin of the quadrangle the bed runs about 4 feet thick and contains more or less bony coal.

WADSWORTH COAL BED

The Wadsworth bed is so named because it was mined long ago by Frank Wadsworth at Tacoa station. A mine recently opened about a mile southwest of Falliston is also probably on this bed. Although not known to the writer the Wadsworth coal undoubtedly crops out in the belt of vertical rocks around the Tacoa anticline to the northeast of Tacoa and thence southward on the west limb of the anticline to Sydenton, where it was once mined, and half a mile farther south to the old Star Cahaba No. 2 mine. It is uncertain whether the outcrop crosses the axis of the Belle Ellen syncline near the old No. 2 mine and turns back northward or continues southward and crosses the axis at some point in the Montevallo quadrangle. It has been mapped doubtfully by broken lines, according to the second supposition. If this supposition is correct, however, the bed underlies but a very narrow strip along the synclinal axis. In the vicinity of Sydenton there are three abandoned mines, which are shown on the map. At the old Star Cahaba No. 2 mine, half a mile southwest of Sydenton, a section was measured. (See fig. 10, section 1.) The composition of the coal is shown in analysis 3770 in the table (p. 20). The bed in this vicinity is reported by Squire to average 3 feet 3 inches in thickness. At Langston Ford, 1½ miles northwest of Sydenton, the bed was measured. (See fig. 10, section 2.)

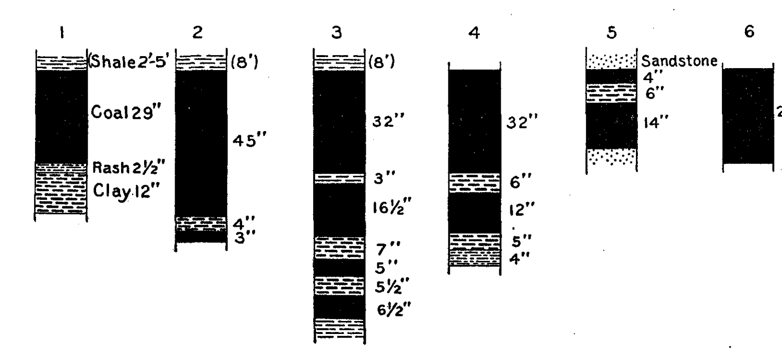
FIGURE 10.—Sections of Wadsworth, Pump, and Buck coal beds

1, Wadsworth coal at Star Cahaba mine No. 2, south of Sydenton; 2, Wadsworth coal, half a mile north of Langston Ford; 3, Wadsworth coal at pumping station mine, Birmingham waterworks; 4, Wadsworth coal in SE. ¼ SW. ¼ sec. 7, T. 18 S., R. 1 W.; 5, Pump coal on creek at switch and water tank half a mile south of Tacoa; 6, Buck (Atkins) coal at Falleston mine. Scale: 1 inch=5 feet

Very little is known of the bed between Langston Ford and the vicinity of the pumping station in the Vandiver quadrangle. A bed of which 18 inches is exposed near the center of sec. 16, T. 19 S., R. 2 W., is regarded as the Wadsworth. At the mine at the pumping station the bed, which is tentatively identified as the Wadsworth, is more than 6 feet thick. (See fig. 10, section 3.) The bed has been prospected farther north and shows from 4 to 6 feet of coal. At a pit in the SE. ¼ SW. ¼ sec. 7, T. 18 S., R. 1 W., it is made up as shown in section 4 of Figure 10. On the wagon road just south of the northern boundary of the quadrangle it has been opened, and a thickness of 6 to 8 feet is indicated. It is a valuable bed in this part of the Cahaba field.

BIG BONE (COKE OVEN) COAL

The Big Bone coal bed of the region south of these quadrangles, which was supposed to be the Harkness by the writer in another report,[25] has been traced northward to a point near Tacoa, and it apparently connects with the Coke Oven bed of

[23] Squire, Joseph, Report on the Cahaba coal field, 131 pp., 1 pl., Alabama Geol. Survey, 1890. Butts, Charles, The northern part of the Cahaba coal field: U. S. Geol. Survey Bull. 316, pp. 76–115, 1907.

[24] Butts, Charles, The northern part of the Cahaba coal field: U. S. Geol. Survey Bull. 316, pp. 76–115, 1907.

[25] Butts, Charles, The southern part of the Cahaba coal field, Ala.: U. S. Geol. Survey Bull. 431, pp. 89–146, 1911.

Squire. Its extension north of Tacoa is not certainly known, but it appears to break up into a number of thin beds, which may be the same as the group of thin worthless beds designated by the geologists of the Tennessee Coal, Iron & Railroad Co. the Big Dirty coal, or at least is included in that group. Its probable horizon is mapped with a broken line. It is not known to be of value in the Bessemer quadrangle.

PUMP COAL (ALICE AND JONES BEDS)

The Pump coal bed was examined only at creek level just west of the water tank half a mile south of Tacoa, where the bed has the section shown in section 5 of Figure 10.

According to Squire, there is another bed only a small distance below this. The two beds correspond to beds above the Big Bone in the Montevallo quadrangle, called Alice and Jones by the prospectors of the Tennessee Coal, Iron & Railroad Co., who traced those beds northward to the vicinity of the water tank above mentioned. In the Montevallo quadrangle, at a locality 5 miles south of the margin of the Bessemer quadrangle, these beds are about 40 feet apart and $2\frac{1}{2}$ to 3 feet thick with partings.

BUCK (ATKINS) COAL BED

At the Falliston mine the Buck bed contains 2 feet 5 inches to 3 feet of clear coal. (See fig. 10, section 6.) The chemical character of the coal is shown in analysis 3744 (p. 20). The bed probably persists north of this locality and is probably one of a number of apparently thin beds which are present in the Acton basin and which show in the road southeast of Bains Bridge. In the Little Cahaba basin a bed exposed on Coal Branch in the central part of sec. 18, T. 18 S., R. 1 W. (see fig. 11, section 1), seems to lie at the horizon of the Buck, and this view is corroborated by the existence of another bed a short distance above in the relative position of the Youngblood (Black shale) bed. (See fig. 11, section 1.)

At points one-fourth of a mile distant on either side of the locality in sec. 18, T. 18 S., R. 1 W., the bed, though it differs somewhat from its composition in that locality, still has a clear bench of 27 inches on the south side and 26 inches on the north side.

YOUNGBLOOD (BLACK SHALE, COKE) COAL BED

The Youngblood seems to be a valuable bed along the whole length of its outcrop. In a cut on the Louisville & Nashville Railroad half a mile north of Mossboro, which is just beyond the south margin of the Bessemer quadrangle, the bed is 3 feet 2 inches thick, apparently all clear coal. In the vicinity of Falliston 2 feet 8 inches to 5 feet of coal is reported. A quarter of a mile south of Buck Creek the bed is 4 feet 3 inches thick. (See fig. 11, section 2.)

North of Buck Creek the bed is believed to make a large zigzag outcrop around the axes of the Tacoa anticline and Belle Ellen syncline, where the rocks are vertical, the outcrop crossing the syncline in the vicinity of Sydenton and extending thence northward along the west limb of the syncline to the Helena fault about on the east margin of the Bessemer quadrangle. At a prospect on Bailey Brook in the western part of sec. 19, T. 19 S., R. 2 W., a bed identified as the Youngblood is 3 feet 4 inches thick. (See fig. 11, section 3.) In the Little Cahaba basin a bed close above the Buck bed near the center of sec. 18, T. 18 S., R. 1 W., regarded as the Youngblood, is 21 inches thick.

CLARK (LITTLE PITTSBURG?, MOYLE?) COAL

The Clark coal bed, well known in the Montevallo quadrangle, has been traced northward to a point where it seems to fall into the position of the Little Pittsburg on Buck Creek. Just south of the Bessemer quadrangle the bed is 15 inches thick. At Coalmont it is reported to average 4 feet thick in Coalmont Nos. 1 and 2 mines. Elsewhere in the quadrangle the bed is of doubtful value, but a bed that may be so identified shows a good thickness at some places in the

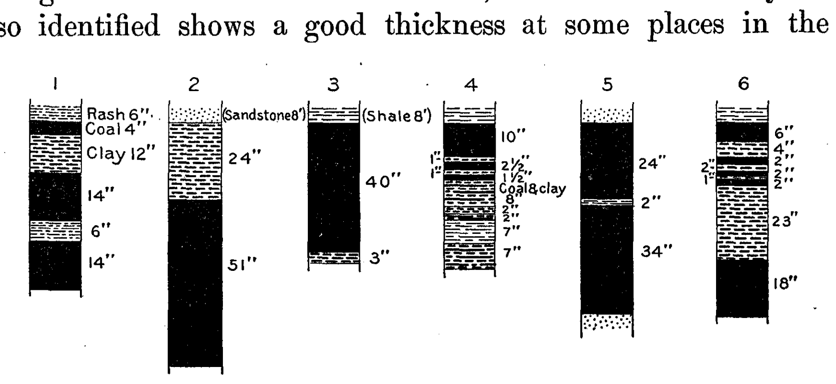

FIGURE 11.—Sections of Buck, Youngblood, Clark, and Thompson (upper) coal beds

1, Buck (Atkins)? coal on Coal Bed Branch, SE. ¼ NW. ¼ NE. ¼ sec. 18, T. 18 S., R. 1 W.; 2, Youngblood (Black shale?) coal one-fourth mile south of Buck Creek and about half a mile west of Helena; 3, Youngblood (Black shale) coal on Bailey Brook, W. ½ sec. 19, T. 19 S., R. 2 W.; 4, Clark (Little Pittsburg?) coal on Buck Creek about half a mile west of Helena; 5, Thompson coal at Coalmont mine; 6, Thompson coal two-thirds of a mile southeast of Bains Bridge. Scale: 1 inch=5 feet

Acton and Little Cahaba basins. An effort was made to mine this bed (Little Pittsburg) on Buck Creek half a mile west of Helena, the type locality of the Little Pittsburg. A measurement was made on the weathered outcrop. (See fig. 11, section 4.)

In the Acton basin, on the road three-quarters of a mile southeast of Bains Bridge, a bed of clear coal 2 feet thick may be the Clark (Little Pittsburg?).

On the west side of the Little Cahaba basin in Coal Bed Branch, in the northwest corner of sec. 19, T. 18 S., R. 1 W., the bed shows 3 feet 9 inches of coal, but 6 feet is reported, and at a place near by 5 feet is reported.

On the east side of the basin, in the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 9, T. 18 S., R. 1 W., the bed, if it is the same as that just described, is broken into four or five benches 2 to 4 inches thick separated by 2 to 8 inches of clay, and its worthless character at this place is evident.

GHOLSON COAL

The Gholson bed, which is of good thickness several miles south of the Bessemer quadrangle, has been traced to a point about 1 mile north of Coalmont but is not known farther north. It may be the same as the Quarry or Smith Shop bed of Squire on the Louisville & Nashville Railroad a short distance west of Helena. At Coalmont No. 1 mine, however, it is reported to average 4 feet in thickness.

THOMPSON (LOWER) COAL BED

The Thompson (lower) coal bed in the Bessemer quadrangle is just beneath the Straven conglomerate (see p. 14), whereas the Thompson bed of the Montevallo quadrangle is said by the geologists of the Tennessee Coal, Iron & Railroad Co. to overlie the Straven conglomerate. To meet this situation the names Thompson (upper) and Thompson (lower) have been adopted. The Thompson (upper) bed does not extend into the Bessemer quadrangle, at least as a minable bed. The Thompson (lower) bed appears to be minable only in the Eureka basin syncline in the Bessemer quadrangle. (See economic-geology map.) On account of the fact that the bed is close below the Straven conglomerate, it is also called the Conglomerate coal bed. The bed is mined at Coalmont, where its condition is as shown in section 5 of Figure 11. The composition of the coal here is given in analysis 3745 (p. 20). At the north end of the Eureka basin the bed is said to be 5 feet thick. In the Helena basin the bed is reported to be irregular in thickness on account of the conglomerate roof, by which the coal is liable to be displaced at any point. In the Acton basin the bed is variable. At Acton No. 2 mine it is full of clay partings and practically worthless (see fig. 11, section 6), but at Acton No. 1 mine, 1 mile northwest of Acton No. 2, it is in better condition. (See fig. 12, section 1.) It was not seen in the Little Cahaba basin.

HELENA COAL BED

The Helena bed is the uppermost minable coal in the Bessemer quadrangle. It was mined years ago half a mile south of Roebuck, where Squire reports the coal to be 4 feet thick and to have 2 to 3 inches of bony coal near the middle. It is reported to be 5 feet thick at the northern extremity of its outcrop in the Eureka basin and to average 4 feet 6 inches in thickness at Coalmont No. 3 mine, at the south edge of the Bessemer quadrangle. It probably is a minable bed throughout the area underlain by it in this basin.

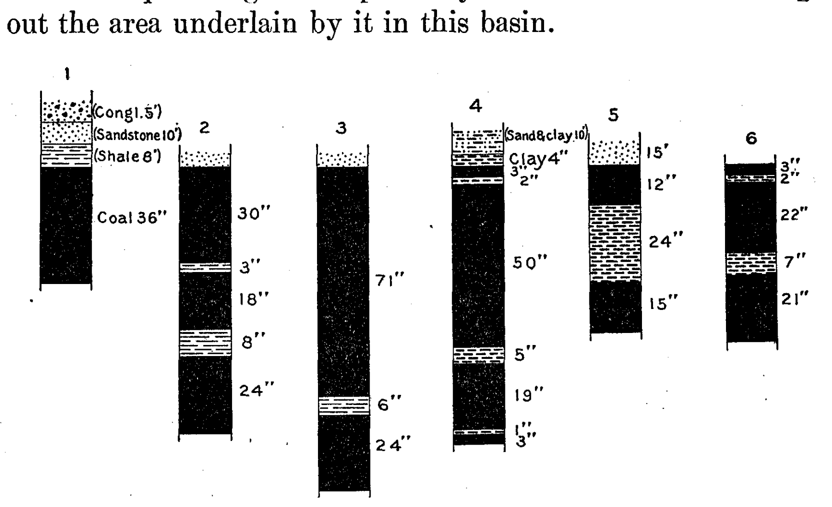

FIGURE 12.—Sections of Thompson and Helena coal beds

1, Thompson coal, 1¾ miles east of Bains Bridge; 2, Helena coal in NE. ¼ sec. 10, T. 20 S., R. 3 W.; 3, Helena coal in SW. ¼ sec. 10, T. 20 S., R. 3 W.; 4, Helena coal 1¼ miles east of Bains Bridge; 5, Helena coal in Acton mine No. 2, main entry; 6, Helena coal in Acton mine No. 2, 100 feet down main slope. Scale: 1 inch=5 feet

Squire reports that the bed is only 6 inches thick at the south end of the Helena basin, but near the north end its thickness and character make it a valuable bed, although its area is small. (See fig. 12, sections 2 and 3, which are taken from Squire.) In the NW. $\frac{1}{4}$ sec. 2, T. 20 S., R. 3 W., the bed is 8 feet 5 inches thick and has a 6-inch parting of shale 2 feet above the bottom.

In the Acton basin the bed is also in good condition and was mined at Acton No. 1 mine. It varies considerably, however, as shown by sections 4, 5, and 6, in Figure 12. Analysis 3771 (p. 20) shows the composition of the coal at Acton No. 2 mine, 1 mile southwest of Acton No. 1. In the Little Cahaba basin the Helena is a thick bed but underlies only a small area along the axis of the V-shaped syncline.

YESHIC (?) COAL

A thin coal in the Eureka basin above the Helena is probably the Yeshic, which is not known to be minable in the Bessemer quadrangle.

COOSA COAL FIELD

The writer has no detailed knowledge of the coals of the Coosa field in these quadrangles, and in fact no such information is obtainable, for no adequate prospecting on them has been done. A few test pits have been sunk on a number of steeply dipping beds, but the pits were in such a condition that no satisfactory examination could be made.

Cunningham coal bed.—On the Cunningham estate, in the NW. $\frac{1}{4}$ sec. 10, T. 20 S., R. 2 W., a bed of coal about 7 feet in thickness has been opened. The bed dips eastward. In the writer's opinion it lies in a narrow syncline overturned on the southeast, as shown in structure section D–D′ of the Vandiver quadrangle. Indications of the bed, although the layers are thin, were observed in a railroad cut at Tafton. In the absence of positive proof to the contrary, it seems best to assume that in this locality there is but a small area of coal as thick as that at the Cunningham opening. The stratigraphic position of this bed is close above the Shades sandstone, as shown in the columnar section for the Coosa field and in Figure 5.

Coal associated with a stratum of black shale is reported by A. M. Gibson on Muddy Prong of Yellowleaf Creek in secs. 34 and 35, T. 18 S., R. 1 E., and sec. 4, T. 19 S., R. 1 E. This locality was not visited by the writer, who, however, saw the black shale at other places. A coal bed 18 inches thick is also reported by Gibson in the NE. $\frac{1}{4}$ sec. 15, T. 20 S., R. 2 W., where the coal is said to be about 50 feet above the Shades sandstone. It is thus in the same position stratigraphically as the Cunningham bed and that of the Campbell bed of the Cahaba field as described in the Birmingham folio.

Clow coal bed.—There are indications of the Clow bed close above the Pine sandstone from Yellowleaf Narrows to a point east of Little Narrows, but nothing further is known of it.

Nivens coal bed.—The Nivens coal bed, about 200 feet above the Clow, has been uncovered in grading operations on the Atlanta, Birmingham & Atlantic Railroad just east of Yellowleaf Narrows. At this place the bed is 6 feet thick and dips steeply to the east, but the coal is so thoroughly weathered that it is impossible to ascertain the character of the bed. It is unknown elsewhere, but a pit in sec. 32, T. 20 S., R. 2 W., may be on the same bed, and it is mapped as possibly extending southward to that point.

Howard coal bed.—The Howard coal bed, which is apparently about 400 feet above the Pine sandstone member and therefore about 200 feet above the Nivens coal, is reported to be 2 feet 8 inches to 2 feet 10 inches thick at the Howard farm, in the SE. $\frac{1}{4}$ sec. 3, T. 19 S., R. 1 W., but it is not known as a workable bed elsewhere. It probably lies in a nearly flat attitude in the bottom of the Dunnavant syncline and thus in a structurally favorable condition for mining. The Howard is correlated with the Gould coal of the Cahaba coal field.

Wolf Ridge coal bed.—The Wolf Ridge coal bed, which is known only by report, is probably thin and may be dismissed without further comment. It is about 600 feet above the Howard bed.

Straight Ridge coal bed.—The Straight Ridge coal bed, 800 feet above the Wolf Ridge bed, is reported to reach a thickness of 2 feet but could not be observed at the time of the writer's survey.

Martin coal bed.—The Martin coal bed, which lies 750 feet above the Straight Ridge bed, is said to have great thickness. At some places it is undoubtedly thick, but so far as the writer could observe it differs greatly in thickness from point to point. As a thin bed is known not far above it and as the bed dips steeply it may not be correctly identified at all points on its supposed outcrop. Half a mile south of Calvary Church, in the highway just north of the bridge across Yellow Creek, the bed if correctly identified is only a few inches thick. Farther west, in the S. $\frac{1}{2}$ sec. 24, T. 20 S., R. 2 W., the bed is about 2 feet thick and apparently is all clear coal. On the Minor farm, in the SE. $\frac{1}{4}$ sec. 14, T. 20 S., R. 2 W., the bed is $3\frac{1}{2}$ to 6 feet thick but was so badly slumped when it was examined that reliable detailed measurements could not be made. In the southwest corner of sec. 7, T. 20 S., R. 1 W., an entry had been driven 20 to 30 feet on a 2-inch to 12-inch bed that appears to lie at the horizon of the Martin coal. Half a mile northwest of Coalville, on the Martin farm, the type locality, the bed has been extensively prospected and is reported to be 12 feet thick. The openings, however, were in such condition that the bed could not be examined, and no definite statements concerning the thickness and character of the bed are warranted. Gibson,[26] who examined the bed when the opening was made, says that the bed consists of solid coal 12 feet 10 inches thick. At Chelsea an old opening was pointed out in which the coal is reported to be 2 feet thick. The bed has been prospected extensively in the northeast corner of sec. 26, T. 19 S., R. 1 W. At one place an opening had been driven in a considerable distance and the bed is 12 to 14 feet thick, but detailed sections were not obtainable. At another pit a few yards west of that opening the coal is 3 feet thick. The great thickness at the first opening appears to be due to a squeeze that has resulted from the bending of the rocks around the axis of the

[26] Gibson, A. M., Report upon the Coosa coal field with sections, p. 126, Alabama Geol. Survey, 1895.

Yellow Branch anticline, which probably lies near this place. (See map.) In a long outcrop on the Wilder farm, in the SE. ¼ sec. 24, T. 19 S., R. 1 W., according to Gibson,[27] this bed is 4 to 6 feet thick.

MINING CONDITIONS

The coal beds of the Cahaba and Coosa fields are generally inclined at angles exceeding 20°. In some places the beds are vertical or nearly so; in others they have a low dip or lie practically flat. The lay of the beds at any place can be determined by sections and dip symbols on the maps. In general the rocks that overlie and underlie the coal beds are stable and give no unusual trouble in mining; at least the writer has heard very few complaints in regard to these conditions. Neither is there any unusual trouble from water or gas. The construction of railroads to the mines presents no great difficulties. At present abundant timber and water is obtainable in immediate proximity to the mines.

GENERAL CHARACTER OF THE COAL

The chemical composition of the coal is shown by the subjoined table of analyses by the United States Bureau of Mines.

Analyses of coal from the Warrior and Cahaba coal fields in the Bessemer-Vandiver district, Ala.

[F. M. Stanton, of the U. S. Geol. Survey, and H. H. Cooper, of the Bureau of Mines, analysts]

Laboratory No.	Form of analysis	Proximate				Ultimate					Heating value (British thermal units)
		Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	
3579	A	3.2	25.4	67.7	3.69	0.56	5.05	82.28	1.36	7.06	14,620
	B		26.2	70.0	3.81	.58	4.85	84.96	1.40	4.40	15,090
	C		27.3	72.7		.60	5.05	88.33	1.46	4.56	15,690
3580	A	3.1	26.9	66.3	3.75	.55	5.30	82.04	1.48	6.88	14,680
	B		27.7	68.4	3.87	.57	5.12	84.65	1.53	4.26	15,150
	C		28.8	71.2		.59	5.32	88.05	1.59	4.45	15,750
4292	A	3.2	27.0	66.0	3.8	.57					
	B		27.9	68.2	3.9	.59					
	C		29.0	71.0		.61					
4293	A	2.8	26.5	67.2	3.5	.59					14,640
	B		27.3	69.1	3.6	.61					15,070
	C		28.3	71.7		.63					15,630
4338	A	3.2	26.2	63.9	6.71	.61	4.99	78.33	1.42	7.94	14,070
	B		27.0	66.1	6.93	.63	4.78	80.95	1.47	5.24	14,540
	C		29.0	71.0		.63	5.14	86.98	1.58	5.62	15,630
4353	A	3.6	26.2	63.2	7.0	.58					
	B		27.2	65.6	7.2	.60					
	C		29.3	70.7		.65					
	A	3.0	28.1	62.4	6.52	1.71	5.28	79.14	1.35	6.00	14,080
	B		29.0	64.3	6.72	1.76	5.10	81.55	1.39	3.48	14,510
	C		31.1	68.9		1.89	5.47	87.42	1.49	3.73	15,550
3771	A	2.8	33.3	58.2	5.70	.44	5.20	77.96	1.52	9.18	13,990
	B		34.3	59.8	5.86	.45	5.04	80.16	1.56	6.93	14,380
	C		36.4	63.6		.48	5.35	85.15	1.66	7.36	15,280
80488	A	2.5	33.6	53.3	10.6	.41					12,950
	B		34.4	54.7	10.9	.42					13,280
	C		38.6	61.4		.47					14,300
3745	A	2.7	32.6	58.5	6.23	.87	5.08	76.55	1.12	10.15	13,860
	B		33.5	60.1	6.41	.89	4.9	78.72	1.15	7.93	14,250
	C		35.8	64.2		.96	5.34	84.01	1.23	8.46	15,230
3769	A	3.6	33.2	58.6	4.56	1.08	5.13	77.57	1.23	10.43	14,050
	B		34.4	60.9	4.73	1.12	4.91	80.46	1.28	7.50	14,570
	C		36.1	63.9		1.18	5.15	84.45	1.34	7.88	15,300
80483	A	3.5	31.3	58.2	7	1.34					13,340
	B		32.4	60.4	7.2	1.39					13,820
	C		35.0	65.0		1.50					14,900
80432	A	3.1	28.5	53.8	14.6	1.21					12,360
	B		29.4	55.5	15.1	1.25					12,750
	C		34.6	65.4		1.47					15,010
80427	A	2.5	33.7	50.8	13.0	.72					12,780
	B		34.5	52.2	13.3	.74					13,100
	C		39.8	60.2		.85					15,110
3744	A	2.6	34.2	60.0	3.18	.66	5.32	78.62	1.32	10.90	14,450
	B		35.1	61.6	3.27	.68	5.16	80.72	1.35	8.82	14,730
	C		36.3	63.7		.70	5.34	83.43	1.40	9.13	15,330
3770	A	3.7	33.7	58.9	3.75	.48	5.48	80.12	1.51	8.66	14,360
	B		35.0	61.1	3.89	.50	5.26	83.16	1.57	5.62	14,900
	C		36.4	63.6		.52	5.48	86.52	1.63	5.85	15,500
80390	A	2.2	34.2	58.4	5.2	.93					14,210
	B		35.0	59.7	5.3	.92					13,990
	C		36.9	63 1		.99					15,110
80394	A	3.9	31.0	54.0	11.1	.97					12,710
	B		32.3	56.2	11.5	1.01					13,230
	C		36.5	63.5							14,950
3646	A	2.1	28.2	61.5	8.2	1.98					
	B		28.8	62.8	8.4	2.02					
	C		31.4	68.6		2.21					

3579. Dolomite No. 2 mine. Pratt bed, 77-inch cut.
3580. Dolomite No. 2 mine. Pratt bed, 68-inch cut.
4292. Dolomite No. 2 mine, room 30 off west entry 31. Pratt bed, 48½-inch cut.
4293. Dolomite No. 2 mine, east entry 29. Pratt bed.
4338. Dolomite No. 2 mine, run of mine 1. Pratt bed.
4353. Dolomite No. 2 mine, run of mine 2. Pratt bed.
(?) Dolomite No. 3 mine of Woodward Iron Co. Pratt bed.
3771. Acton No. 2 mine, in Acton basin, 5 miles northeast of Helena. Helena bed, 68-inch cut.
80488. Roebuck No. 3 mine of Eureka Coal Co., at Helena. Helena bed.
3745. Coalmont mine. Thompson bed, 58-inch cut.
3769. Prospect in Acton basin, 4½ miles northeast of Helena Thompson bed, 15-inch cut on lower bench near mouth of slope.
80483. Roebuck No. 4 mine of Eureka Coal Co., at Helena. Thompson bed.
80432. Coalmont No. 4 mine of Brookside-Pratt Mining Co., at Coalmont. Thompson bed.
80427. Coalmont No. 2 mine of Brookside-Pratt Mining Co., at Coalmont. Clark bed.
3744. Falliston mine, half a mile east of Falliston. Buck bed, 29-inch cut.
3770. Star Cahaba No. 2 mine, 1 mile west of Tacoa. Weathered 3-foot cut on Wadsworth bed at entrance to mine.
80390, 80394. Cahaba mine of Birmingham Waterworks Co. Wadsworth bed.
3646. Star Cahaba No. 1 (Elvira) mine, 1 mile west of Sydenton. Gould bed at 4-foot entry.

[27] Op. cit., 128.

The samples of coal were obtained by channeling the bed from top to bottom and rejecting the impurities that are rejected in mining. About 50 pounds of coal was thus cut from a fresh working face and reduced by pulverizing and quartering to a sample containing 1 quart. This sample was sealed in a galvanized-iron can, in which it was transmitted to the chemical laboratory. By these means analyses were obtained that probably nearly represent the actual composition of the coal as it is mined. A number of other analyses are published in Squire's report on the Cahaba field.

In the table the analyses are given in three forms, marked A, B, and C. Analysis A represents the sample as it comes from the mine. This form is the one best suited for a comparison of one coal with another. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. Analysis B thus represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis C represents the coal after all moisture and ash have been theoretically removed. This form is supposed to represent the true coal substance, free from the most significant impurities. Analyses B and C are obtained from analysis A merely by recalculation. They should not be used in determining the value of the coal for practical purposes, for they represent theoretical substances that do not exist.

In the analytical work it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore, in the proximate analyses the moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas in the ultimate analyses the ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. The determination of the calorific value to individual units is not reliable, and hence the British thermal units are given to the nearest tens.

According to these analyses, the Pratt coal of the Warrior field in the Bessemer quadrangle averages 3.2 per cent moisture, 26.6 per cent volatile matter, 65.2 per cent fixed carbon, 5.0 per cent ash, and 0.74 per cent sulphur. The coals of the Cahaba field average 2.8 per cent moisture, 32.3 per cent volatile matter, 57 per cent fixed carbon, 7.9 per cent ash, and 0.92 per cent sulphur.

As samples of the Coosa coals suitable for analyses could not be taken, definite knowledge of their chemical composition is lacking. Probably they do not differ materially from the coals of the Cahaba basin. In both the Warrior and Cahaba fields the amount of impurities—clay and shale partings and sulphur—in some beds makes washing necessary before coking.

IRON ORE

GEOLOGIC AND GEOGRAPHIC RELATIONS

The hematite iron ore of the Birmingham district occurs in the Red Mountain formation. This formation carries ore beds wherever it is present, but only on Red Mountain north of Sparks Gap and eastward beneath Shades Valley and the Cahaba coal field to an unknown limit is there an ore bed of sufficient thickness and persistence and of good enough quality to be worked with profit at present. Outside of the area just outlined the beds of ore are in general comparatively thin, and even where thick they carry only a small proportion of good or indifferent ore in streaks separated by ferruginous shale or sandstone.

ORE BEDS ON RED MOUNTAIN

Big seam.—The Big seam only is of present value in the Bessemer and Birmingham quadrangles. Its geologic relations have been set forth under the heading "Stratigraphy" (p. 8). In the Bessemer quadrangle it extends as a minable bed on its outcrop along the crest of Red Mountain from Sparks Gap to the north boundary of the quadrangle. From its outcrop it dips eastward beneath Shades Valley and the Cahaba coal field and probably extends to the Helena fault north of the Acton basin and thence north to the north boundary of the Vandiver quadrangle. Along the west base of Shades Mountain it is 1,900 to 2,000 feet deep, and beneath the deepest part of the Cahaba trough in the Acton basin it is not less than 7,000 feet and probably is 8,000 feet deep. On its outcrop along Red Mountain and throughout the areas explored in deep mining the Big seam is 16 to 20 feet or more thick and is separated into two benches as a general rule by a parting near the middle. The upper bench, 7 to 12 feet thick, is a fairly uniform and homogeneous bed of ore which is so far superior in quality and quantity to the ore of other areas or beds that nearly all the active red-ore mines of the Birmingham district are concentrated upon it within the Bessemer quadrangle. The thickness of the upper bench decreases to 4½ feet at Sparks Gap, where the bench is also broken by thin partings, showing plainly a deterioration southwestward, and it probably becomes worthless not far southwest of Sparks Gap. The lower bench is broken by partings of shale and sandstone. In some places it has no good ore; in others it has a layer of possibly minable grade 2½ to 4½ feet thick, as at the Woodward and Sloss mines, east of Bessemer.

Ida seam.—The Ida seam consists of 2 to 6 feet of rather siliceous ore associated with 14 to 16 feet of ferruginous sandstone. It has been recognized at many of the workings from Bald Eagle Gap, in the Birmingham quadrangle, to a point south of Clear Branch Gap. The seam is in general from 3 to 5 feet thick where worked, and soft ore only has been obtained from it in surface workings. Such ore carries 35 to 44 per cent of metallic iron, and 32 to 42 per cent of silica. The Ida seam occurs 20 to 50 feet above the top of the Big seam.

Hickory Nut seam.—The Hickory Nut seam, which is not an iron ore, comprises 3 to 5 feet of ferruginous sandstone, characterized by a great abundance of *Pentamerus oblongus*, the internal casts of which resemble the partly open hull of a hickory nut. It lies about 12 to 20 feet above the Ida seam.

Irondale seam.—As shown under the heading "Stratigraphy" (p. 8) the Irondale seam is not of economic value in the Bessemer quadrangle.

CHARACTER OF THE ORES

The iron ores of the Red Mountain formation are red hematite, and as much of this ore is fossiliferous it is called fossil ore. Some of it is also "oolitic." The mass of the ore is amorphous red hematite mixed with calcium carbonate, silica, alumina, magnesium carbonate, and other minerals in minor quantities. The ore with its associated minerals occurs in beds analogous to strata of sandstone, shale, and limestone and is interbedded with such rocks.

As the ores of this region have been fully described elsewhere it seems unnecessary to go more into detail concerning the less valuable deposits.[28] The following description is therefore confined to the areas that carry ore at present workable.

The fossil ore consists of aggregates of fossil skeletal forms such as bryozoans, crinoids, corals, and brachiopods. These forms, consisting of broken and waterworn fragments, which were originally composed of calcium carbonate, were gathered by the action of waves and currents into beds and subsequently cemented together by calcium carbonate and iron oxide, the organic calcium carbonate of the fossils being at the same time replaced by iron oxide. More or less clay, fine sand, and small quartz pebbles were likewise included in the beds during their formation.

The oolitic ore consists of aggregates of flat grains with rounded edges, somewhat of the size and shape of flaxseeds. These grains generally lie with their flatter sides parallel to the bedding planes of the rock, and the mass is cemented by ferric oxide and more or less calcium carbonate. The flat grains have a nucleus of quartz, generally very minute, about which successive layers of iron oxide and in many grains very thin layers of silica and aluminous material have been deposited. One of the two varieties of ore generally predominates in a bed, but in some localities the fossil and oolitic materials are mixed in nearly equal proportions. The fossil ore where unweathered, as compared with the oolitic ore in the same condition, is apt to be the more calcareous, whereas the oolitic ore may carry higher proportions of silica and alumina.

Where the material is accessible to surface water the calcium carbonate is dissolved out of the beds, thereby increasing the proportional content of iron oxide, silica, and other constituents. Such altered ore is popularly termed "soft ore"; it is usually porous and friable as compared with the unaltered material, which is termed "hard ore." The "soft ore" is practically exhausted.

Chemical composition.—Conditions of blast-furnace practice determine the grade of material that may be regarded as an ore. For example, a lower percentage of metallic iron and a higher percentage of impurities may be allowed in a limy ore than in one that contains but little lime. Where brown iron ore is available a red ore high in calcium carbonate can be used as a flux, although it runs so low in iron and so high in lime that it could not be used by itself. In general, the hard and semihard ores used in the Birmingham district range in major constituents as follows: Metallic iron, 32 to 45 per cent; calcium carbonate, 5 to 20 per cent; silica, 2 to 25 per cent; alumina, 2 to 5 per cent; magnesia, 1 to 3 per cent; phosphorus, 0.25 to 1.5 per cent; sulphur, a trace to 0.5 per cent; manganese (locally), 0.25 per cent; and water, 0.5 to 3 per cent. The ore is therefore of the non-Bessemer kind. In the soft ore the lime generally runs less than 1 per cent, so that the percentages of the other constituents are proportionately higher.

The analyses in the table on page 21 show a typical hard ore (No. 1), a typical soft ore (No. 4), and intermediate or semihard grades (Nos. 2 and 3). These analyses represent samples of ore from a single slope on the same horizon of the Big seam in Red Mountain, near Birmingham, at distances respectively of 540, 480, 420, and 240 feet from the mouth of the slope. Beyond the point at which the material represented by analysis No. 1

[28] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala., with chapter on the origin of the ores by E. C. Eckel: U. S. Geol. Survey Bull. 400, 204 pp., 17 pls., 1910.

occurs there is no great change in the character of the ore, for as mined at present the seam carries an average of 35 per cent of metallic iron in this particular mine.

Analyses of iron ores from the Big seam (of Clinton age), showing gradation from hard to soft ore

	1	2	3	4
Iron, metallic (Fe)	37.00	45.70	50.44	54.70
Silica (SiO_2)	7.14	12.76	12.10	13.70
Alumina (Al_2O_3)	3.81	4.74	6.06	5.66
Lime (CaO)	19.20	8.70	4.65	.50
Manganese (Mn)	.23	.19	.21	.23
Sulphur (S)	.08	.08	.07	.08
Phosphorus (P)	.30	.49	.46	.10

Specific gravity.—The Red Mountain ore exhibits a rather wide variation in specific gravity, which is due to variations in composition and structure. Experiments with 1-inch cubes and lumps of ore show that the specific gravity of certain southern Appalachian so-called Clinton ores ranges from 2.93 to 3.56. These figures correspond roughly to weights of 183 to 225 pounds per cubic foot and to volumes of 12.25 to 10 cubic feet per long ton.

BENEFICIATION OF LOW-GRADE ORE

The ore in the lower bench of the Big seam, which is not mined, contains about the same percentage of metallic iron as that in the upper bench, but owing to the larger percentage of silica and alumina and the smaller percentage of calcium carbonate it can not be profitably smelted at the present prices of iron. However, this ore can be treated so as to eliminate much of the insoluble matter and to increase the proportion of metallic iron in the residue. Such treatment is technically called beneficiation. In the future, as the deposits of higher-grade ore become exhausted and the price of iron increases, these lower-grade ores, of which there is an enormous quantity in the Birmingham district, can probably be utilized. Much of this ore may be permanently lost, however, through the settling of the roof of the present mines in the upper bench of the Big seam, which will make mining the lower bench impossible or so costly as to be prohibitive.

MINING CONDITIONS

The ore bed and inclosing rocks dip southeastward under Shades Valley at angles of 10° to 30°. Locally the dip is greater than 30°, but over most of the area of the Big seam it is less than 20°. In a few mines, as Spaulding, Woodward, and Potter No. 1, faults have been encountered ranging in displacement from 14 to 300 feet though the maximum amount is unusual.

In a number of the mines the considerable irregularities of dip produce structural rolls. Exposures in Shades Valley also disclose local irregularities, such as vertical or overturned beds. Slight faults, such as those in the mines, are known, and probably there are others. There is a fault just east of Graces Gap and another on the east side of the area of Fort Payne chert in the vicinity of Morgan.

The beds inclosing the ore make a strong roof and floor to the mines, and this feature, combined with the thickness of the ore and the generally medium dip, are favorable to mining. The water supply is adequate and near at hand. The mines are easily accessible by railroad, and transportation is cheaply provided.

The pillar and stall method of mining is followed. Most of the mines consist of slopes driven at right angles to the strike with side headings driven to right and left on the level.

DEVELOPMENTS

Twenty-six slope mines are now operating in the part of Red Mountain between Sparks Gap and Birmingham. The deepest slope in 1908 was 2,301 feet long and is probably 5,000 feet or longer by this time (1926). Probably four-fifths of the Red Mountain ore mined in the Birmingham district, amounting to 6,312,207 tons in 1925,[29] comes from these mines. Detailed information on the mines and their products is given elsewhere.[30]

LIMESTONE AND DOLOMITE

The Chickamauga and Newala limestones and the Ketona dolomite afford the best rock for lime, flux, cement, and other uses. The Conasauga limestone should afford rock suitable for some uses.

Chickamauga limestone.—The Chickamauga limestone crops out in a narrow strip at the west foot of Red Mountain, under which it dips at angles of 10° to 20°. Much rock is accessible, however, free from cover of higher formations. Presumably it does not differ here materially from the rock at Gate City, in the Birmingham quadrangle. Analyses of samples from an old quarry half a mile north of Gate City show a composition of about 90 to 93 per cent calcium carbonate, 2.5 to 6 per cent silica, and 1 to 3.50 per cent iron oxide and alumina. The rock is nonmagnesian and suitable for cement. It is not so well adapted for lime and flux, however, as other rock in the district and is not likely to be in much demand for such use.

[29] Figures furnished by Bureau of Mines, U. S. Dept. Commerce.

[30] Burchard, E. F., and Butts, Charles, Iron ores, fuels, and fluxes of the Birmingham district, Ala., with chapters on the origin of the ores by E. C. Eckel: U. S. Geol. Survey Bull. 400, 204 pp., 17 pls., 1910. See also chapters on iron ore in annual volumes of Mineral Resources.

Newala limestone.—The Newala limestone is extensively exploited in Cahaba Valley for lime burning. The Keystone quarry and lime works are in this area. Part of the Newala limestone, comprising probably a thickness of 600 to 800 feet, is, with the exception of a few local beds of dolomite that are called sandstone by the quarrymen, a very pure calcium carbonate. The quantity of this rock is practically inexhaustible.

The following table gives analyses of the Newala limestone and the lime made from it. The Keystone quarry is in the Bessemer quadrangle; the other quarries are in the same belt of limestone but in the Montevallo quadrangle. The analyses are all given because the variations shown doubtless exist also in the Newala of the Bessemer-Vandiver area. They represent the extremes as well as the general average composition with sufficient accuracy for all practical purposes. The samples were collected and the analyses made by Robert S. Hodges, chemist of the Alabama Geological Survey.

Analyses of Newala limestone from quarries in Cahaba Valley, Ala.

	1	2	3	4	5	6	7
Silica (SiO_2)	0.53	0.45	0.29	0.23	0.17	0.45	0.74
Alumina (Al_2O_3)	.11	.17	.19	.15	.11	.21	.36
Iron oxide (Fe_2O_3)	.21	.25			.06		.12
Calcium carbonate ($CaCO_3$)	96.13	96.10	98.56	77.66	99.13	57.64	97.77
Magnesium carbonate ($MgCO_3$)	3.00	3.05	.78	22.01	.23	41.50	.69
	99.98	100.02	99.94	100.05	99.70	99.93	99.69

1. Quarry of Keystone Lime Co., Keystone, Ala. General average.

2–4. Quarry of Longview Lime Co., Longview, Ala. 2, General average; 3, selected sample; 4, coarse-grained rock.

5, 6. Quarry of Newala Lime Works, Newala, Ala. 5, Close-grained rock; 6, coarse-grained rock.

7. Quarry of Shelby Lime Works, Saginaw, Ala. General average.

The samples for the general average analyses were taken by chipping pieces from the face of the quarry amounting to about 40 pounds and representing a thickness of rock of about 200 to 300 feet. The select samples of course represent the best grade of stone. As shown by analysis 5 the best grade of stone contains over 99 per cent calcium carbonate. The granular layers (sandstone of the quarrymen) are highly magnesian. The most highly magnesian limestone approaches closely the composition of dolomite, as shown by analysis 6, but the high content of calcium carbonate of the general average samples indicates but a small proportion of the high magnesian rock. For a series of analyses representing such a thickness of stone along an outcrop of 10 miles or more, the content of silica, alumina, and iron oxide is very low.

Analyses of lime made from Newala limestone from Cahaba Valley, Ala.

	1	2	3	4
Silica (SiO_2)	0.34	0.57	0.14	0.82
Alumina (Al_2O_3)	.12	.23	.05	.12
Iron oxide (Fe_2O_3)	.10		.04	.26
Calcium oxide (CaO)	97.20	69.60	98.28	98 05
Magnesium oxide (MgO)	1.81	6.48	1.42	.62
Carbon dioxide (CO_2)	.11	.83		
Moisture	.30	22.45		
	99 98	100.16	99.93	99.87

1. Keystone Lime Co.
2. Longview Lime Co., hydrated lime
3. Newala Lime Co.
4. Shelby Lime Co.

Ketona dolomite.—The Ketona dolomite yields a nearly pure calcium-magnesium carbonate, as shown by the analyses on page 3. A large part of the flux used in the blast furnaces of the region is derived from the Ketona, which is quarried in the neighborhood of Birmingham. A wide area of this rock in Opossum Valley forms a direct continuation of the area in which the quarries at Thomas and North Birmingham are located, and the rock is presumably of equal quality and as favorably situated for quarrying. There is another area of equally good rock exposed around the base of the Salem Hills southwest of Bessemer. In Cahaba Valley north of Helena the outcrop of the Ketona is narrow, indicating a steep dip, but south of Helena the outcrop widens and the dip is probably not so steep. On Shoal Creek, $2\frac{1}{2}$ miles south of Maylene, in the Montevallo quadrangle, the rock dips 20° E. and is of excellent quality—in fact, rather better than in Birmingham Valley, as shown in the table of analyses.

The thickness of the formation in the valley south of Helena seems to be greater than elsewhere, but whether the quality of the whole mass is equal to that on Shoal Creek is unknown.

Conasauga limestone.—Very little is definitely known concerning the quality of the Conasauga limestone. Specimens collected from a quarry at Wheeling, near Bessemer, showed the following composition:[31]

Analysis of Conasauga limestone from Wheeling, Ala.

Silica (SiO_2)	1.20
Iron oxide and alumina (Fe_2O_3 and Al_2O_3)	.49
Calcium carbonate ($CaCO_3$)	89.03
Magnesium carbonate ($MgCO_3$)	8.04
Sulphur dioxide (SO_2)	.115
	98.875

[31] U. S. Geol. Survey Bull. 400, p. 198, 1910.

This analysis is insufficient to determine the general character of the Conasauga limestone. The rock analyzed is suitable for flux or for lime for most purposes. The Conasauga is utilized on a large scale for cement manufacture at Boyles, a few miles northeast of Birmingham.

Quarrying conditions.—Except the Chickamauga, which crops out on the west slope of Red Mountain, the limestone and dolomite formations crop out on the level valley floors and dip generally at high angles, necessitating open-pit quarrying below the level of the surface and consequently continual pumping and the hoisting of the rock to a considerable height. Successful operations, therefore, demand a rather expensive equipment.

LIME AND CEMENT

The raw materials of lime and cement abound but are not much utilized. The Newala, Lenoir, and Chickamauga limestones are suitable for lime and cement; the Lenoir is utilized by the large cement mill at Leeds, in the Birmingham quadrangle, the Chickamauga supplies the lime works at Chepultepec, 30 miles north of Birmingham, and the Newala supplies the limestone for the Keystone lime works and also for several other large lime works in Cahaba Valley south of Keystone. (See analyses in second column.)

The cement plant at Leeds obtains its shale from the Floyd shale. Probably much of the shale in the Pottsville formation is suitable for cement.

CLAY AND SHALE

The limestone and dolomite formations of the region are generally overlain by a layer of residual clay that is in places as much as 6 feet thick. This clay has been rather extensively utilized for common brick in the vicinity of Birmingham. In 1908 clay of this sort overlying the Conasauga limestone was utilized at the Standard Brick Works, 1 mile west of Bessemer. Shale suitable for making brick is present in enormous quantities in the Floyd, Parkwood, and Pottsville formations. Both the Pottsville and Parkwood shales are utilized in the Birmingham region for common, pressed, paving, and chemical brick of most excellent quality.

ROAD METAL

The limestones and dolomites already described will afford exhaustless supplies of material for road making, both for foundations and surfaces. The sandstones of the coal measures and other beds will yield abundant material for foundation work. The chert of the region, especially the Fort Payne chert, is an ideal material for surfacing roads. A characteristic of the Fort Payne which especially facilitates its use for this purpose is its minutely fractured condition, at least near its outcrop. It can be dug or blasted from its beds to considerable depths and comes out in a condition to go on the road with little or no further preparation. About 2 miles west of Bessemer chert is taken out in this way to a depth of about 100 feet. The comparatively brittle nature of the Fort Payne chert allows it to pulverize and become firmly compacted into a hard, smooth mass. The formation will probably yield chert practically ready for the road at almost any place along its outcrop, and the supply easily accessible to transportation along the east flank of Red Mountain and in West End Mountain is inexhaustible.

Chert from the Copper Ridge dolomite has been used to some extent for road dressing. It is taken from the banks adjacent to the roads, where the finer portions of the residual chert mixed with clay have accumulated at the bases of slopes. A considerable quantity of this material has been taken from a pit half a mile northwest of Mobile Junction, Bessemer.

BUILDING STONE

Abundant sandstone for rough masonry occurs in the Pottsville formation, Parkwood formation, Hartselle sandstone, and Red Mountain formation. A little brown sandstone has been taken from the Red Mountain formation in the vicinity of Gate City for superstructural work. However, very little stone of a quality suitable for such work can be obtained. In fact, the use of cement has practically supplanted that of stone for all kinds of coarse masonry, and there is practically no commercial demand for such rock as this region possesses.

SOILS

The Bessemer-Vandiver district has a variety of soils. The shale and sandstone of the Pottsville formation yield a soil that ranges from a sandy to a clay loam, depending on whether sandstone or shale predominates in the underlying rocks, from the disintegration of which the soil is derived. These types of soil are blended and modified by admixture with each other as a result of the creep of the soil down the slopes. The soils are 8 to 10 inches thick and are underlain by about 3 feet of sandy clay subsoil that contains fragments of rock. The soils themselves contain a considerable percentage of rock fragments, but as a rule the fragments are fine and constitute no obstacle to cultivation. The soil is of moderate fertility.

The valleys underlain by limestone and dolomite have some of the best soil. The soil which overlies the Ketona dolomite is a red clayey loam of great thickness and of high natural fertility. The areas of Copper Ridge dolomite and of Fort Payne chert have a soil composed of stony loam which is comparatively unfertile on the hills and ridges but is productive in the valleys and low-lying flat lands among the hills, where it has accumulated by transportation from the higher ground. On the slopes and hills the soil is generally a white clay loam full of chunks of chert and boulders, which are an impediment to cultivation, but in the lower grounds the fragments of chert, though plentiful, are finer and less troublesome. The areas of Conasauga limestone have a reddish, yellowish, or black clay loam of good fertility. Locally these areas are low-lying, poorly drained, and unfit for tillage.

The areas of Floyd shale in Shades and Cahaba valleys have a clay soil, in some places ill drained and little suited to cultivation.

The alluvium along the streams is the best soil of the region, but it is of small extent.

WATER RESOURCES

Surface water.—The average annual precipitation in northeastern Alabama, is 50 to 54 inches. This precipitation is usually so uniformly distributed throughout the year that the surface water supply is ample for all needs, including potable water, water for stock, and water for industrial establishments that require large quantities for steam, coal washing, blast furnaces, and other uses. There are a good many large springs in the limestone areas. Hawkins Spring north of Bessemer, which has a flow of 2,700,000 gallons daily, is one of the largest. This indicates a considerable underground circulation in the limestone. Springs are less common and smaller in the belts of shale and sandstone, as Shades Valley and the Cahaba coal field. Here, however, a sufficient supply of water for domestic uses can be obtained in wells generally not over 50 feet deep.

Ground water.—Three wells, 100 to 150 feet deep, drilled in the Conasauga limestone at Schillinger's brewery, in Birmingham, yield 250 gallons of water a minute each and have never shown any signs of exhaustion. Probably this limestone and the other limestones that crop out in the valley would yield abundant water, which would, however, have to be raised by pumping. The structure in the Cahaba coal field and along the Dunnavant syncline is ideal for artesian wells. The Shades and Pine sandstones, which should be good water carriers, crop out along the high ridges and underlie the surface at moderate depths on the flanks or near the axes of the synclines. It seems almost certain that strong flowing wells could be obtained by drilling to the sandstone beds on Patton Creek near Little Valley Mountain in the Bessemer quadrangle or anywhere along the valley bottom between Oak and Double Oak mountains from Big Narrows to Dunnavant. The structural conditions are displayed in structure sections A–A′ and B–B′ for both the Bessemer and Vandiver quadrangles.

Potable and domestic water.—Potable water is supplied by many springs and by the streams fed by such springs, and permanent supplies of potable water for farm use are obtainable almost everywhere from wells less than 50 feet deep. The chemical character of this water varies according to the nature of the underlying rock formations. The range in quality and composition of this water is shown in the accompanying table of analyses. The water from the limestone formations is of course hard water; that from the areas of Floyd shale varies according to the location of the well, some being high in hardness and some low. The analyses of the water of the Allinder and adjoining wells, Nos. 13 to 16, show the highest hardness. The differences are probably due to the presence or absence of limestone layers in the vicinity of the wells. Nearly all the samples from the Pottsville areas are of low hardness; they are freestone waters.

No notable mineral water is known or reported from the Bessemer-Vandiver area.

Approximate analyses of waters of the Birmingham district, Ala.

[R. S. Hodges, chemist, Alabama Geological Survey, analyst. Parts per million]

	Date of collection	Total hardness	Alkalinity	Sodium and potassium	Magnesium	Calcium	Iron	Chlorine	Sulphate radicle	Bicarbonate radicle	Total
1	Jan. 17, 1913	152	148	1.0	12.6	40.0	Trace	1.9	3.7	180	239.2
2	Nov. 14, 1912	169	153	21.6	13.1	46	Trace	31.5	18	186	315.2
3	Nov. 14, 1912	163	158	9.6	12.3	45	Trace	7.5	15	193	282.4
4	Nov. 14, 1912	174	155	.7	7.1	58	Trace	5	13	189	272.8
5	Nov. 14, 1912	163	155	2.5	17.8	36	Trace	4	8.2	189	257.5
6	Jan. 17, 1913	157	154	4.3	16.9	35.1	Trace	4.4	6.5	187.8	255
7	Nov. 14, 1912	160	150	10.8	5.4	55	Trace	3	28.6	183	285.8
8	Jan. 17, 1913	101	92	7.5	8.4	26.6	Trace	3.4	20.5	112.2	178.6
9	Nov. 14, 1912	167	150	6.6	8.4	53	Trace	3	26.6	183	280.6
10	Jan. 17, 1913	113	115	29.9	16.8	17.6	Trace	2.9	56.9	140.3	264.4
11	Nov. 14, 1912	16	5	.7	1.8	3	0.5	3	.8	6	23
12	Jan. 17, 1913	14	5	Trace	1.1	3.9	Trace	3.4	2.8	6.1	17.3
13	Nov. 14, 1912	697	449	309.1	29.1	231	Trace	150.8	679	547	1,946
14	Jan. 17, 1913	543	200	90.1	64.9	110.9	Trace	164.1	295.6	244	969.6
15	Jan. 17, 1913	411	205	41.1	30.9	113.6	Trace	51.9	213.2	250.1	700.8
16	Jan 17, 1913	221	185	29.4	24.6	47.8	.3	24.5	63.1	225.7	415.4
17	Jan 17, 1913	97	25	21.1	11.7	19.6	Trace	64.6	26.2	30.5	173.7
18	Nov. 14, 1912	55	49	3.6	3.4	16	.5	3	9.4	59	94.9
19	Jan 17, 1913	24	20	3.2	.6	7.8	.1	2.4	7.3	24	45.4
20	Nov. 14, 1912	15	6	2.3	1.8	3	Trace	5.5	6	7	25.5
21	Nov 14, 1912	160	128	43.2	25.1	22	1.0	77.5	16	156	340.8
22	Nov. 14, 1912	69	64	3	2	25	Trace	4	6	78	118
23	Nov. 14, 1912	14	10	2	2	2	1	2.5	4	12	25.5
24	Nov. 14, 1912	60	74	12.8	8.4	9	1.5	2.5	10	90	134.2
25	Nov. 14, 1912	110	126	17.2	13.4	22	1	10.5	6.9	153	224
26	Nov. 14, 1912	10	13	5.3	1.2	2	Trace	2.5	5.7	16	32.7
27	Nov. 14, 1912	12	15	4	1	2	1	2.2	3	18	31.2
28	Nov. 14, 1912	31	29	6	2	8	.5	3	10	35	64.5
29	Nov. 14, 1912	41	44	6	4	9	1.5	4.5	5	53	83
30	Nov. 14, 1912	272	249	1.8	31.6	57	Trace	6	17.6	303	417
31	Nov. 14, 1912	245	163	12	25	56	Trace	36	55	199	383
32	Nov. 14, 1912	235	227	5.7	21.3	59	Trace	6.5	11	277	380.5
33	Jan. 17, 1913	170	134	34.5	15.7	42.3	Trace	9.3	94.3	163.4	359.5
34	Jan. 17, 1913	131	71	21.8	9	36.8	1	9.8	90.6	86.6	254.7
35	Jan. 17, 1913	142	47	14.4	11.3	38	.2	16.1	100.0	57.3	237.3
36	Jan. 17, 1913	48	[a]	15.1	4.7	8.2	Trace	2.9	54.5	------	85.6
37	Jan. 17, 1913	13	22	7.8	.4	4.5	.2	2.4	4.5	26.8	46.2
38	Jan. 17, 1913	38	22	.5	4.2	8.6	Trace	1.9	15.1	26.8	57.1

[a] Acidity.

1. Hawkins Spring, 4 miles north of Bessemer; flows 2,700,000 gallons daily; water supply for Bessemer. Conasauga limestone.

2. Ice plant, Bessemer; shallow well; water used for ice manufacture. Conasauga limestone.

3. South Bessemer Spring; large spring used by ice plant. Conasauga limestone?

4. Houston Spring, about 1 mile north of Bessemer; used by fertilizer plant. Conasauga limestone.

5, 6. Moore's spring near Muscoda; water used for domestic purposes; large supply. Formation uncertain.

7, 8. Muscoda mine, Tennessee Coal & Iron Co. Water from heading 52 in No. 4 mine; used for domestic supply Red Mountain formation.

9, 10. Muscoda mine, Tennessee Coal & Iron Co. Mine water from slopes 4, 5, 6; used for boilers. Red Mountain formation.

11, 12. Shallow well of Chambers Parsons, on Helena road about three-fourths mile east of Muscoda; domestic supply. Floyd shale?

13, 14. Well of B. F. Allinder, about 2½ miles from Bessemer on Helena road. Floyd shale.

15. Well of F. M. Turner, across road from Allinder; about 30 feet deep. Floyd shale.

16. Well of P. A. Goodwin, about 200 yards from Allinder's well, nearer Shades Creek. Floyd shale.

17. Shallow well of Anne Cox, about one-fourth mile from Shades Creek. Floyd shale.

18, 19. Shades Creek at road crossing between Bessemer and Helena. Floyd shale.

20. Shallow well of Mr. Brown, about one-half mile east of Shades Creek; about 40 feet deep. Floyd shale.

21. Well of Mr. Brown, about three-fourths mile east of Shades Creek; about 35 feet deep. Floyd shale.

22. Morgan station; well at school about 5 miles southeast of Bessemer. Floyd shale.

23. Well of Mr. Hill, about 7 miles southeast of Bessemer, Helena road; about 30 feet deep. Parkwood formation.

24. Shallow well of Mr. L. S. Hollingsworth, at Genery's Gap; domestic supply. Parkwood or Pottsville formation.

25. Well of S. S. Doss, 8 miles from Bessemer and 2 miles from Cahaba River. Pottsville formation.

26. Small spring at roadside one-half mile east of Cahaba River. Pottsville formation.

27. Trigger Creek, on Bessemer and Helena road. Pottsville formation.

28. Well at Falliston about 15 feet deep. Pottsville formation.

29. Well at Falliston west of railroad, about 50 feet deep. Pottsville formation.

30. Helena spring. Rome formation?

31. Shallow well at Helena. Rome formation.

32. Well of Mr. Ruffin at Helena; about 25 feet deep. Rome formation.

33. Impounding reservoir of Tennessee Coal & Iron Co.; sample taken near intake that supplies 28,000,000 gallons daily. Pottsville formation.

34. Composite sample taken from various points in impounding reservoir. Pottsville formation.

35. Village Creek; sample taken below Jefferson County sewage disposal plant. Pottsville formation.

36. Camp Branch, one-fourth mile below Edgewater. Pottsville formation.

37. Corbet Creek. Pottsville formation.

38. Tap water from Morris Hotel, Birmingham Water Works, Cahaba River. Pottsville formation.

WATER POWER

Stream flow.—No regular gaging stations have been maintained, but the following miscellaneous discharge measurements have been made on streams in the Bessemer and Vandiver quadrangles. These measurements and the data in the accompanying table compiled from records at gaging stations on streams adjacent to this area give an indication of the flow that may be expected.

Miscellaneous discharge measurements of streams in Bessemer-Vandiver district

Date	Stream	Tributary to—	Locality	Discharge
1901				*Sec.-ft.*
Jan. 28	Hawkins Spring	Valley Creek	Four miles northeast of Bessemer	15.8
" 29	Cahaba River	Alabama River	At Sydenton	549
Mar. 29	do	do	do	1,117
1905				
Apr. 3	do	do	do	167
" 3	do	do	Below Buck Creek near Sydenton	227
" 3	Buck Creek	Cahaba River	At Helena	69
1903				
Nov. 12	Little Cahaba River	do	At Pledger's mill, Shelby County	13
" 12	do	do	One-half mile above Deshazo's mill, near Bridgeton	21
" 12	do	do	At ford below Deshazo's mill, near Bridgeton	28
Sept. 30	do	do	do	30
" 30	do	do	do	29
1904				
Aug. 6	do	do	do	78
" 6	do	do	At Birmingham-Columbiana road crossing, about 1 mile above mouth	66

Potential horsepower.—Cahaba River and the larger creeks are capable of developing considerable power for gristmills, sawmills, small electric plants, and other uses. Cahaba River in the vicinity of Blocton, about 10 miles southwest of Bessemer, would yield 500 net horsepower with a 34-foot dam and an 80 per cent turbine at ordinary low water.

In this district the flow of Cahaba River is of course smaller and the potential power correspondingly less, though still considerable. A number of gristmills and sawmills utilizing 10 to 40 horsepower have been operated on different streams. Buck Creek at Helena supplies power for running a small electric plant for lighting the town. These plants, however, have developed but an insignificant part of the possible water power of the region. Similar small plants could doubtless be built on Cahaba River, Shades Creek, Valley Creek, and other streams.

December, 1925.