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GEOLOGIC ATLAS

OF THE

UNITED STATES

BIRMINGHAM FOLIO

ALABAMA

BY

CHARLES BUTTS

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BIRMINGHAM FOLIO
NO. 175

GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

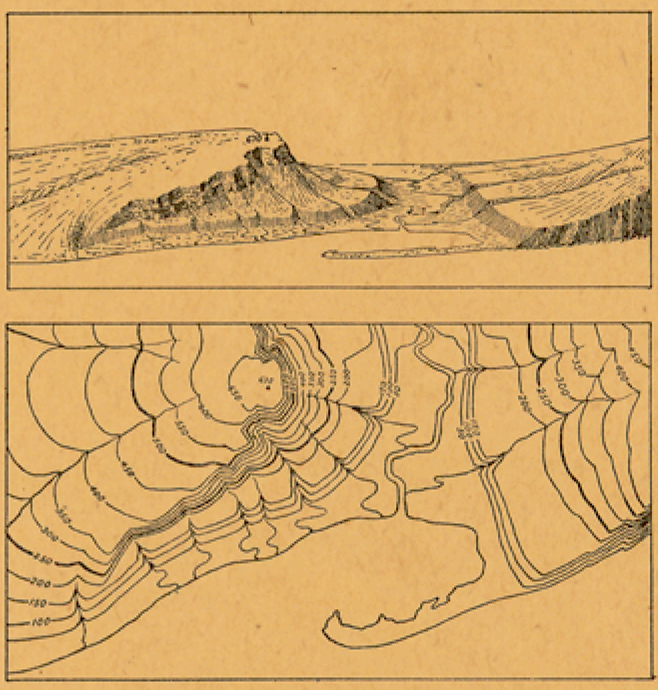


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*,

DESCRIPTION OF THE BIRMINGHAM QUADRANGLE.

By Charles Butts.

INTRODUCTION.

LOCATION, EXTENT, AND GENERAL RELATIONS.

As shown by the key map (fig. 1), the Birmingham quadrangle lies in the north-central part of Alabama. It is bounded by parallels 33° 30′ and 34° and meridians 86° 30′ and 87° and contains, therefore, one-quarter of a square degree. Its length from north to south is 34.46 miles, its width from east

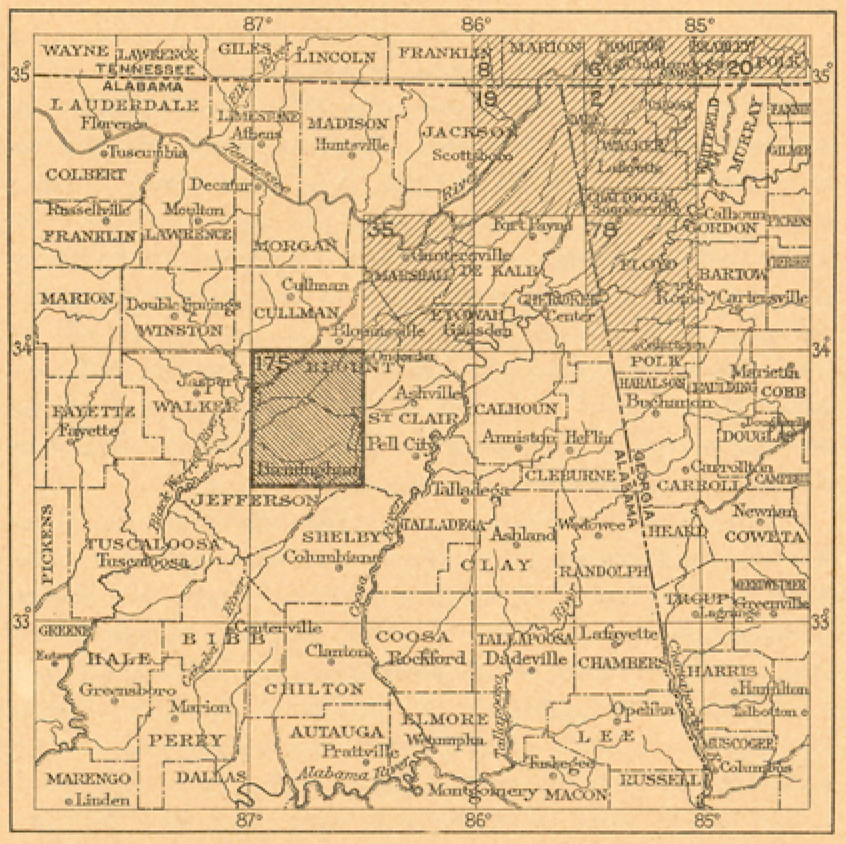


FIGURE 1.—Index map of northeastern Alabama and northwestern Georgia.
Darker ruled area covered by Birmingham folio. Other published folios indicated by lighter ruling, as follows: Nos. 2, Ringgold; 6, Chattanooga; 8, Sewanee; 19, Stevenson; 20, Cleveland; 35, Gadsden; 78, Rome.

to west is 28.78 miles, and its area is 992 square miles. The quadrangle is mainly in Jefferson and Blount counties, but it includes small parts of Walker and Cullman counties on the northwest and of St. Clair and Shelby counties on the southeast.

In its geographic and geologic relations it forms a part of the Appalachian province, which extends from the Atlantic Coastal Plain on the east to the Mississippi lowlands on the west and from Alabama to Canada. A summary description of the Appalachian province follows.

GEOGRAPHY AND GEOLOGY OF THE APPALACHIAN PROVINCE.

Subdivisions.—As shown in figure 2, the southern part of the Appalachian province embraces four natural subdivisions, each of which is characterized by distinct types of topography, rocks, and geologic structure. These subdivisions are, from east to west, the Piedmont Plateau, the Appalachian Mountains, the Appalachian Valley, and the Appalachian Plateau.

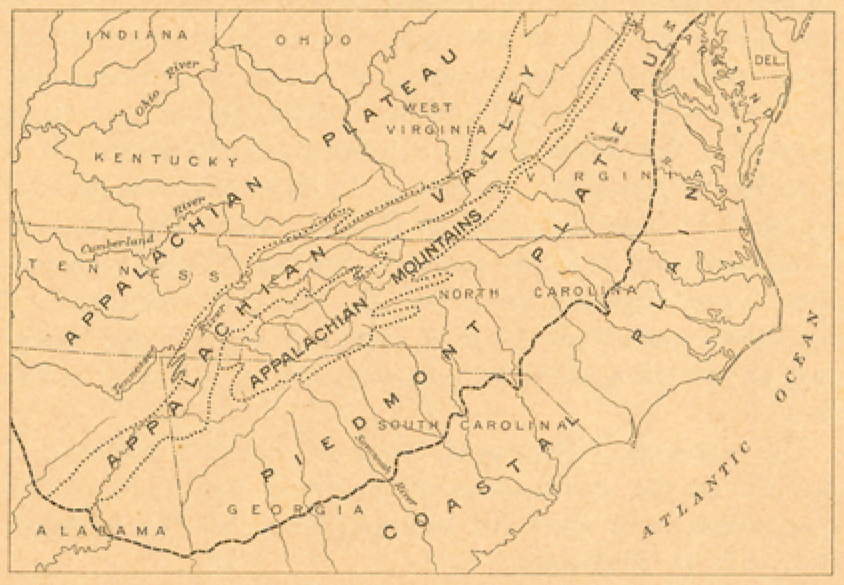


FIGURE 2.—Map of the southern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain.

The dividing line between the Piedmont Plateau and the Appalachian Mountains is the Blue Ridge; that between the Appalachian Mountains and the Appalachian Valley is the western border of the mountains known as the Unaka Range; and that between the valley and the Appalachian Plateau is the eastward-facing escarpment known in Pennsylvania, Maryland, and West Virginia as the Allegheny Front and through Tennessee as the Cumberland escarpment, which continues into Alabama as the eastern face of Lookout and Blount mountains. The Birmingham quadrangle lies partly in the Appalachian Valley and partly in the Appalachian Plateau.

Relief.—Viewed broadly, the Piedmont Plateau presents the aspect of a nearly level surface, its elevation ranging through long distances from 500 to 1500 feet above the sea. The plateau surface has been more or less dissected by the streams that flow across it toward the Atlantic. The Appalachian Mountains occupy a broad belt extending from southwestern Virginia through western North Carolina and eastern Tennessee to northeastern Georgia. This belt is a region of strong relief, characterized by points and ridges 3000 to 6000 feet or over in height, separated by narrow V-shaped valleys. The general level of the Appalachian Valley is much lower than that of the Appalachian Mountains on the east and of the Appalachian Plateau on the west. Its surface is characterized by a few main valleys, such as the Cumberland Valley in Pennsylvania, the Shenandoah Valley in Virginia, the East Tennessee Valley in Tennessee, and the Coosa Valley in Alabama, and by many subordinate narrow longitudinal valleys separated by long, narrow ridges rising in places 1000 to 1500 feet above the general valley level. The highest of these valley ridges approach the altitude of the Appalachian Plateau and the western foothills of the Appalachian Mountains. The Appalachian Valley lies nearly 3000 feet above sea level in southwestern Virginia, on the divide between Tennessee and Kanawha rivers. From this region the valley descends northward to an elevation of 500 to 1000 feet on Potomac and Susquehanna rivers and southward to an elevation of 500 feet along Coosa River in northeastern Alabama.

The Appalachian Plateau is highest along its eastern margin, from which it slopes gradually westward. The culminating point of this division of the province is in central West Virginia, where its altitude is 4000 feet above the sea. From this point the surface slopes southward to 2000 feet in southern Tennessee and to 500 feet north of Tuscaloosa, Ala., where it is overlain by Cretaceous and Lafayette deposits. In Tennessee the highest parts of the plateau region are known as the Cumberland Plateau and Waldens Ridge. West of Tennessee River the Cumberland Plateau extends into Alabama. In Georgia and Alabama there are semidetached parts of the same general surface known as Lookout, Blount, and Sand or Raccoon mountains. The surface of the Cumberland Plateau slopes gently westward and in Tennessee terminates in a westward-facing escarpment about 1000 feet high, which separates it from the lower plain known in Tennessee as the Highland Rim. In Tennessee the Highland Rim is a very distinct plain or plateau about 1000 feet above the sea, but in northern Alabama it is scarcely distinguishable. In the region of Monte Sano, near Huntsville, and for some distance to the south the escarpment terminating the Cumberland Plateau descends about 1000 feet to the central plain of Tennessee and northern Alabama.

Peneplains.—The Cumberland Plateau, the surfaces of Lookout and Raccoon mountains, the crests of the highest ridges in the Appalachian Valley, and the western foothills of the Appalachian Mountains probably represent very closely parts of an ancient nearly level surface, which once, perhaps, lay near to sea level but which was subsequently uplifted and dissected. This ancient surface is believed to have resulted from erosion during a long period, in which there was no considerable crustal movement, either up or down, in the region. In this way the Appalachian province, except the Appalachian Mountains, was finally reduced nearly to sea level, with here and there unreduced areas of greater or less extent rising above the general level. Such a surface is called a peneplain. The peneplain just described may be continuous with the Schooley peneplain of New Jersey and Pennsylvania, but as the continuity has not been proved it will be referred to in this folio by the more local term Cumberland peneplain.

The Highland Rim in Tennessee, the surfaces and ridges of Wills Valley at an approximate elevation of 1000 feet above sea level, the similar surfaces in the southern part of the Appalachian Valley in Tennessee, Georgia, and Alabama, and the surfaces of the Piedmont Plateau may be regarded as representing a second peneplain having at the present time a general altitude of 1000 feet above sea level. This has been called by Hayes[a] the Highland Rim peneplain. In central Tennessee the Cumberland and Highland Rim peneplains are separated from each other by an escarpment 1000 feet high and are very distinct features, but to the south their surfaces approach each other and appear to merge and become indistinguishable along a line passing south of Huntsville and Gadsden, Ala., to Cartersville, Ga.

A third peneplain, lying below the Highland Rim peneplain, is represented by surfaces bordering Coosa River at altitudes varying from 500 to 600 feet and rising along the Appalachian Valley northward to about 700 feet in southern Tennessee. This is called the Coosa peneplain. The lowlands along the Tennessee, in Sequatchie Valley, and along Big Wills Creek are parts of the same peneplain. Below the Coosa peneplain the streams of the southern part of the Appalachian province have eroded their present channels.

Drainage.—The northern part of the Appalachian province is drained through St. Lawrence, Hudson, Delaware, Susquehanna, Potomac, and James rivers into the Atlantic and through Ohio River into the Gulf of Mexico; the southern part is drained by New, Cumberland, Tennessee, Coosa, and Black Warrior rivers into the Gulf. In the northern part many of the rivers rise on the west side of the Great Appalachian Valley and flow eastward or southeastward to the Atlantic; in the southern part the direction of drainage is reversed, the rivers rising in the Blue Ridge and flowing westward across the valley to the Mississippi basin and the Gulf of Mexico. This arrangement of the rivers is the result of a complex series of changes that can not be discussed here.

Rocks and structure.—Crystalline rocks of igneous and metamorphic origin prevail in the Piedmont Plateau and the Appalachian Mountains, the proportion of sedimentary rocks being small. The rocks have been greatly folded and faulted. Their character and attitude are such that they resist erosion in about the same degree throughout, hence the great irregularity of the forms resulting from erosion in the Appalachian Mountains.

The Appalachian Valley presents in its rocks and structure a great contrast to the subdivisions on each side of it. Its rocks are predominantly limestones, but it contains also extensive formations of sandstone and shale. By great pressure exerted from the southeast these rocks have been thrown into long, narrow folds following the course of the valley, and have also, especially in the southern part of the valley, been broken to great depths along lines up to 100 miles in length having the same trend; along these lines the lower rocks have been thrust generally northwestward over the upper rocks, in places to the extent of many thousand feet. There were thus produced many alternations of limestone, sandstone, and shale, forming bands of varied lengths and breadths, extending in a northeast-southwest direction. Limestone being subject to more rapid erosion than shale and sandstone, the streams have gradually adjusted themselves to the limestone bands, along which they have eroded valleys, leaving the sandstone bands standing between the valleys as ridges, thus producing the characteristic topography of the Appalachian Valley.

The rocks of the Appalachian Plateau are mostly sandstone, conglomerate, or shale. In the southern part of the province these rocks are underlain by cherty limestone. They are for the most part nearly horizontal, except along Wills, Murphrees, and Sequatchie valleys, where their horizontality has been destroyed by folding and faulting. This folding, by bringing up the underlying valley limestones into the field of erosion, has resulted in the formation of the valleys just named, to which Lookout, Blount, and Raccoon mountains owe their existence as separated plateaus. The rocks of the Appalachian coal field are included in the Appalachian Plateau.

TOPOGRAPHY.

RELIEF.

Surface types.—Two distinct types of surface features occur in the Birmingham quadrangle—the valley type and the plateau type. The valley type is characterized by alternating ridges and valleys having a northeast-southwest direction; the plateau type shows no regular arrangement of ridges and valleys. The boundary between the two types is Sand Mountain, extending from Ensley to a point on the east border of the quadrangle 3 miles north of Cheputepec. These two parts of the quadrangle may be termed the valley region and the plateau region. The two types of topography are the result of differences in the character of the rocks and in the geologic structure. A study of the sections on the structure section map will yield a clearer notion of the relation of topographic features to the kind of rocks and to the attitude in which they lie.

In the valley region the rocks (limestones, sandstones, conglomerates, and shales) have been faulted and folded and are generally inclined at high angles. The faults and folds extend in a northeast-southwest direction and have determined the trend of the valleys and ridges; the alternation of belts of limestone and shale which are easily eroded with belts of more resistant sandstone and conglomerate has determined their position and extent. The valleys follow the limestone and shale belts; the ridges coincide with the belts of more or less steeply inclined sandstone or conglomerate.

The rocks of the plateau region are entirely shale and sandstone. Away from the boundaries of the valley region they

[a] Hayes, C. W., Physiography of the Chattanooga district in Tennessee, Georgia, and Alabama: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, pp. 1-58.

lie practically flat, and on account of their flatness their resistance to erosive forces has been equal in all lateral directions and 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. These peculiarities characterize the topography of nearly all that part of the quadrangle lying northwest of Sand Mountain.

Birmingham Valley.—As described by McCalley,[a] Birmingham Valley lies between Shades Mountain and its northward continuation, Blackjack Ridge, on the southeast and Sand Mountain on the northwest, and extends from Springville, northeast of the Birmingham quadrangle, to the vicinity of Vance, 30 miles southwest of the quadrangle, where the Paleozoic rocks are completely covered by Cretaceous rocks. At Birmingham the width of the valley is 7 miles. Within the valley thus defined lie several subordinate valleys, separated by ridges that in places reach the level of the bounding ridges. These, from southeast to northwest, are Shades Valley, one-half to 1 mile wide; Red Mountain, reaching 1100 feet in height; Jones Valley. 1 to 2 miles wide; the chert ridge extending from Blount Mountain to Birmingham, where it is known as Cemetery or Enon Ridge; and Opossum Valley, 1 mile wide. The Birmingham Valley is anticlinal, being eroded upon the crest of an anticlinorium. At the south end of Blount Mountain the valley divides into two arms. The northwestern arm, Murphrees Valley, extends to the west of Blount Mountain and ends a few miles north of the quadrangle in Bristows Cove. Within Murphrees Valley are three subordinate narrow valleys separated by West Red Mountain and Gravelly Ridge, with its continuation, Chert Mountain.

The more striking prominences of Birmingham Valley are Butler and Cahaba mountains, whose crests, 1450 feet above the sea, are the highest points in the quadrangle. The rounded knobs at the south end of Blount Mountain are curious and interesting features that will be discussed in a subsequent part of this folio. Blount Mountain itself is a striking feature, its sides rising abruptly 400 to 600 feet above the streams at its base. As Birmingham Valley is a good example of an anticlinal valley, so Blount Mountain is a good example of a synclinal mountain. Sand Mountain, West Red Mountain, Red Mountain, and Shades Mountain and its northern continuation, Blackjack Ridge, are also prominent features in Birmingham Valley due to inclined resistant rocks such as sandstone and chert.

Other valleys.—In the north-central part of the quadrangle, extending from Reid station past Bangor, lies the narrow south end of a valley known farther north as Brown or Sequatchie Valley. Near the southeast corner of the quadrangle is Cahaba Valley, in which is situated the town of Leeds. Flat and Chestnut ridges, in the Cahaba coal field, and Pine and Oak ridges and Oak Mountain, in Cahaba Valley, are other conspicuous features of the valley region.

Cumberland peneplain.—The higher divides and hills of the plateau region, including the Warrior coal field, approach a common altitude, and when viewed from a distance, so that the valleys are not seen and the inequalities are softened and fade out, they appear to merge into a common surface sloping gently southward. If the valleys were filled up to the level of the hilltops, such a surface would result. It is believed that these hilltops approach very nearly to the uplifted level of such a surface which once existed near sea level and that they are remnants of that surface left in the general dissection of the region by erosion. This old surface probably was a part of the Cumberland peneplain.

Other plateau features.—Wornock and McPherson mountains, on the north margin of the quadrangle, are prominent in the landscape, and the eastern escarpment of Arkadelphia Mountain, in the northwest corner, rising like a great rampart 300 feet above the valley, is a commanding feature from a wide area to the southeast.

The isolated hills at Coalburg and just north of Littleton are interesting. The hill at Coalburg is not easily explained, though it is a plausible supposition that the little stream south of Coalburg, extending past Stockton, formerly flowed east of Coalburg along the valley now occupied by the Southern Railway and emptied into Fivemile Creek a short distance below Upper Coalburg, leaving the hill connected by a low neck with the high ground to the southwest. This neck was finally worn away by the combined action of the little stream and Fivemile Creek and the course of the former diverted. The little hill north of Littleton is evidently a cut-off spur. Locust Fork of Black Warrior River formerly flowed around it, and Cane Creek emptied at the apex of the bend. At present the river flows through the abandoned channel in times of high water.

At Macknally Ford is a spur connected with the upland on the south by a narrow neck. The river impinging on the east side of this neck in the apex of the bend will ultimately cut through the neck and abandon the part of its present channel passing around the north end of the spur, the result being an isolated hill like that at Littleton.

[a] McCalley, Henry, Report on the valley regions of Alabama, pt. 2, Alabama Geol. Survey, 1897, p. 11.

DRAINAGE.

By reference to the map it will be seen that the Birmingham quadrangle is drained almost wholly by Locust and Mulberry forks of Black Warrior River and their tributaries. A small area in the southeastern part is drained by Cahaba River. A detailed description of the streams seems superfluous, for their names, sizes, direction of flow, and relative importance are obvious from an inspection of the map. There are, however, some interesting peculiarities of a number of the streams to which it seems well to call special attention. Along much of its course Locust Fork flows in a gorge 150 to 200 feet deep. It is a meandering stream and its bed is well graded. On one or both sides Mulberry Fork is bordered by wide flats 50 feet above its bed. Neither stream is navigable, though in former days coal was transported downstream in flatboats at times of flood.

The most striking peculiarities are displayed, however, by a number of the smaller streams which cut through the highest ridges in deep gorges. Blackburn Fork of Little Warrior River, Gurley Creek, Self Creek, Cunningham Creek, and Fivemile Creek, cutting through West Red Mountain and Sand Mountain, may be cited as examples. The natural courses for these streams to follow would seem to have been in Murphrees and Birmingham valleys. Likewise Murphy Creek flows across the head of Brown Valley and cuts through the monoclinal ridge west of Blount Springs in a deep gorge. An explanation of the apparently abnormal course of these streams will be given in the chapter on geologic history (p. 14).

Many of the principal tributaries of Black Warrior River, such as Gurley, Self, Turkey, Cunningham, Fivemile, Village, and Valley creeks, head in Birmingham Valley. In like manner the east side of the valley is drained into Cahaba River. Hence Birmingham Valley is a valley only in being bounded by ridges, but as respects the main drainage of the region it is a watershed. The gradient and flow of these streams are discussed in the section on economic geology.

RELATION OF TOPOGRAPHY TO MAN'S ACTIVITIES.

The topographic features of a region have an intimate relation to man's activities. His farms are located on the level or gently sloping areas; hence the population of a region may depend greatly on the extent of such areas within it. The accessibility of a region to railroads depends on the surface features, and the building of railroads is in large part essential to its settlement and the development of its agricultural and mineral resources.

In the Birmingham quadrangle agriculture is confined largely to the flat-topped ridges, to the flood plains of the rivers and larger creeks, and to the limestone valleys and coves, like Birmingham and Cahaba valleys and Guinn Cove. The routes taken by railroads in the quadrangle have been controlled entirely by the topography, and along the railroads are situated cities, towns, and mines. Thus the location of Birmingham has been conditioned largely by a favorable combination of topographic features. The gaps through Sand Mountain on the west and Red Mountain on the east, such as Boyles Gap and Red Gap, have permitted the entrance of railroads by which the city is brought into communication with the east and west, and the northeast-southwest valleys facilitate communication with the north and south. The direction of the longer streets of Birmingham and its suburbs is determined by the topography, which in turn depends on the kinds and structure of the underlying rocks—in other words, on the geology of the valley.

DESCRIPTIVE GEOLOGY.

The geology of this region has been well described and mapped by the Alabama Geological Survey. Such changes as have been made are mostly in details and not in essentials. Two new formations and a number of members in the old formations have been recognized and mapped. A few different formation names have been used, as explained in the descriptions. Here again the change is not one of substance but of form, in order to bring the nomenclature into harmony with the general usage.

The rocks of the Birmingham quadrangle are all of sedimentary origin and range in age from Cambrian to Carboniferous. These rocks were originally deposited on the ocean floor in a nearly horizontal attitude. In a large part of the quadrangle this attitude has been fairly well preserved, but in areas of considerable size the strata have been folded and faulted to such an extent that the original position as well as the original relations of the rocks has been destroyed. In addition to the consolidated rocks, there are local superficial deposits of gravel and alluvium of Recent age which are of little stratigraphic importance.

STRATIGRAPHY.

CAMBRIAN SYSTEM.

The Cambrian system comprises the Rome ("Montevallo") formation, Conasauga ("Coosa") limestone, and the lower part of the Knox dolomite. In accordance with customary usage in the Appalachian province the top of the Cambrian is placed at some undetermined horizon in the Knox, though its exact position is unknown on account of the lack of fossils from which it might be determined; but this mode of treatment may be changed in the future. The Rome and Knox are much the same here as in Tennessee, but the Conasauga is in this region predominatingly limestone, whereas in northeastern Alabama and adjacent parts of Tennessee it is mostly shale.

ROME ("MONTEVALLO") FORMATION.

Name.—The name Rome was applied to this formation by Hayes,[a] from Rome, Ga., which is situated in an area of the formation. The name Montevallo (Variegated) shale and sandstone had been previously introduced by Smith[b] for the same formation, from Montevallo, Ala., near which it has a wide outcrop. As the name Rome has been established for this formation throughout the southern Appalachian region by long usage in literature, especially in a large number of publications of the United States Geological Survey, it will be employed in this folio instead of the less well-known and local term "Montevallo." The use of Rome furthermore expresses the equivalency of this particular occurrence of the formation with other occurrences in this region.

Character and distribution.—In this quadrangle the Rome formation appears on the weathered outcrop mostly as a rather stiff greenish shale. It contains some red shale, thin impure limestone, thin cherty layers near the top, and in one section thin layers of brown rotten sandstone. At Helena, 15 miles southwest of the quadrangle, the formation shows, in addition to the kinds of rock already mentioned, a good deal of shale that weathers into thin yellow flakes, one or more thin bands 1 foot or less thick of quartzite in shale, and near the top a 20 to 30 foot bed of calcareous sandstone. The formation is decidedly variegated in color, and it preserves this characteristic as far north as northern Tennessee and possibly into southern Pennsylvania, where similar variegated shales and sandstones occur at what may be fairly regarded as the same geologic horizon.

The Rome formation outcrops in a narrow band running in a northeast-southwest direction across the southeast corner of the quadrangle, interrupted 2 miles northeast of Henryellen by an interval of about a mile in which the formation does not appear to outcrop. The best exposure of the formation is on one of the eastern tributaries of Black Creek, in the northern part of sec. 35, T. 16 S., R. 1 E., where the thickness of the outcrop is about 500 feet. About the same thickness appears to be exposed all along its outcrop.

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. It is not impossible that the Rome is brought up to outcrop on the west side of Opossum Valley between Ensley and North Birmingham by the fault on the east side of the Warrior coal field. Further discussion of this point will appear in the description of the Conasauga limestone.

Thickness.—At no point in the quadrangle are any rocks exposed of formations known to underlie the Rome, and it is therefore impossible to determine its full thickness in this region. At Helena, farther south, about 1000 feet appears to be exposed, and it is not unlikely that the formation reaches that or even a greater thickness. In the southwest corner of the Rome quadrangle, Georgia, about 60 miles to the northeast, the thickness of the formation, according to Hayes,[c] is 700 feet.

Age.—A small collection of fossils was obtained northeast of Helena, on the continuation of the Rome belt south of this quadrangle, from which the following forms have been identified by C. D. Walcott:

Micromitra (Paterina) major.	Pædeumias transitans.
Micromitra (Paterina) williardi.	Wanneria halli.
Obolus smithi.	Agraulos?
Wimanella shelbyensis.	Hyolithes.

These are of Georgian (Lower Cambrian) age and substantiate the identification of the rocks here described with the Rome formation, known by its fauna in other regions to be mainly of Georgian age. As the fossils of the above list were obtained near the top of the formation, not far below the overlying Ketona dolomite member, it establishes the fact that all these shales are of the Lower Cambrian age and that there is no representative of the Middle Cambrian Conasauga ("Coosa")

[a] Hayes, C. W., Bull. Geol. Soc. America, vol. 2, 1891 (issued February 9), p. 143.

[b] Smith, E. A., Report on the Cahaba coal field, pt. 2, Alabama Geol. Survey, 1891 (issued in January), p. 148.

[c] Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey 1902.

formation in this part of the quadrangle, the Ketona (basal Knox) dolomite member being in unconformable contact with the Rome.

CONASAUGA ("COOSA") LIMESTONE.

Name.—The name Conasauga was introduced by Hayes[a] in February, 1891. It is taken from Conasauga River in northwestern Georgia, where the rocks to which it was applied outcrop over an extensive area. The name Coosa was introduced by Smith[b] in January, 1891, for the same rocks, from Coosa Valley, in the Gadsden region, where the rocks are widely exposed. For the reasons stated on page 2 in connection with the name of the Rome formation the name Conasauga limestone will be used in this folio in place of Coosa.

Character.—In the Birmingham quadrangle the Conasauga is made up mostly of rather thin bedded dark-gray amorphous limestone interbedded with more or less soft, fissile, and probably calcareous shale, which weathers to a gray or yellowish color. Some beds of the shale are decidedly yellowish green and very fissile. The limestone can be distinguished from the overlying Ketona dolomite member by the following characteristics: The limestone is thin bedded, generally dark gray, and nongranular and effervesces freely in cold dilute acid; the dolomite is thick bedded, light gray, and coarsely granular and does not effervesce when treated with cold acid. The character of the limestone is well shown in Plate IV on the illustration sheet. Many layers of the limestone are full of a branching form that may be of organic origin, and on the weathered surface of many beds occur thin, dark curving streaks one-half to 1 inch long that look like the edges or cross sections of thin shells, but no fossils appear when a piece of such limestone is broken, and the organic nature of the forms seen is therefore doubtful.

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.

At some points, especially in the vicinity of Bessemer and at old Jonesboro, thin layers of chert occur in the shale. These layers generally are not over half an inch thick. The chert is opalescent and waxy in appearance. It is dark within but rusty on the weathered surface. At the localities where this chert occurs a great many small prismatic pieces of it are likely to be scattered upon the surface. The interbedded chert and shale are well displayed on Twenty-fourth street in Bessemer, as shown in Plate I on the illustration sheet. From the almost continuous beds of limestone where the formation is best exposed in this region one would suppose 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. It is possible, however, that the proportion of limestone and shale may vary much along the strike and that there may be much more shale in some places than in others not far removed.

Distribution.—The Conasauga limestone underlies much of the width of Opossum Valley from Bessemer to Ketona, north of which it narrows until it disappears about a mile north of Greene. It outcrops extensively in Jones Valley, occupying a belt about a mile wide in the city of Birmingham and extending in a narrow belt as far north as Huffman. It also outcrops in Murphrees Valley, along a strip half a mile wide, extending from Remlap to the east edge of the quadrangle. It is so well exposed at many points in the areas described that it is hardly necessary to describe in detail localities where it can be seen.

The yellow-green fissile shale of the formation is well displayed on the Louisville and Nashville Railroad south of Swansea and also at the top of the formation along the wagon road three-fourths of a mile north of Swansea, on the west side of the valley. The gray and yellowish shale of the formation was seen at a number of places in the vicinity of Bessemer, about 10 miles southwest of Birmingham. There is also a good exposure of the shale, with limestone layers, on Fourteenth street, Birmingham, opposite the street-car barn. In the shale at this point minute trilobites of the genus *Agnostus* are abundant and these forms are commonly present in other localities.

The Conasauga is bounded on the west side of Opossum Valley by a fault, along which it has been thrust up into contact successively with all the younger rocks to the base of the Pottsville formation. There is some doubt, however, as to whether all the area mapped as Conasauga in Opossum Valley is really occupied by this formation. In a strip between the Southern Railway and the Opossum Valley fault, extending from North Birmingham to Pratt City, no exposures of the underlying rocks were found, and it is possible that the Rome formation may have been brought up to outcrop next to the fault along the west side of the strip. There being no positive evidence of the presence of the Rome, however, the whole area is mapped as Conasauga.

Thickness.—Calculated from the width of the outcrop and the angle of dip, with the assumption that there are no irregularities in structure to vitiate the result, the thickness of the Conasauga in Opossum Valley, between Thomas and North Birmingham, is certainly 1100 feet, and if the formation extends across the doubtful strip above described to the fault on the west and maintains the same dip its thickness is 1900 feet. These figures are comparable to those given by Hayes for the thickness of the Conasauga in northeastern Alabama—1600 to 2000 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. As the Conasauga appears to be absent from the section in Cahaba Valley, it must die out somewhere underneath the Cahaba coal field. Whether its absence is due to nondeposition or to erosion is unknown. The Conasauga limestone areas have been eroded to low, flat valleys locally known as Flatwoods.

Age.—The Acadian (Middle Cambrian) age of the Conasauga rocks is established by the fossils listed below, and it follows that this limestone is correctly identified with the Conasauga farther to the northeast, where the formation is predominantly a shale. With two exceptions the fossils were collected outside of the quadrangle, but on the continuation of the outcrop of the formation in Jones and Opossum valleys to the south. The determinations were made by C. D. Walcott.

Louisville and Nashville Railroad, about 1 mile north of Boyles station, near top of Conasauga:
- Crepicephalus sp.

Ketona, at west edge of quarry, top of Conasauga:
- Lingulella quadrilateralis.
- Ptychoparia sp.

Northwest of Bessemer, just east of highway bridge across Valley Creek, middle of Conasauga:
- Ptychoparia sp.
- Agnostus sp.
- Crepicephalus sp.
- Lingulella sp. undet.

Bessemer, upper third of Conasauga:
- Anomocare sp.
- Ptychoparia sp.
- Acrotreta sp.

One-half mile northeast of McCalla, middle of formation:
- Scenella sp.
- Agnostus sp.
- Ptychoparia sp.

Louisville and Nashville Railroad, 1 mile north of Woodstock, top of Conasauga:
- Lingulella buttsi.
- Lingulella desiderata.
- Dicellomus appalachia.
- Acrotreta kutorgai.
- Agnostus.
- Ptychoparia.

UNCONFORMITY AT THE TOP OF THE CONASAUGA.

In Birmingham Valley the Ketona dolomite, which is the basal member of the Knox dolomite, overlies without any observed discordance the Conasauga limestone, but in Cahaba Valley the Ketona rests upon the Rome formation, the Conasauga, which in northeastern Alabama normally occurs between the Rome and the Knox, being absent. There is thus an unconformity between the Knox and the Rome in the southeast corner of the quadrangle.

CAMBRO-ORDOVICIAN ROCKS.

The lower part of the Knox dolomite, with its basal member, the Ketona dolomite, is of Cambrian age and the upper part is of Ordovician age, but the line of division between these two parts has not been definitely determined in this quadrangle. However, it seems to be recognizable, in the Cahaba Valley in the vicinity of Pelham, south of this area, where a distinct series of limestone is intercalated between the Knox proper and the base of the Chickamauga. The formation is here treated as a unit under the general designation Cambro-Ordovician.

KNOX DOLOMITE.

The Knox dolomite and its equivalents, as embraced under other names, constitute the thickest formation, the most persistent in character over great areas, and the most widely extended geographically of all the formations of the Appalachian Valley. It is well developed at Knoxville, Tenn., a large part of that city being built upon the formation, and derives its name from typical exposures in Knox County, Tenn. The lower few hundred feet of the Knox has on account of its lithologic character been separated in this area as the Ketona dolomite member.

Character and thickness.—The Knox dolomite in this quadrangle is a thick-bedded prevailingly light-gray crystalline rock. So far as analyses show, the rock has nearly the composition of the mineral dolomite, the carbonate of magnesium ranging from 40 to 43 per cent and the carbonate of calcium averaging very nearly 56 per cent. The composition of mineral dolomite is carbonate of magnesium 45.6 per cent, and carbonate of calcium 54.4 per cent. So far as exposures of the formation in this region permit one to judge, it does not throughout its thickness differ from the samples analyzed, and it may fairly be assumed that its chemical composition is approximately uniform. Near Cahaba River, 25 miles south of Birmingham, however, beds of limestone of considerable thickness occur in the dolomite, and it may contain limestone in the Birmingham quadrangle.

The most distinctive characteristic of the Knox dolomite is its chert. This occurs in nodules and stringers included within the dolomite and in layers interbedded with the dolomite as if originally deposited in that form, though it is probably of secondary origin. Some of these chert beds are 10 feet or more thick and in places, on account of their resistant nature, project above the ground like dikes for considerable distances. The chert does not occur to any appreciable extent in the lower 500 or 600 feet of the formation, and this chert-free part has been separated as the Ketona dolomite member, to be subsequently described. On account of its resistance to solution and disintegration, in the course of general degradation great quantities of chert in the form of bowlders and smaller débris accumulate on the surface and in the soil and tend to give the impression that the underlying rocks are mostly chert, though in reality the chert may constitute but a small part of the rocks.

Two rather distinct types of chert are recognizable—a tough, dense, compact chert, even when weathered, characterizing the middle of the formation, and a chert which weathers to a soft, chalky or mealy state, commonly with drusy cavities and generally though sparingly fossiliferous, occurring in the part of the Knox overlying the portion carrying the dense chert. The soft type of chert was noted in this quadrangle only on the ridge just west of Chepultepec; elsewhere in the Birmingham Valley only the lower Knox carrying the dense chert occurs, the upper Knox having been eroded away. The soft chert is a persistent feature of the Knox in Cahaba Valley south of this quadrangle, where its stratigraphic position is the same as at Chepultepec. It has been traced to the south boundary of the Birmingham quadrangle in a recent survey and it probably is present in Cahaba Valley in this quadrangle, though it was not discriminated in the field. Probably the parts of the Knox distinguished by the two types of chert should be treated as separate members.

Microscopic examination shows that the chert is crystalline quartz. C. W. Washburne has made extensive studies of it and concludes that it was originally disseminated throughout the dolomite but subsequently segregated in its present form by solution and redeposition, replacing the dolomite mainly along the bedding planes, where the solvent waters could travel most easily. The original form of the silica, whether organic—as sponge spicules, radiolarian skeletons, or frustules of diatoms—or inorganic—as grains of sand, etc.—is unknown. Scattering grains of quartz sand are found in the chert, and possibly it was originally for the most part clastic quartz.

The chert is usually white but varies through shades of yellow and pink. A little oolitic chert occurs in places. The oolites are spherical or ovoid, the spherical being 0.6 to 0.7 millimeter in diameter and the ovoid 1.1 millimeter in the long and 0.6 millimeter in the short diameter. These granules have a thin outer shell of insoluble material filled with a more soluble opaline-appearing substance, the hollow shells remaining after the soluble substance has been removed.

If the dip is uniform and if, as appears to be the case, there is no repetition due to faults, the thickness of the Knox, as calculated from the dip and width of outcrop in Murphrees Valley, is 3300 feet.

Distribution.—The Knox dolomite is confined to Birmingham, Murphrees, and Cahaba valleys. The distribution of the formation within these valleys can be best understood by a study of the areal geology map. The structural conditions determining the distribution of the Knox as well as of other formations will be described in the section on geologic structure. The Knox has extensive areas of outcrop. Its areas are generally characterized topographically by low rounded hills and flat intervening valleys, as shown by Plate III on the illustration sheet. In Murphrees Valley the Knox makes a ridge thickly strewn with chert débris, which is known as Gravelly Ridge. In Birmingham the ridge known as Enon or Cemetery Ridge is formed by the upper cherty part of the Knox.

Ketona dolomite member.—As previously mentioned, the Ketona member includes the lower 400 to 600 feet of the Knox, which is nearly free from chert and in places contains less than 1 per cent of silica. The name is taken from Ketona, 5 miles north of Birmingham, where there is a large quarry in the rock. The dolomite is almost all thick bedded, light gray, and rather coarsely crystalline. The character of the bedding is shown in Plate II on the illustration sheet. Chemically this rock is nearly pure dolomite in the vicinity of Birmingham, as shown by the following averages of a number of analyses from Ketona and North Birmingham quarries:

Average analyses of Ketona dolomite member near Birmingham.

	1.	2.
SiO_2	1.31	0.70
Al_2O_3	.96	.638
$CaCO_3$	55.08	56.041
$MgCO_3$	42.47	43.091

1. Ketona quarry, average analyses for four months.
2. North Birmingham quarry, average of ten analyses of carload samples, aggregating 50 carloads and extending over a period of more than three years.

[a] Hayes, C. W., Bull. Geol. Soc. America, vol. 2, 1891, p. 134.
[b] Smith, E. A., Report on the Cahaba coal field, Alabama Geol. Survey, 1891, p. 148.

The Ketona outcrops in a belt at the base of the chert ridges of Birmingham Valley. It extends along Opossum Valley to Mount Pinson and along Murphrees Valley southward nearly to Village Springs. In Jones Valley the outcrop extends northward nearly to Chalkville. At the north end of Enon Ridge the belts in Opossum and Jones valleys are connected by a broad area of nearly flat-lying Ketona.

Economically the Ketona dolomite is important, for it supplies most of the flux used in the blast furnaces of the district.

Age.—The lower part of the Knox is regarded as of Upper Cambrian age and the upper part as Ordovician and equivalent in part to the Beekmantown of New York. The following statement concerning the fossils collected and their correlation is made by E. O. Ulrich:

Recognizable fossils are as a rule exceedingly rare in the Knox, and those found are almost without exception only silicified molds in the chert residue. Masses of the compound cryptozoon *C. proliferum*, a supposed gigantic calcareous alga, are seen occasionally and are believed to be fairly diagnostic of the lower and middle parts of the cherty Knox. The rounded masses of the simple cryptozoon *C. minnesotensis* seem to be confined to the upper half of the chert-bearing division. The other fossils consist chiefly of gastropods, with fewer cephalopods, trilobites, and brachiopods.

Somewhere about the middle of the cherty division one or several zones locally afford small faunules. No systematic search for these fossils has been made in the valley, yet in the course of the work of the Survey in the southern Appalachian region a considerable collection of this middle Knox fauna has accumulated. Some of this material was collected within this area at Chalkville and other places. A partial list comprises the following species:

Clarkella n. sp.
Ophileta n. sp. (cf. O. compacta).
Euconia? n. sp. (Resembles E. ramsayi (Billings).)
Sinuopea typicalis.
Gastropod of undescribed genus.
Dikellocephalus sp. undet.

These six species are the most diagnostic fossils of the beds between the Potosi and Proctor dolomites in Missouri; and the three gastropods are found in the corresponding lower to middle part of the Oneota dolomite of the Prairie du Chien group in the upper Mississippi Valley. Furthermore, two of the gastropods have been collected in the western part of the valley near Lexington, Va., while the *Ophileta* and the unnamed new genus and species are represented in the National Museum by a number of specimens from Beauharnois, near Montreal, Canada.

A much higher fossiliferous zone, distinguishable by the character of its chert, is locally developed in Alabama as described on page 3. It is well developed in the ridge passing west of the old town of Chepultepec and in the Cahaba Valley southeast of Birmingham. At both of these localities the Knox seems to be at least 1000 feet thicker than it is in the vicinity of Birmingham and in the two Knox areas east of Murphrees Valley. About 20 species of fossils have been collected from this zone near Chepultepec, where most of them were found within 200 or 300 feet of the top of the formation. The following list includes the more important forms:

? Archeocyathus.
Scenella n. sp.
Helicotoma uniangulatum (Hall).
Helicotoma n. sp. (last whorl disjoined).
Liospira? n. sp.? (cf. Pleurotomaria arabella Billings).
Liospira? n. sp. (cf. Pleurotomaria normani Billings).
Liospira? n. sp. (flat-spired, narrow-whorled).
Gen. et sp. nov. (resembles Murchisonia argylensis Sardeson).
Sinuopea turgida (Hall).
Sinuopea depressa.
Sinuopea sweeti (Whitf.).
Orthoceras? sp. (obliquely annulated, septa thin, siphuncle marginal, diameter under one-half inch).
Cameroceras sp. undet. (one-half to 1 inch in diameter, septa very thin).
Piloceras newton-winchelli?

Ten of these species occur in Missouri in the chert of the Gasconade formation, at least three in the upper part of the Little Falls dolomite at Little Falls, N. Y., and three others in the same formation near Whitehall, N. Y.

No Ordovician appears to be present in the Knox in Birmingham Valley and generally none of the upper beds that are shown at Chepultepec. In Cahaba Valley, however, Ordovician rocks probably constitute several hundred feet of the upper part of the Knox, but owing to the complete concealment of the strata they were not observed.

Unconformity at the top of the Knox.—There is a strong unconformity between the Knox and the next succeeding formation, showing that an erosion interval of considerable length intervened. The evidence for an unconformity is fairly abundant and quite conclusive. In the first place, on the surface of much of the Knox in Birmingham Valley rests a chert conglomerate, the Attalla conglomerate member of the Chickamauga limestone. There must have been a post-Knox land surface from which this conglomerate was derived, for its chert has in all probability come from the Knox itself. Moreover, this conglomerate rests at different places upon beds at different horizons in the Knox, from the basal Ketona up to the very top of the formation. This shows that the Knox must have been eroded locally down to and into the Ketona before the deposition of the conglomerate.

At some points in the quadrangle, notably near Chalkville and at the base of Foster Mountain, parts of the Chickamauga limestone lying at different horizons abut laterally against the Knox dolomite, as if the limestone were deposited in lagoons or old stream channels eroded into the Knox. At Chalkville a thin deposit of cherty limestone carrying many fossils of Black River age lies against a hill of the Knox, as shown in figure 3.

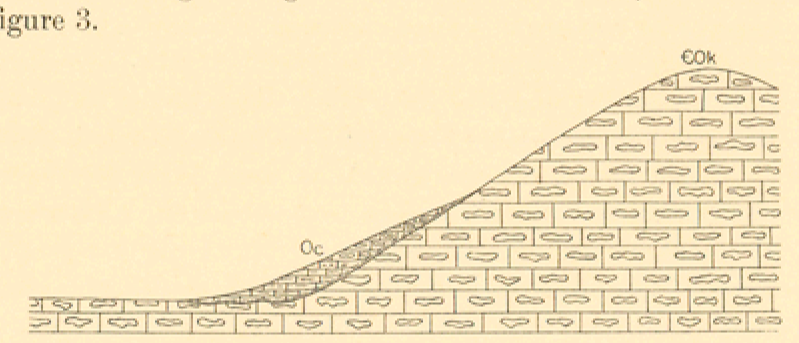


FIGURE 3.—Ideal section half a mile west of Chalkville.
Shows unconformable contact of Chickamauga limestone (Oc) with the underlying Knox dolomite (COk). Vertical scale twice the horizontal.

At the foot of Foster Mountain the basal Chickamauga, consisting of shale, conglomerate, and variegated limestone, lies against the Knox, as shown in figure 4. In this locality the

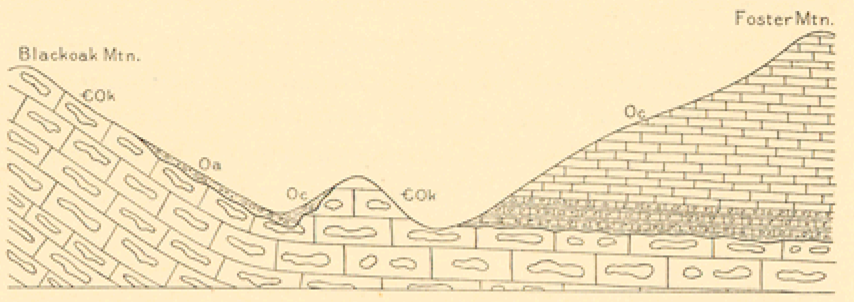


FIGURE 4.—Ideal section from Blackoak Mountain to Foster Mountain.
Shows unconformable contact of Chickamauga limestone (Oc) and its basal Attalla conglomerate member (Oa) with the underlying Knox dolomite (COk). Vertical scale twice the horizontal.

basal Chickamauga was clearly deposited in an old erosion channel between Knox walls as the transgressing waters gradually submerged the old land surface. Variegated limestone deposited under such circumstances has been observed elsewhere. Additional evidence of the unconformity is found in the fact that at a few points Clinton rocks bearing iron ore rest upon the Knox dolomite or are separated from it by only a thin deposit of the Chickamauga. An outlier half a mile west of Morrow Gap and several patches of Clinton rocks on Flint Ridge, north of Bessemer and south of this quadrangle, are cases in point.

ORDOVICIAN SYSTEM.

The Ordovician system is represented in this area by the Chickamauga ("Pelham") limestone (including the basal Attalla conglomerate, or breccia, as it is often called, mentioned under the preceding heading) and in Cahaba Valley by the upper portion of the Knox, equivalent in part to the Beekmantown limestone of the New York section, as described under the heading "Cambro-Ordovician rocks." At the base of the Clinton formation, at certain points on Red Mountain east of Birmingham and farther south, lie a few feet of rocks carrying an Eden fauna of upper Ordovician age. These rocks are too thin and too irregularly distributed to map on the scale here used and on this account are included with the Clinton. With this exception, however, there are no representatives of the Utica and Lorraine formations, which constitute the upper part of the Ordovician column in New York, nor of the partly corresponding Athens and Sevier shales of Tennessee. Locally, too, as will be pointed out later, the typical Trenton is unrepresented.

CHICKAMAUGA ("PELHAM") LIMESTONE.

Name.—The Chickamauga limestone was first so termed by C. W. Hayes in 1891, the name being taken from Chickamauga Creek, in northwestern Georgia, along which the limestone is typically developed. In 1891 also E. A. Smith used the name Pelham, from Pelham, Ala., for the same limestone. As the name Chickamauga has been used in a great many publications of the United States Geological Survey relating to the southern Appalachian region, it will, in order to avoid confusion in the Survey publications, be retained here, although the name "Pelham" may be locally as appropriate.

Unconformable deposition.—As already noted, in the Birmingham Valley the Chickamauga limestone, including locally a greater or less thickness of the Attalla conglomerate member at the base, was deposited upon the eroded surface of the Knox dolomite. In places—for example, Hendrick Mill, northwest of Swansea—the Chickamauga rests directly upon the Knox and the basal 40 feet of the limestone contains scattering fragments of angular or partly rounded chert, indicating that somewhere an area of Knox was still subject to erosion while at this point the Knox had been submerged and was being buried by Chickamauga sediments. The old Knox surface, upon which the Attalla conglomerate and the other basal Chickamauga beds, whether shale or limestone, were deposited, was an uneven surface, with valleys and, where close to the shore, inlets separated by land of greater or less elevation. Indeed, the old surface may have been similar to that existing to-day, with its valleys, hills, and ridges, though probably there were no such extremes of relief. If the present surface were to be gradually submerged, it is easy to understand that the water would first occupy the valleys, in which coarse débris of angular chert and fine sand would be deposited by the streams as they ran down from the land. This débris would be ultimately cemented to form a conglomerate, upon which would sooner or later be deposited finer sediment, and if animal forms found the shallow water favorable to their existence they would multiply and supply an abundance of limy sediment, to make limestone at a later period. It would also follow from such conditions that the beds in contact with the old surface would differ considerably in age at different points. In short, the result would be similar to that shown in this region, where the beds of the limestone in contact with the Knox range from the basal member of the Chickamauga, as at Foster Mountain, to those at Chalkville which contain Black River fossils and which occur near the top of the Chickamauga.

Attalla conglomerate member.—To the conglomerate or breccia unconformably overlying the Knox in Birmingham Valley the name Attalla is here applied, from the town of that name in northeastern Alabama, in the vicinity of which it is well developed. The Attalla conglomerate member ranges from a medium-grained sandstone to a coarse conglomerate. In general it is composed mostly of rather small angular fragments of chert embedded in a siliceous matrix composed of comminuted chert or quartz. In many places well-rounded quartzite pebbles are present in varying numbers. Perfectly rounded pebbles of quartzite 4 or 5 inches in diameter have been found embedded in great masses of the conglomerate composed almost wholly of fine sand and small angular chert fragments. As a rule the quartzite pebbles are $1\frac{1}{2}$ inches in diameter or less. At one locality there is a small area of medium-coarse sandstone composed entirely of quartz grains. The thickness of the Attalla conglomerate varies considerably, but in general there is nothing to indicate that it is more than 20 to 40 feet.

The conglomerate appears to rest upon the eroded edges of all the upturned beds of the Knox dolomite, from the top to the bottom. Some of the sandstone knolls south of Birmingham may even rest upon the Conasauga. It passes beneath the Chickamauga limestone, but nowhere, so far as known, is the conglomerate overlain by rocks older than Chickamauga. It is therefore older than the rest of the Chickamauga, which it underlies, and younger than the Knox, from which it has evidently been derived. It is possible also that some of the conglomerate is the result of cementation of comparatively recent stream gravels, such as can be seen loose in the small streams running down from the Knox uplands and depositing their loads of angular chert and fine sand wherever the velocity of the streams is checked by a lessening of the grade of their beds. The conglomerate is just the kind of rock that would be formed by the cementation of such chert gravels.

This conglomerate is very patchy in its distribution, occurring as isolated areas of small extent, a number of which are mapped, though probably not all. It can be seen at several points on Cemetery Ridge in Birmingham, also at the base of Red Mountain, west of South Highlands, where it has been exposed in grading a street. The sandstone phase can be seen near West End, a little south of this quadrangle, where it makes a conspicuous little knoll about 500 feet southeast of the Alabama Great Southern Railroad. The best exposures of the conglomerate, however, are on the headwaters of Fivemile Creek, where it cuts through the chert ridge between Jones and Opossum valleys, and along the east side of the highway from Eastlake to Clay. West of Clay it passes under the shale in the lower part of the Chickamauga limestone in Foster Mountain.

Character of the Chickamauga.—In Birmingham Valley the Chickamauga is generally a rather light-gray, dove, or pale-blue limestone. Granular and amorphous layers of varying thickness alternate throughout. In general the thickness of the layers ranges from 2 feet to a few inches. Near the base of the formation on the west side of Murphrees Valley are thick layers of buff rock that works well and is well suited for masonry. At the south end of Blount Mountain the basal 50 feet is composed of alternating layers of shale and limestone, the latter being more or less impure, containing chert fragments and much siliceous matter. Some of these shale and limestone beds are purple or streaked or mottled with purple. This purple mottling at the base appears also in the vicinity of McCalla, southwest of the quadrangle, and on the North Bessemer electric-car track at Interurban Heights, where both purple shale and purple-mottled limestone occur.

The following detailed section, measured on the west side of Foster Mountain, illustrates the character of the formation:

Section of Chickamauga limestone on Foster Mountain.

	Feet.
Top of Foster Mountain.	
27. Gray granular limestone, rather thick bedded, weathering to thin layers, fossiliferous	45
26. Dove-colored amorphous limestone, with *Tetradium cellulosum; Beatricea* at base	60
25. Dove-colored amorphous limestone	20
24. Gray granular limestone, with *Beatricea*	5
23. Concealed	20
22. Rather thick-bedded gray granular limestone; weathers to 1-inch layers; fossils plentiful, *Girvanella* and *Dystactyospongia*	80
21. Concealed	20
20. Bluish splintery limestone	5
19. Concealed; débris of green and bluish limestone, with numerous brachiopods	25

	Feet.
18. Bluish rather thick bedded granular limestone; some chert nodules	5
17 Concealed	15
16. Bluish to grayish limestone; gastropods	5
15. Concealed; débris of bluish and dove-colored limestone	35
14. Thick-bedded gray limestone	20
13. Concealed	15
12. Gray and bluish, rather thick bedded limestone, with gastropods, *Lophospira*	35
11. Buff impure limestone, thick bedded, sandy layers; *Scolithus* at bottom	10
10. Thick-bedded limestone, with variegated layers, pink and buff, with pebbly conglomerate in places	5
9. Shale with thin layers of earthy limestone that show as plates of nodules	5
8. Buff siliceous limestone, with *Lingula*	1
7. Shale with nodular limestone layers like No. 9; fossiliferous	5
6. Buff earthy limestone, siliceous, with pebbles of chert	1
5. Pink clay	1
4. Yellowish sandy shale, with *Lingula*	5
3. Calcareous sandstone, with chert inclusions and *Lingula*	2
2. Pink clay	1
1. Sandy and calcareous red, yellow, and gray shale	4
Knox dolomite.	
	450

The section at this locality is probably complete and may be regarded as typical for Birmingham Valley. The rocks are nearly flat and afford a good opportunity for measurement.

No good exposures of the lower part of the Chickamauga occur in the portion of Cahaba Valley lying in this quadrangle, but on Buck Creek, 10 miles to the south, between Helena and Pelham, the lower beds are well exposed. Here the formation is over 1000 feet in thickness, the lower 800 feet of which consists of nearly pure limestone. An analysis of it at Leeds shows about 92 per cent carbonate of lime, with smaller amounts of magnesium carbonate, silica, and alumina. Mr. Ulrich says:

> The upper 100 to 200 feet of the formation in Cahaba Valley consists of cobbly-weathering, more or less argillaceous limestone containing fossils of Black River age but of altogether different kinds from those found in Birmingham Valley.

The clayey material is so distributed that it appears on weathered surfaces of the rock as a network of drab earthy bands inclosing patches of the purer blue limestone. This is a highly characteristic feature of the top beds of the Chickamauga in Cahaba Valley. It is somewhat fossiliferous, the large *Maclurea magna*, some specimens of which are 6 inches across, being of common occurrence on the weathered faces of the beds.

Thickness.—As shown in the section above, the limestone at Foster Mountain is 450 feet thick. The same thickness appears in Butler Mountain, just north of Foster Mountain, where the very summit carries loose sandstone of probable Clinton or Eden age, so that there can be little doubt that the full thickness of the Chickamauga is present. The thickness as computed from the width of outcrop and the angle of dip on Blackburn Fork of Little Warrior River and at the Dale Gap is 425 and 430 feet, respectively. The full thickness of the Chickamauga in Birmingham Valley, therefore, may be placed at about 450 feet. As the limestone was deposited on an uneven surface, however, the lower part is probably absent over considerable areas and the thickness is correspondingly less. At the Gate City quarry the thickness appears not to exceed 360 feet, and it is probable that at some points it is not over 200 feet. In Cahaba Valley, as stated, the formation attains much greater thickness, the maximum probably being not less than 1100 or 1200 feet.

Distribution.—The distribution of the Chickamauga areas is shown on the map. In general the formation appears at the base of Red Mountain and West Red Mountain, but it is absent from some strips along these ridges. Thus it does not outcrop along the west side of Opossum Valley from a point 2 miles north of Tarrant Gap to the south margin of the quadrangle. It is also absent along the west side of Blount Mountain from Village Springs to the east margin of the quadrangle. In these strips it is concealed by the Conasauga limestone, which has been thrust over it along a fault. The limestone appears to be lacking on the west side of Red Mountain from Clay nearly to Ayres. Its absence here may be due to nondeposition instead of to a fault. The formation also appears in the fault block to the south of Henryellen. Cahaba Valley is eroded in the limestone, the outcrop of which is practically coterminous with the valley.

The best exposures of the Chickamauga limestone are about the south end of Blount Mountain, where the conspicuous knobs known as Foster, Butler, Praytor, Hayes, and Bear mountains are eroded out of its rocks. It is almost fully exposed along Blackburn Fork where that stream cuts through Red Mountain, northwest of Swansea.

Age.—It has long been known that the Chickamauga limestone is the time equivalent of the Chazy and Mohawkian (including Lowville, Black River, and Trenton) limestones of New York. The following details of correlation are based upon the views of E. O. Ulrich. The lower half or even more of the full Chickamauga section is the equivalent of the Stones River of middle Tennessee, which in turn represents the greater part of the Chazy limestone of New York. Indeed, the same faunal succession can be recognized in the Foster Mountain section as in the Tennessee Stones River, though the lithologic differences on which the subdivisions in Tennessee are based can probably not be made out so clearly in Alabama. The Lowville limestone, which overlies the Chazy in New York, is represented in Alabama also, as indicated by its characteristic fossil, *Tetradium cellulosum*. It is Nos. 24 to 26 of the Foster Mountain section (p. 4). The 45 feet of granular limestone forming the top of Foster Mountain represents the Trenton limestone of New York, the upper part of the Black River limestone and the lower Trenton being unrepresented. This 45 feet, plus 85 feet of the Foster Mountain section, which is correlated with the Lowville, constitutes all of the Chickamauga that is referable to the Mohawkian of the New York section. All below No. 24 of the section (p. 4) is to be regarded as of Stones River age. In some sections, as at Gate City, only beds of Stones River age appear to be present, as some of the fossils collected within 20 feet of the top of the limestone in the quarry appear to be characteristic of beds older than the Lowville and near the top of the Stones River in Tennessee. In Cahaba Valley probably all the limestone west of Leeds is of Stones River age, as the characteristic Chazy *Maclurea magna* occurs in the beds outcropping in the town. The top of the limestone at Leeds appears to be about the horizon of the upper Black River. If the lower Black River or the Lowville is represented, its representative lies somewhere between Leeds and the eastern margin of the limestone.

Unconformity at the top of the Chickamauga.—As already noted (p. 4), the top of the Chickamauga does not at all points lie at the same geologic horizon. Thus at the south end of Blount Mountain the top of the limestone is as young as middle Trenton, but at Gate City the top reaches up only about to the top of the Stones River horizon, the Lowville, Black River, and Trenton horizons being unrepresented. The top of the Chickamauga in Cahaba Valley also lies near the horizon of the upper part of the Black River limestone. It has been stated that in the Red Mountain section, just east of Birmingham, a thin stratum of sandstone of Eden age is present.

It thus appears that, with the exception of a thin stratum of sandstone of Eden age in the Red Mountain section referred to under the description of the next overlying (Clinton) formation, a great stratigraphically unrecorded time interval separates the top of the Chickamauga limestone in this area from the Clinton formation. In other words, the section in the vicinity of Birmingham does not contain, with the exception of a few feet of sandstone of Eden age, any deposits corresponding in age to the Trenton limestone and overlying formations to and including the Medina sandstone, aggregating as a maximum in New York and Pennsylvania between 2500 and 3600 feet of strata. In Cahaba Valley, moreover, this part of the general section lacks, besides the beds absent in Birmingham Valley, the whole of the Clinton and later Niagara formations and the formations representing the Cayuga and Helderberg of New York and Pennsylvania—that is, all of the Ordovician rocks of New York above the Black River limestone, the entire Silurian system, and the Lower Devonian beds of the New York section are unrepresented in Cahaba Valley, the Chickamauga being here succeeded directly by a few feet of Devonian sandstone of Oriskany age. In passing northeastward through Tennessee and Virginia the sections become more complete and the unrepresented formations appear and expand. This subject will receive further treatment in the section on historical geology (pp. 12–13).

SILURIAN SYSTEM.

The Silurian system is represented in this quadrangle only by the Clinton ("Rockwood") formation.

CLINTON ("ROCKWOOD") FORMATION.

Name.—The Clinton formation takes its name from the town of Clinton, Madison County, N. Y., where its iron ore has been mined for many years. The name "Rockwood" was used by the United States Geological Survey for the iron-bearing beds of the southern Appalachian region when it had not been definitely established that they were the equivalent of the New York Clinton. Recent study of the fossils from the Alabama region has, however, shown that the "Rockwood" and Clinton can be correlated with sufficient closeness to warrant the extension to that region of the more widely known name Clinton.

Character.—The Clinton formation consists mostly of shale and sandstone, with beds of iron ore which are more or less calcareous or sandy. There is great variation in the lithologic character of the formation from place to place, as shown by the sections in figure 5. The sandstone of the formation is largely greenish or brown. Some of it is very fine grained and evenly bedded, some carries fine quartz pebbles, and in places there are highly ferruginous beds. The character of the sandstone is shown in Plate V, on the illustration sheet, a reproduction of a photograph taken at Graces Gap, on Red Mountain, several miles south of the quadrangle.

The shale in the formation is mainly a soft clay shale of a gray, greenish, or in places very characteristic greenish-yellow color.

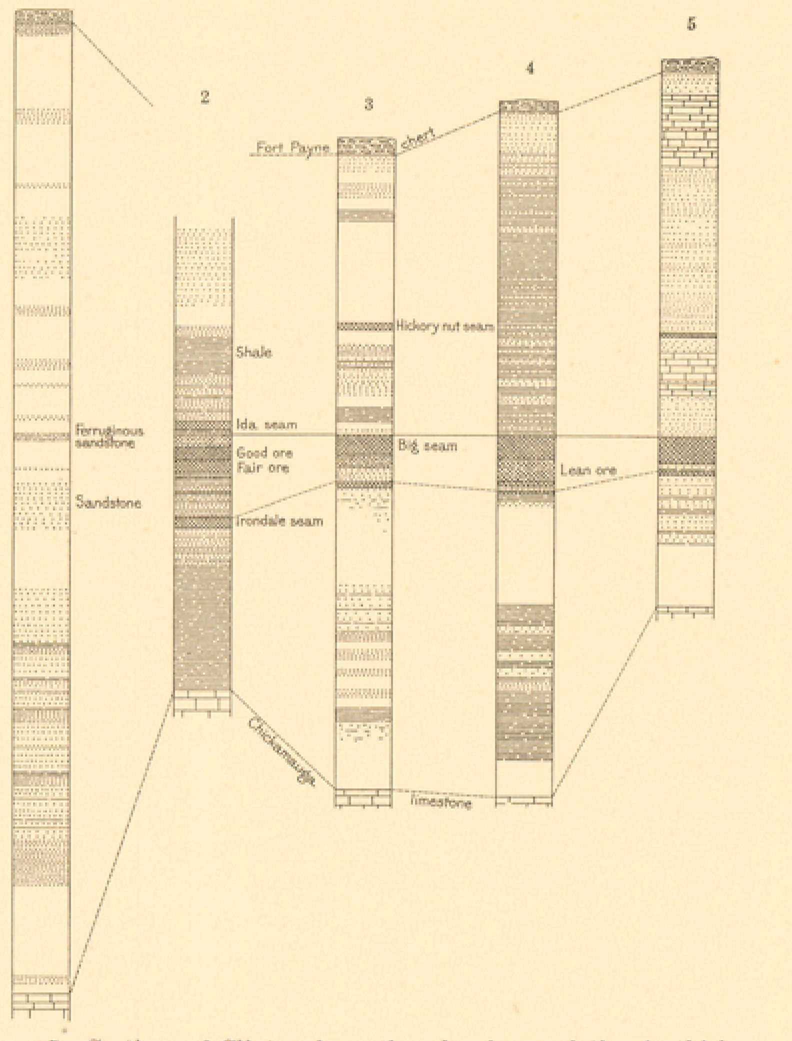


FIGURE 5.—Sections of Clinton formation showing variation in thickness and character of the rocks.

1. Cunningham Gap in West Red Mountain.
2. Half a mile northwest of Irondale.
3 Half a mile southwest of Lakeview, on road across Red Mountain.
4. Walker Gap in Red Mountain, south of Birmingham quadrangle.
5. Shades Valley, half a mile east of Bessemer, south of Birmingham quadrangle.

Scale, 1 inch = 100 feet.

Locally as much as 35 feet of shaly sandstone, containing fossils which, according to Ulrich, are characteristic of the arenaceous upper part of the Eden shale in Ohio and Kentucky, is found between the Clinton and the top of the Chickamauga. As this intervening bed could not be mapped separately, it is provisionally included with the Clinton. It is well shown on Red Mountain near Birmingham on the Louisville and Nashville Railroad just south of Lone Pine Gap.

Iron ore.—The Clinton carries ore throughout the quadrangle, but the beds that are profitable to work under present conditions are, so far as known, confined to West Red Mountain north of Village Springs and to Red Mountain from Morrow Gap southward beyond the quadrangle to a point a few miles south of Bessemer. In the former locality is a single thin bed and in the latter are two workable beds, the Big seam above and the Irondale seam 20 feet below, as shown in section 2, figure 5, and in Plate VI, on the illustration sheet. The presence of good ore in the fault block south of Henryellen, as just mentioned, indicates its extension beneath the full width of the Cahaba trough in this latitude.

Although the four seams shown in the sections along Red Mountain are supposed to be continuous beds whose distances apart differ at different points, yet with the exception of the Big seam and the Irondale seam from Morrow Gap to the south margin of the quadrangle they may be local overlapping lenses. Throughout the remaining areas of the Clinton one to three beds, 18 inches to 6 feet thick, of mostly low-grade ore are present. Whether these beds are persistent and can be correlated from point to point or whether they are local overlapping lenses can not be satisfactorily determined.

The ore beds vary in number, thickness, and position in the different sections, as shown in figure 5. On the weathered outcrop the ore beds are sandy and noncalcareous, but mine workings show that below the zone of active weathering they are highly calcareous, the lime carbonate amounting to nearly or quite 20 per cent in places. Some of the layers of ferruginous sandstone mentioned above are rich enough in metallic iron to be regarded as an ore, but as they have never been followed underground it is not known whether they are also calcareous. The unweathered ore varies in content of metallic iron from 40 per cent down, only that running above 35 per cent being regarded as workable at present.

The rocks of the formation are fossiliferous and the calcium carbonate of the ore beds is derived from fossil shells, many of which have been replaced by iron or have left their impressions in the ferruginous ooze in which they were entombed. The "red fossil" ore is made up in this way. (See Pl. VIII, illustration sheet.) Small flattened grains occur throughout the ore beds, as shown in Pl. XI. These are oolitic in structure and origin, consisting of concentric layers of ferric oxide around sand grains as a nucleus. Beds of wholly oolitic ore, such as occur in New York, do not appear to be present in Alabama.[a]

[a] For a fuller description of the Clinton ores see Bull. U. S. Geol. Survey No. 400, 1910.

Thickness.—The Clinton varies considerably in thickness, as shown by the sections of figure 5. The least thickness shown is 246 feet and the greatest 500 feet at Cunningham Gap through West Red Mountain. The variation shown by the sections is probably due in part to errors of measurement, as it is difficult to obtain exact measurements of moderately dipping strata which are only partly exposed, the top and bottom of which can not be determined exactly, and which may vary more or less in dip from point to point across their outcrops. But even after allowing for possible errors of measurement there still remains a considerable variation in the actual thickness of the formation.

Distribution.—The Clinton formation makes the conspicuous ridges of Red Mountain and West Red Mountain, the former terminating on the northeast in Cahaba Mountain. It apparently outcrops on all sides of the part of Blount Mountain included in this quadrangle, though it is more or less concealed along the western base, on the east side of Murphrees Valley. It has been shown on the State geologic map as outcropping in a number of discontinuous areas along this strip, but the writer, who has followed the outcrop pretty closely, is inclined to believe it present all along, though as it is adjacent to a fault of great throw it may be faulted out in places where it does not show. The formation appears to be faulted out for a mile just north of Tarrant Gap and along two other strips between Tarrant Gap and Thomas. At Thomas and just southwest of Pratt City are two little areas of Clinton that occur in comparatively small wedgelike blocks along the fault between the coal measures and the Cambrian limestone on the east, as shown in figure 8 (p. 11). A strip of Clinton carrying good ore also occurs in a large fault block south of Henryellen, on the west side of Cahaba Valley. The top of the Clinton is exposed at Blount Springs over a very small area on the arch of the Sequatchie anticline. The geologic map of Alabama published by the State Survey shows a strip of Clinton along Oak Ridge south of Leeds. The writer, however, could find no Clinton in that locality and has shown none on the map. In this quadrangle the formation is believed to be absent east of the fault to the east of the Cahaba coal field.

Age.—As now known the Clinton formation at Clinton, N. Y., the type locality, represents not only the beds previously assigned to the Clinton in the Genesee Valley, but also the overlying Rochester shale. From a study of the fossils collected in the Birmingham quadrangle E. O. Ulrich concludes that at least the upper half of the formation in West Red Mountain on the west side of Birmingham Valley and nearly the whole thickness in Red Mountain proper represents the upper part of the Clinton as shown at its type locality and approximately the Rochester shale of western New York. Possibly the lower part of the formation in West Red Mountain, where it is thicker than elsewhere, and also patches at the base in Red Mountain are of lower Clinton age. Apparently the formation was deposited in a transgressing sea, which spread over the western part of the area before it reached the eastern side. Consequently the lower Clinton strata on the western side of the quadrangle are the oldest, and eastward successively younger beds are in contact with the eroded pre-Clinton surface, those in Red Mountain being mostly of Rochester age. This supposition is corroborated by the fact that the Clinton formation is absent from the region east of Cahaba Valley, which indicates that the transgressing water never reached so far east.

UNCONFORMITY AT THE TOP OF THE CLINTON.

In Alabama the oldest formation present above the Clinton is the Frog Mountain sandstone of Oriskany age. In New York, Pennsylvania, and Canada there intervenes between the Clinton and the Oriskany, as a maximum, approximately 2500 feet of rocks belonging to Niagaran, Cayugan, and Helderbergian time. Hence during the interval required for the accumulation of 2500 feet of rocks, mainly limestone, in the New York-Pennsylvania region no sediments were deposited in this part of Alabama, or if any were deposited they were eroded away before the deposition of the Frog Mountain. As already stated, the Clinton formation is not present in the Cahaba Valley, the Frog Mountain sandstone resting there upon the Chickamauga, so that not only the whole Silurian system but also the Upper Ordovician and Lower Devonian are lacking. In other words, in the southeast corner of the quadrangle there are no rocks to represent the time necessary for the deposition of about 6000 feet of rocks elsewhere.

DEVONIAN SYSTEM.

The Devonian system is represented in this part of Alabama by the Frog Mountain sandstone and the Chattanooga shale. The black shale is well known and has always been recognized as Devonian, but sandstone of this period has not hitherto been recognized in this part of the State. In Cherokee County, however, Hayes has observed the Frog Mountain sandstone, 800 to 1200 feet thick, which carries a few poorly preserved fossils of Oriskany age. In the vicinity of Rome, Ga., is a formation of chert and sandstone 50 feet thick, known as the Armuchee chert,[a] that carries fossils of Oriskany age and is believed to be contemporaneous with the Frog Mountain sandstone. It is believed that the sandstone here described is the same as the Frog Mountain, so that name is applied to it.

FROG MOUNTAIN SANDSTONE.

Character and distribution.—As developed in this quadrangle the Frog Mountain sandstone is a rather coarse quartz sandstone or quartzite. In places small quartz pebbles occur in it and here and there, as north of Trussville, it contains abundant small phosphatic nodules. Its thickness ranges from 4 to 20 feet. In some places the black shale is underlain by 10 feet or less of coarse sandstone, in which no fossils have been found but which may be and very probably is the Frog Mountain. Plate VII on the illustration sheet shows this sandstone with the thin streak of black shale and the succeeding Fort Payne chert above and the Clinton formation below, apparently in unconformable contact. A similar section is exposed in Graces Gap, several miles to the southwest, in the Bessemer quadrangle. The best development of this sandstone occurs along Oak and Mill ridges east of Leeds. Here it is 10 to 20 feet thick, and it is persistent along this strip within the limits of the quadrangle.

The following sections show its relations, character, and thickness:

Section of Devonian rocks in cut of Southern Railway one-half mile east of Leeds.

		Feet.
Chert (Fort Payne).		
Shale, purple (Chattanooga)		2
Sandstone, hard, brown, pebbly	Frog Mountain sandstone	2
Sandstone, soft, green		2
Sandstone, brown, cherty		5
Chalky rock, with fossils (thin)		
Sandstone, brown, cherty		1+
Concealed		10 ?
Limestone (Chickamauga).		
		22

Section of Devonian and overlying rocks in NE. ¼ sec. 1, T. 18 S., R. 1 W., about 4 miles southwest of Leeds.

		Feet.
Shale, soft, black (Floyd).		
Chert (Fort Payne)		90
Concealed (Chattanooga shale?)		4
Sandstone, quartzitic, with pebbles	Frog Mountain sandstone	10
Concealed, probably sandstone		10
Limestone (Chickamauga).		

Much of the sandstone along this strip weathers to a brownish or pale-yellowish color and a more or less porous or chalky texture.

As indicated in the foregoing description, the known occurrences of the Frog Mountain sandstone in this area are in the synclinal area north of Trussville, on Cahaba River in the SW. ¼ sec. 6, T. 16 S., R. 1 E., along Red Mountain southward from Birmingham, and along Oak Ridge across the southeast corner of the quadrangle.

Age.—Fossils have been found in this sandstone at a number of points and determined by E. M. Kindle. Lists and localities are given below.

At Clear Branch Gap, a gap through Red Mountain 5 miles southwest of Bessemer, about 15 miles southwest of the Birmingham quadrangle, the following collection was obtained from about 6 inches of quartzitic sandstone, separated from the Fort Payne chert by about 1 foot of dark and green clay shale and underlain by 10 feet of sandstone, supposed to be Clinton but possibly Frog Mountain:

Hipparionix proximus.
Spirifer tribulus.
Anoplotheca flabellites.
Eatonia peculiaris.
Meristella cf. lata.

On 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 following collection was made:

Stropheodonta sp. undet.
Leptostrophia sp. undet.
Leptostrophia cf. oriskania.
Anoplia nucleata.
Spirifer cf. submucronatus.
Spirifer sp. undet.
Anoplotheca flabellites.
Beyrichia sp. undet.

The material here is a soft white chalky rock, probably decomposed chert, and was mistaken in the field for the Fort Payne, which outcrops at the same point continuously with the Devonian bed, so that the Devonian was not differentiated and therefore its thickness was not determined.

On the outcrop of the Frog Mountain on Oak Ridge, half a mile east of Leeds, the fossils given in the following list were collected.

Zaphites sp. undet.
Chonetes mucronatus.
Spirifer sp. undet.
Beyrichia sp. undet.

Besides these forms, fish remains occur rather commonly in the sandstone 4 miles southwest of Leeds, also in the sandstone north of Trussville.

[a] Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

The first collection listed above is a distinctly characteristic Oriskany fauna. The species of the other collections occur in both the Oriskany and the Onondaga limestone. It is believed, however, that the rocks from which they were obtained are more probably to be regarded as of Oriskany age.

CHATTANOOGA SHALE.

Character and distribution.—The Chattanooga shale overlies the Frog Mountain sandstone or, where that is absent, the Clinton formation. It 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 weathered down to a clay, as it is on some outcrops, especially where it is thin. In a ravine at the base of Blount Mountain, 1½ miles northeast of Remlap, there is a clean exposure of 10 feet of densely black shale, locally called carbon. It is immediately below the Fort Payne chert and is underlain by 20 feet of thick-bedded sandstone. In Dale Gap the following section was obtained:

Section in Dale Gap.

	Feet.
Chert (Fort Payne)	140
Concealed (probably shale)	10
Sandstone, brown	3
Sandstone, shaly	1
Sandstone, pink, fine grained	1
Shale, cherty, ferruginous, green	1
Shale, black, reddish, and lavender bands, 1-inch sandstone layer, bottom 14 inches ferruginous (Chattanooga)	8
Sandstone, green, very fine grained (Clinton?)	170

The Chattanooga shale is perfectly concordant in bedding with the underlying sandstone and the overlying chert. It is a question whether the 16 feet of rocks between the black shale and the chert are Devonian or Carboniferous, as no fossils could be found to determine their age.

At Blount Springs, on the Sequatchie anticline, the Chattanooga is about 20 feet thick and carries a layer of fine-grained sandstone in the middle. At Lone Pine Gap on Red Mountain, just east of Birmingham, the Chattanooga consists of about 4 inches of green clay above and 12 inches of black clay below. (See Pl. VII.) Similar beds represent the shale throughout the southern part of the quadrangle. The Chattanooga, though thin, is persistent, appearing wherever its horizon is exposed.

Age.—The 20 feet or so of Frog Mountain sandstone and Chattanooga shale are the sole representatives in this region of the whole Devonian system, which is some 7000 feet thick in central Pennsylvania. Just what part of the Devonian is represented by the Chattanooga shale is a mooted question. The writer is inclined to correlate it with the Middle Devonian, and some observers place it near the top of the Devonian.

UNCONFORMITY AT THE TOP OF THE CHATTANOOGA SHALE.

If the Chattanooga shale is of Hamilton age and represents perhaps only a part of the Hamilton formation farther north, it is evident that there are no rocks in Alabama corresponding to most of the Hamilton and to the Portage, Chemung, and Catskill formations of the northern Appalachian region. Furthermore, a study of the fossils collected in Alabama during the present survey has led to the conclusion that the basal Mississippian rocks corresponding to the Kinderhook are probably absent. If these conclusions are correct, there is a stratigraphic gap in this part of the Alabama Paleozoic section of at least 6000 feet. In other words, there are here no rocks equivalent to the Portage, Chemung, and Catskill formations, aggregating 6000 feet in central Pennsylvania. On the other hand, if the Chattanooga is latest Devonian, then the unconformity at its top is of relatively minor importance and that between its base and the top of the Frog Mountain sandstone is of great time value.

CARBONIFEROUS SYSTEM.

The rocks of the Carboniferous system are divided into two series—the Mississippian (lower Carboniferous) below and the Pennsylvanian (upper Carboniferous or "Coal Measures") above. These names are taken from Pennsylvania and the Mississippi Valley, the regions in which the two series are typically developed. In this quadrangle the Mississippian series includes the Fort Payne chert, the Bangor limestone, Pennington shale, Floyd shale, and the Parkwood formation; and the Pennsylvanian series includes only a part of the basal formation or group of the series as developed in the type locality. These basal Pennsylvanian rocks of the Birmingham quadrangle constitute the Pottsville formation, the name being taken from Pottsville, Pa., in the anthracite coal field, the rocks of which are approximately equivalent to those of the Alabama coal fields.

MISSISSIPPIAN SERIES.

GENERAL STATEMENT.

Overlying the Devonian black shale unconformably are rocks of Mississippian (lower Carboniferous) age. The basal Mississippian rocks throughout the region are those of the Fort Payne chert. This formation is succeeded in Brown and Murphrees valleys by the Bangor limestone, with its included Hartselle sandstone member, and the Bangor in turn by the Pennington shale. At the south end and along the east side of Blount Mountain and on the east side of Shades Valley the Pennington shale is overlain by the Parkwood formation, which is absent from the section west of Birmingham Valley. The Bangor limestone passes laterally into shale south of Boyles Gap in Opossum Valley and south of Oxmoor in Shades Valley, a few miles south of this area. South of Boyles Gap and Oxmoor, therefore, the Mississippian rocks above the Fort Payne chert consist of the Floyd shale, including the Hartselle sandstone member, and the Parkwood formation, which overlies the Floyd. The Floyd shale is the equivalent of the Bangor limestone and Pennington shale. In reports of the Alabama Geological Survey[a] the Floyd shale and the Parkwood formation have been treated together as the "Oxmoor or shale and sandstone phase" of the upper part of the lower Carboniferous rocks, and the Bangor limestone has been called the "Bangor or limestone phase" of the same rocks, the two phases being regarded as contemporaneous. The writer's study of the geology of the region has led him to the conclusion that only the Floyd shale and the rocks included by the Alabama Survey in the Bangor limestone are contemporaneous. The Parkwood formation of Shades Valley and Blount Mountain is absent from the section in Murphrees and Brown valleys, having been eroded west of Birmingham Valley before the deposition of the coal measures (Pottsville formation), so that they rest unconformably on the Pennington shale.

The variations in the stratigraphy of the Mississippian formations above the Fort Payne chert are shown in the sections below. (See also fig. 6.)

Section of Mississippian rocks above the Fort Payne chert in Brown and Murphrees valleys.

		Feet.
Pottsville formation (coal measures).		
Shale (Pennington)		100±
Limestone	Bangor limestone	350
Shale		30
Sandstone (Hartselle member)		100
Shale		50
Limestone		160
Fort Payne chert.		
		790

Section of Mississippian rocks above the Fort Payne chert near Irondale.

		Feet.
Pottsville formation (coal measures).		
Shale and sandstone (Parkwood)		2,000±
Shale, dark, calcareous (?) (Pennington)		292
Limestone	Bangor	317
Shale, soft, dark, calcareous (?)		39
Sandstone (Hartselle member)		117
Shale, dark, calcareous (?)		97
Limestone		88
Fort Payne chert.		
		2,950

In the vicinity of Readers Gap, south of this quadrangle, borings show only dark shale, probably calcareous, in the 500 feet immediately over the Fort Payne chert. The well logs are corroborated in the main by all that can be seen of the formation. South of Boyles Gap and Oxmoor good sections and accurate measurements of the rocks under discussion are not obtainable. A compiled section, probably a close approximation, is as follows:

Compiled section of Mississippian rocks above the Fort Payne chert south of Boyles Gap and Oxmoor.

		Feet.
Pottsville formation (coal measures).		
Shale and sandstone (Parkwood; in Shades Valley only)		2,000±
Shale, some calcareous; sandstone and limestone lenses	Floyd	700
Sandstone (Hartselle member)		0–100
Shale, dark, calcareous		200
Fort Payne chert.		
		3,000

FORT PAYNE CHERT.

Character.—The Fort Payne chert succeeds the Chattanooga shale unconformably. The name is taken from the town of Fort Payne, in De Kalb County, Ala., where the chert is well developed. On its outcrop the formation is made up of chert layers 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 Plate IX, on the illustration sheet. This illustration shows the thicker-bedded chert. The thinner, more unevenly bedded chert, which is the prevailing type, is shown in Plate VII.

The chert is generally of a yellowish color. Weathered pieces are commonly whitish, with small red patches. It is brittle or finely jointed, so that it breaks easily, and usually it is difficult to trim fossils out of it without breaking them into small pieces. In some localities the beds are so much shattered that the chert can be blasted out to a depth of 100 feet in a condition to be used for road surfacing without other preparation than a few blows of a sledge on the larger pieces.

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 calcite crystals. The chert is at present fine-grained crystalline quartz, but it probably was not originally in this form. The processes by which it may have attained its present condition will be discussed in the section on historical geology.

Thickness of the formation ranges from 90 to 200 feet, or possibly a little more in some sections. In Dale Gap 140 feet is exposed. At Blount Springs the thickness appears to be about 250 feet, though the top of the formation could not be exactly determined where it was measured. Well borings in Shades Valley report 125 to 200 feet of chert and limestone that are included within the limits of the Fort Payne. In the area east of Leeds the chert is probably not over 100 feet thick. (See section, p. 6.)

Distribution.—The Fort Payne is a persistent formation over all of northeastern Alabama. In the Birmingham quadrangle it outcrops in a considerable area on the Sequatchie anticline at Blount Springs and in a very small area north of Bangor. In Birmingham and Murphrees valleys it is exposed along Red Mountain and West Red Mountain and around Blount Mountain. It outcrops in the two small fault blocks at Thomas and Pratt City and in the block south of Henryellen. There is a small patch of the formation on the top of a little knob $1\frac{1}{2}$ miles southwest of Leeds and a long, narrow strip in the continuation of the same knob extending to the south margin of the quadrangle. At this point chert of Knox age is faulted up into contact with the Fort Payne, so that chert of the latter formation, with its characteristic fossils, occurs on the west side of a low ridge and chert of the Knox, with its fossils, on the east side. The chert also outcrops along the crest of Oak and Mill ridges, east of Leeds.

Age.—Extensive collections of fossils were made from the Fort Payne and were studied by G. H. Girty, who expresses the opinion that the formation in this district 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, is not determinable with the material in hand.

BANGOR LIMESTONE.

Character and distribution.—The Bangor limestone is named from the town of Bangor, Ala., where it is typically exposed. As shown in the sections on this page, it is lithologically composite, being made up of limestone, sandstone, and shale, the limestone predominating. The sandstone has been separately mapped as the Hartselle sandstone member.

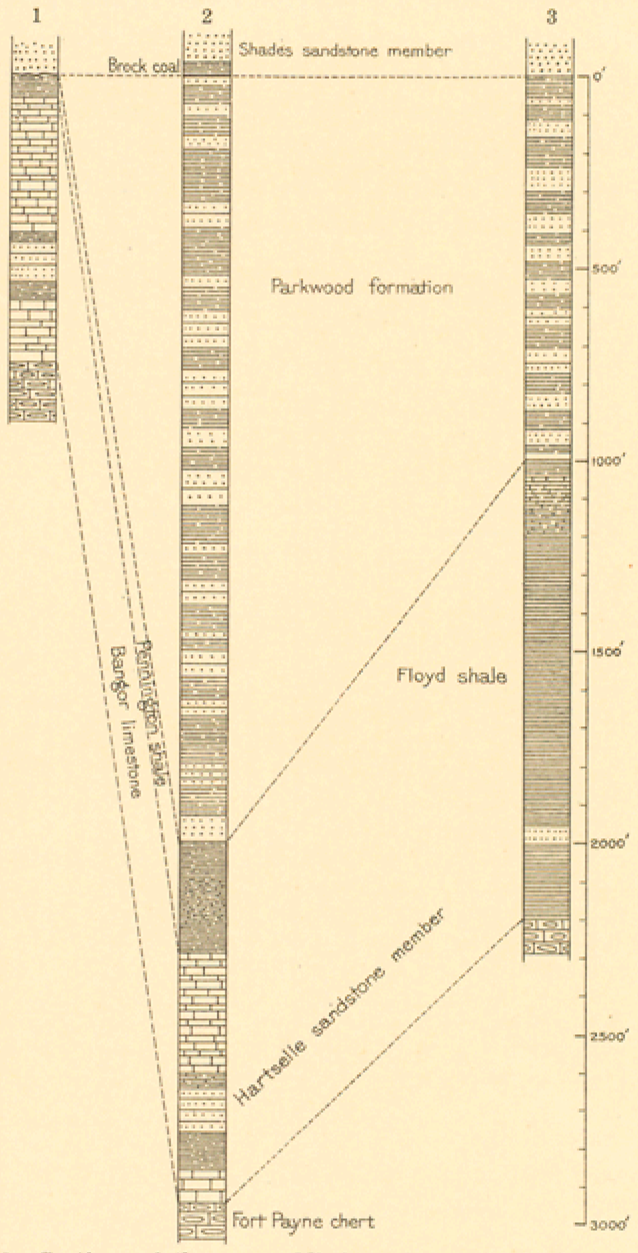


FIGURE 6.—Sections of the upper Mississippian rocks in Brown, Shades, and Cahaba valleys.

1. Brown Valley, near Bangor.
2. Shades Valley, 1 mile south of Irondale.
3. Cahaba Valley, east of Leeds.

Scale, 1 inch = 500 feet.

The section in Brown Valley (fig. 6) is typical of the Bangor limestone in the Birmingham quadrangle. In detail it is as follows:

As shown in the above section, the limestone is prevailingly light gray and rather coarsely crystalline. In places it contains oolitic and amorphous layers. A dark-colored band 12 feet thick appears in one quarry. At the Dale quarry bands of red and green shale occur near the top of the limestone and a 2-foot bed of clay and shale 100 feet below the top. Shale partings occur generally between the layers of limestone. The limestone is as a rule medium thick bedded, the layers running up to 2 feet in thickness. In the part of the formation below the Hartselle sandstone member nodules of chert appear at some distance below the sandstone and become more plentiful toward the bottom. It may be that there is no sharp plane of demarcation between the Fort Payne and Bangor, but that they merge by imperceptible stages into each other. No completely exposed section extending from one formation into the other has been seen by the writer, and the real nature of the contact is not known. At Blount Springs, where it is exposed, there is below the Hartselle a sandy shale with rusty or greenish color. It is apparently 50 feet thick. In the vicinity of Bangor the shale above the Hartselle is soft, clayey, and dark, in places even black. The lower shale is well exposed at Reid Spring, 2 miles north of Trussville, and the upper shale in the highway at the Little Cahaba Creek crossing $1\frac{1}{2}$ miles southwest of Argo. In thickness and character the shale at each point is comparable with that shown in the section in Brown Valley.

Section of Bangor limestone in Bangor-Blount Springs area, Brown Valley.

	Feet.
Limestone, light gray, crystalline	350
Shale, dark, fossiliferous	30
Sandstone (Hartselle member)	100
Shale and shaly sandstone	50
Limestone, light gray, crystalline, becoming cherty below	160
	690

The shale below the Hartselle is also well exposed in the railroad cut in Red Gap, at Gate City. The Fort Payne chert is underneath the shale in the cut, but shows on the bluff to the north, being on the upthrow side of an east-west fault about on the site of the highway. There is little doubt that the shales are widely persistent. In Brown Valley fossils were obtained in the upper shale.

Hartselle sandstone member.—About 200 feet above the bottom of the Bangor limestone is the Hartselle sandstone member, 100 feet thick. This sandstone varies from a fine-grained hard rock to one that is coarse grained and friable. The latter phase is well exhibited in Red Gap, where the rock is utilized for sand, being so soft as to pulverize in the hand.

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 west side of Birmingham Valley to Readers Gap, and perhaps farther south. Owing to its resistant character, the Hartselle is a ridge maker, forming, for example, the sharp ridge back of the hotel at Blount Springs and Little Sand Mountain, west of Trussville.

On the west side of West Red Mountain, from Turkey Creek nearly to Tarrant Gap, vertical beds of the sandstone stand here and there like dikes 50 feet or more above the surface, as shown in Plate X on the illustration sheet. This dikelike outcrop is locally known as Rocky Row.

Thickness.—The thickness of the Bangor, as shown in the first section on this page, is 690 feet. It thins along the west side of Birmingham Valley to perhaps 200 feet at Boyles Gap, including the Hartselle, and at Sayreton Gap no limestone appears in the section, the Bangor having passed completely into the Floyd shale.

Distribution.—The Bangor limestone outcrops along both sides of Brown Valley north of Reid station, along both sides of Murphrees Valley, around the south end of Blount Mountain, along the west side of Birmingham Valley to a point between Boyles and Sayreton gaps, and along Shades Valley to the south boundary of the quadrangle. It is not present in the Cahaba Valley. The best exposures of the limestone are in the vicinity of Blount Springs, on the west side of Murphrees Valley, and near the south end of Blount Mountain on the west side.

Age.—The Bangor is a highly fossiliferous formation, and from the study of the material collected in the course of this survey G. H. Girty concludes that the Bangor and probably the Pennington and Floyd shales, as defined beyond, are equivalent to the Moorefield shale, Batesville sandstone, Fayetteville shale, and Pitkin limestone of Arkansas, and probably to the St. Louis limestone and Chester group of the Mississippi Valley. They are also probably the equivalent, in part at least, of the Mauch Chunk shale of the anthracite basins of eastern Pennsylvania.

PENNINGTON SHALE.

Name.—The name Pennington is here applied to the shale which in Brown and Murphrees valleys intervenes between the Bangor limestone and the coal measures (Pottsville formation) and in Shades Valley between the limestone and the Parkwood formation. The name is derived from Pennington Gap in Virginia, where the supposedly equivalent shale was first named.

Character, distribution, and thickness.—In Brown and Murphrees valleys the Pennington consists mainly of gray shale but includes also layers of red and green shales and locally a

[a] McCalley, Henry, Report on the valley regions, pt. 2, Alabama Geol. Survey, 1897, p. 53; Geol. Atlas of Alabama.

little chert. In Shades Valley the Pennington is made up of dark or black and gray shale, a little chert, pink shaly sandstone, and one layer at least of fine conglomerate. It is moderately fossiliferous throughout.

In Shades Valley the top of the Pennington lies at the base of the heavy sandstone making Little Shades Mountain and Bald Ridge west of Oxmoor and at the base of the ridges bounding the valley on the east from Irondale to Trussville and beyond. The Pennington and the portion of the Bangor above the Hartselle sandstone member thus practically coincide with the flat land of Shades Valley north of Irondale, as the Floyd shale does farther south. The Pennington passes into the Floyd with the Bangor limestone.

In Brown and Murphrees valleys and on the west side of Birmingham Valley the Pennington ranges from 30 to perhaps 150 feet in thickness. It is nearly 300 feet thick in a bore hole on the east side of Shades Valley southeast of Irondale.

Age.—The age of the Pennington is discussed in the preceding section on the Bangor limestone.

FLOYD SHALE.

Name.—The name Floyd was introduced by Hayes for a mass of black shale in Floyd County, Ga. This shale corresponds in character and largely in stratigraphic position to the dark and black shale in the southern part of Birmingham Valley, into which the Bangor limestone and Pennington shale pass, as described in the preceding section. The name Floyd is therefore used for the shale of this region. In the reports of the Alabama Geological Survey the term "Oxmoor, or shale and sandstone phase of the upper part of the lower Carboniferous rocks," is used for the Floyd shale and the overlying Parkwood formation.

Character.—The Floyd is composed predominantly of shale. In the strip of the formation south of Sayreton Gap, on the west side of the Birmingham Valley, the exposures do not afford a good knowledge of it and only gray shale and sandstone are to be seen. In Cahaba Valley soft green and black carbonaceous shale predominates. A hard siliceous and calcareous stratum occurs near the base east of Leeds and makes a ridge. This rock is cut by many oblique joint planes into small smooth-faced pieces which strew the surface along the outcrop and are very characteristic. The formation is abundantly fossiliferous.

Thickness.—The thickness of the Floyd can not be determined with certainty but is at least 1000 feet in Cahaba Valley. It may be somewhat less on the west side of Birmingham Valley. As shown on page 7, the equivalent Bangor and Pennington are nearly 1000 feet thick near Irondale.

Distribution.—Only two areas of the Floyd occur in this quadrangle—one of indefinite northern limits on the west side of Birmingham Valley extending from the vicinity of Sayreton Gap to the south margin of the quadrangle, and the other in Cahaba Valley bordering the west side of the Coosa field. The formation in both areas stands nearly vertical, and unless there is duplication by close folding the thickness should be about the same as the width of the outcrop.

Age.—As the Floyd is the equivalent of the Bangor and Pennington, it is of the same age and is discussed in the section on the Bangor limestone.

PARKWOOD FORMATION.

Name.—In Shades and Cahaba valleys, on the west sides of the Cahaba and the Coosa coal fields, and along the south end and east side of Blount Mountain are shales and sandstones from 200 or 300 to 2000 feet thick. Under the designation "Oxmoor or shale and sandstone phase of the upper part of the lower Carboniferous," these shales and sandstones have hitherto been included with the Bangor, but they are here described as a distinct formation, designated the Parkwood, from the town of that name situated upon their outcrop a few miles south of this quadrangle. Oxmoor would be an appropriate name for the formation, but as that name has already been used in two different senses a new name is employed in order to avoid confusion. The Parkwood is defined as including the 1500 to 2000 feet of gray shale and sandstone lying above the base of the sandstone making Little Shades Mountain and Bald Ridge, one-half mile west of Oxmoor, a few miles south of this quadrangle, and below the Brock coal bed, near the crest of Shades Mountain. (See fig. 6.)

Character and distribution.—The Parkwood formation is composed of gray shales and sandstones. The sandstones are generally thick flags and make strata up to 100 feet thick. Some of the sandstone is hard and quartzose, but most of it is probably more or less feldspathic. A good deal is somewhat ferruginous and weathers to a rusty color. No black shale or calcareous matter occurs in the formation, and in this respect it is entirely different from the underlying Bangor. The very few fossils it contains do not differ materially from those of the Bangor, however, and the formation is regarded by Dr. Girty as most probably of Mississippian age. Its thickness appears to be 2200 feet east of Trussville, 1500 feet east of Irondale and at Oxmoor, about 300 feet on the east side of Blount Mountain, and not over 1000 feet on the west side of the Coosa coal field. The formation occurs in this quadrangle only on the south end and east side of Blount Mountain and on the west sides of the Cahaba and Coosa coal fields, dipping eastward beneath the younger rocks.

UNCONFORMITY AT THE TOP OF THE MISSISSIPPIAN

Possibly where the Parkwood is thickest in Shades Valley sedimentation was continuous into Pennsylvanian time, but in the Warrior field, where the Parkwood is absent, the Pennsylvanian rocks rest unconformably upon the Pennington. 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 from Alabama to Pennsylvania.

PENNSYLVANIAN SERIES.

POTTSVILLE FORMATION.

General statement.—The Pottsville formation takes its name from Pottsville, in the anthracite coal field of Pennsylvania. It forms the lowest part of the Pennsylvanian series and, as stated above, it rests, in the Warrior field at least, unconformably upon the eroded surface of the Mississippian rocks. It constitutes the top of the Paleozoic section in Alabama, and in the Birmingham quadrangle no younger rocks occur above it except some local and thin deposits of gravel. The Pottsville rocks are sandstone and shale and coal beds forming the coal measures of the State, the coal beds being their distinguishing characteristic. The sandstones are made up almost wholly of quartz grains, though containing a little mica and feldspar and scattering crystals of magnetite and zircon. The shale consists largely of very fine quartz grains and mica shreds in about equal proportion, together with small amounts of the other minerals occurring in the sandstone. Carbonaceous matter and iron oxide are present in both shale and sandstone as coloring matter.

Although the rocks are probably for the most part of fresh-water origin, yet the presence of marine fossils at certain horizons from bottom to top of the formation in the Warrior and Cahaba fields shows that there were incursions of the sea at intervals during Pottsville time. The basal part of the formation contains one or more beds of siliceous sandstone and conglomerate, close below which in some areas is a coal bed taken as the bottom of the formation. Although these rocks are uniformly varied and properly constitute a single formation, yet a number of members are described and mapped.

There are three areas of Pottsville rocks in the quadrangle, the Warrior coal field, including the Plateau field of Blount Mountain, the Cahaba coal field, and the Coosa coal field. On account of the differences in the coal measures of these fields the rocks of each will be separately described.

The number and position of the coal beds of the Pottsville in the three coal fields are shown in figure 7.

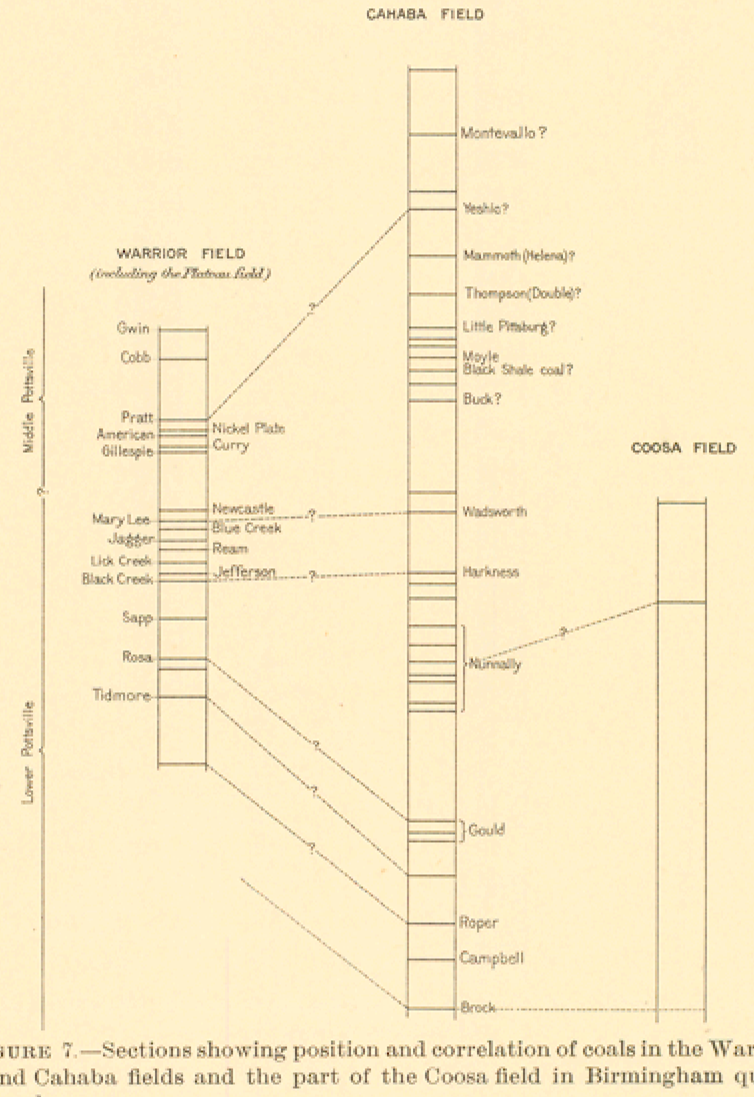


FIGURE 7.—Sections showing position and correlation of coals in the Warrior and Cahaba fields and the part of the Coosa field in Birmingham quadrangle.

Scale, 1 inch = 1000 feet.

Pottsville of the Warrior and Plateau Fields.

General statement.—The Warrior coal field embraces all of the Birmingham quadrangle west of Sand Mountain except the south end of Brown Valley, extending from the vicinity of Reid station to the north edge of the quadrangle. The thickness of the Pottsville in this field in the Birmingham quadrangle is 2300 feet. (See columnar-section sheet). It includes the Boyles, Bremen, Lick Creek, Camp Branch, and Razburg sandstone members and numerous coal beds, which will be described in order from the base up.

Thin coal near the base.—On the Louisville and Nashville Railroad, in Reid Gap, a thin coal is reported just beneath the heavy sandstone next to be described. This coal has not been observed elsewhere, so far as the writer knows, and it may have been deposited locally in low places on the eroded and slightly uneven surface of the old land as it was being transgressed by the water by which the Pottsville rocks were deposited. It is probable that this coal corresponds to one of the inter-conglomerate coals of the basal rocks of the Cahaba field.

Boyles sandstone member.—The basal part of the Pottsville is everywhere in the Birmingham quadrangle a sandstone. In this particular field it is called the Boyles sandstone member because it is well displayed in Boyles Gap. 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. Along Sand Mountain from Wylam to Tarrant Gap the sandstone appears to be about 100 to 250 feet thick. It is 100 feet thick where exposed in Sayreton and Boyles gaps. It becomes thicker toward the north and in places, as in the vicinity of Turkey Creek, appears to have a shale parting of considerable thickness. At Cunningham Gap the sandstone is 400 to 500 feet thick, with a bed of shale 350 feet above the bottom. On Murphy Creek, near Blount Springs, and in Gowdgen Gap north of Swansea, on the east side of Murphrees Valley, it is 600 feet thick.

The Boyles sandstone member outcrops along the crest of Sand Mountain and around the rim of the Blount Mountain plateau, its basal conglomeratic part making cliffs and its top, where the dip is not over 10°, making a long slope back of the ridges. The sandstone also outcrops over a large area on the Sequatchie anticline, making the ridge commonly known as Democrat Ridge. Its outcropping edges form conspicuous bluffs or cliffs along the sides of Brown Valley.

It is probable that the Boyles sandstone member is the equivalent either of the combined Shades and Pine sandstone members of the Cahaba and Coosa coal fields, the shale separating those sandstones not having been deposited in the Warrior field, or of the Pine sandstone member alone. The reasons for this view are as follows: The Rosa coal above the Boyles sandstone is regarded, on the evidence of fossil plants, as probably the same as the Gould coal above the Pine sandstone of the Cahaba field. Also as there is only one siliceous sandstone of the type of these basal sandstones in the Warrior field, it seems reasonably sure that one or the other of the above-stated suppositions is true. Furthermore, in view of the unconformity at the base of the coal measures of the Warrior field it is highly probable that the basal beds of the Cahaba field are older than those of the Warrior field and that the Shades sandstone and the overlying shale of the former are not represented in the latter.

It is possible that only the upper part of the Boyles sandstone member is present south of Tarrant Gap, where the sandstone is generally only about 100 feet thick, as shown in Boyles and Sayreton gaps. South of Valley Creek the sandstone is 300 to 400 feet thick and makes Rock Mountain.

This heavy sandstone has been correlated with the conglomerate at the top of the Lookout formation of northeastern Alabama, but on paleobotanic evidence David White concludes that the top of the Lookout lies near the horizon of the Mary Lee coal, to be described later, and that the beds below that coal, including the Boyles sandstone, correspond to the Lookout formation.

Strata above the Boyles sandstone member.—The Boyles sandstone is succeeded by 600 feet of shale and sandstone, reaching up to the Black Creek coal and containing at least four thin coals. In places the sandstone beds reach a thickness of 40 feet or so and are thick bedded and rather coarse.

Tidmore coal.—In the vicinity of Tidmore a coal bed a few inches thick occurs 25 to 30 feet above the top of the Boyles sandstone. This bed is here named the Tidmore coal.

Rosa coal.—Near Berry Mountain there are two coals, one at 130 and the other at 160 feet above the Boyles sandstone. Both coals appear along the road from Tidwell to Cleveland, about 1 mile north of Tidwell. The lower coal is thin and of no value. The upper coal is mined in the vicinity of Rosa and is therefore named the Rosa coal. It is also known in the region as the Berry Mountain coal, for it has been mined in Berry Mountain, to the north of the quadrangle. Where mined at Rosa for local use it is 15 inches thick. The coal bed mined at Swansea is regarded as the Rosa coal, as it is about the same distance above the top of the Boyles sandstone. At Swansea it is 3 to 4 feet thick. A 12-inch coal outcropping on the Louisville and Nashville Railroad just opposite the powder houses at Gardner probably lies at this horizon, as does also a thin coal showing near Thomas on the road to Republic, just north of its intersection with the Pratt City road. The 200 to 300 feet of shale and sandstone including the Rosa and other coals lying above the Boyles sandstone correspond to the shale and sandstone including the Gould group of coals lying between the Pine and Chestnut sandstones in the Cahaba field. Fossil plants studied by David White show that the Rosa coal is comparable stratigraphically with the Gould bed of the Cahaba field.

Sapp coal.—At Sapp Crossroads a coal 8 inches thick outcrops in the road and is believed to be the same coal as that noted at a number of points in the vicinity of Arkadelphia, where it is 230 feet below the Black Creek coal. This bed is here named the Sapp coal. It was noted at a number of points near water level both north and south of Arkadelphia, and also at several points west of Adville. The bed outcropping on the old track of the Louisville and Nashville Railroad 1 mile north of Gardner is probably the Sapp coal; it is much thicker here than elsewhere.

Black Creek coal.—The Black Creek coal is, as nearly as can be determined by indirect measurement, 600 to 700 feet above the Boyles sandstone and 230 feet above the Sapp coal. The Black Creek coal is a persistent bed, generally about 2 feet thick in this quadrangle. Its outcrop is shown on the economic geology map. In general it is exposed continuously from Warrior to a point 1 mile north of Littleton on the west side of the Coalburg syncline and to Pratt City on the east side of the syncline. From Pratt City southward it is faulted out. On the hills northeast of Warrior are several outliers of the Black Creek coal and on Arkadelphia Mountain is an extensive area of it.

Jefferson coal.—The Jefferson coal lies 40 feet above the Black Creek. In the Coalburg syncline the interval between the coals is occupied by shale and sandstone. In places the Black Creek coal is immediately overlain by 10 to 15 feet of thick-bedded sandstone, but probably it is more generally overlain by a bed of shale, above which is almost everywhere a stratum of sandstone. The Jefferson coal is 2½ to 3 feet thick in the region south of Warrior and eastward to Indio, and it appears to be of good thickness in the vicinity of Sayre. Elsewhere it is not known to be thick enough to be of importance. At Warrior it appears to be represented by two or three benches separated by 20 feet or so of shale. (See fig. 10, p. 15.) It is believed that the lower bench approaches and finally joins the Black Creek coal at some points by the disappearance of the separating shale and sandstone. The writer was not able to verify this assumption.

The Jefferson is not known as a separate bed on Arkadelphia Mountain, and if represented there must be either very thin or else united with the Black Creek.

Bremen sandstone member.—In the Arkadelphia region the Black Creek coal is overlain by 80 feet of gray, coarse-grained, thick-bedded, quartz sandstone, making the plateau surface. This sandstone is here named the Bremen sandstone member, from the town of that name in the northwest corner of the quadrangle. Along Dorsey Creek in this region the Black Creek coal is also underlain by 100 feet of sandstone, making with the overlying Bremen a mass of sandstone about 180 feet thick.

Lick Creek coal.—The Lick Creek is a thin coal appearing in the general region south and southwest of Warrior. It is 30 to 40 feet above the Jefferson coal, from which it is separated by shale and sandstone. The coal is of no value.

The Black Creek, Jefferson, and Lick Creek coals constitute the Black Creek coal group.

Ream coal.—About 80 feet above the Lick Creek coal and 150 feet above the Black Creek coal is the Ream coal. The rocks between the Lick Creek and Ream beds consist of shale in some sections and mostly of sandstone in others. The bed was noted only in the vicinity of Kimberly and Morris. It is thin, so far as known, and in some sections is lacking altogether.

Lick Creek sandstone.—The name Lick Creek is here introduced for a conglomerate and sandstone of wide extent which is well displayed along Lick Creek in the vicinity of Kimberly. The conglomerate varies somewhat in character. In places, as on its northeastern outcrop from Turkey Creek to Macknally Ford, it is mostly a thin-bedded sandstone without pebbles. From Newcastle southward and from Kimberly to Littleton it is of a conspicuously conglomeratic character. The pebbles are generally 1 inch or less in diameter and are mostly quartz or quartzite but include a few of black chert. Its thickness averages about 50 feet. The position of the stratum is a little lower stratigraphically to the northeast than to the southwest, as will be shown in the description of the Jagger coal. One of the best exposures of the conglomerate is at the bridge across Turkey Creek 1 mile northwest of Morris. The west end of the bridge rests upon the conglomerate, of which about 20 feet appears, full of pebbles down to the creek level. The conglomerate is also conspicuous along the ravines and the river gorge in the vicinity of Kimberly and on the knobs north of the river farther west. It makes a ridge covered with pebbles from Newcastle to Sayreton.

Jagger coal.—The Jagger coal lies immediately on top of the Lick Creek sandstone member at and northeast of Kimberly. To the southwest, however, conglomerate continuous with the Lick Creek comes in above the Jagger and appears to be persistent, as described above, while the part of the Lick Creek under the Jagger decreases in thickness and perhaps dies out altogether. On the bank of Locust Fork, just below the mouth of Whites Creek, conglomerate occurs both above and below the Jagger coal, the upper bed continuing to the southwest and the lower bed to the northeast, as described above. A 10-foot bed of conglomerate overlying the Jagger shows well on Trouble Creek at the road crossing near the north margin of sec. 23, T. 15 S., R. 4 W.

The Jagger coal varies in thickness and make-up. In the Morris-Kimberly region it is thick but consists only of carbonaceous shale and is valueless. To the east and northeast of this region it is thin and apparently clean in some places but thick and dirty in others. On Whites Creek it is thin; on Trouble Creek it is reported to be 3 feet thick and clean. So far as known, it is thin along the east side of the Coalburg syncline.

Blue Creek coal.—The Blue Creek coal is separated from the Jagger by 40 to 60 feet of shale, sandstone, and conglomerate. It is mostly a thin bed in this region, but in an area of 15 to 20 square miles about Morris it is of considerable thickness and value.

Mary Lee coal.—From 50 to 60 feet above the Blue Creek coal lies the Mary Lee coal, the interval in the best-exposed sections being occupied mostly by sandstones. The Mary Lee is a thick and valuable coal throughout nearly the whole area of its outcrop, although it is everywhere dirty or broken into alternating layers of coal and clay. In some areas the layers are few and thick; in others they are many and thin. This is the most valuable coal bed in the quadrangle.

Newcastle coal.—The Newcastle coal is 10 to 50 feet above the Mary Lee, the intervening rocks consisting of shale. The smaller interval is seen in the region of Crooked and Turkey creeks and the hills to the north; the greater interval occurs throughout the larger area to the southwest. The Newcastle coal is everywhere thin and valueless except in the region from Newcastle to the Graves mines, or perhaps to Sayreton. It is thickest and most valuable in the immediate vicinity of Newcastle and diminishes in thickness with increasing distance from that place.

The Ream, Jagger, Blue Creek, Mary Lee, and Newcastle beds constitute what is locally known as the Mary Lee group of coals.

Strata above the Mary Lee coal.—Above the Mary Lee is 200 feet of soft clay shale, including at the base the Newcastle coal and here and there thin sandstones. This shale generally weathers to a rusty-yellow color and is everywhere easily identifiable. Above this body of shale are alternating beds of shale and sandstone 135 feet thick, the proportion of sandstone increasing toward the top, so that the upper 30 to 60 feet contains little shale.

Gillespie coal.—The Gillepsie coal bed lies at the top of the sandstone just mentioned, 335 feet above the Mary Lee coal. It appears to be generally present in the quadrangle but is everywhere thin and of little value.

Curry coal.—The Curry coal is 30 to 40 feet above the Gillespie and, like it, is generally present and very thin. The intervening rocks are shale and sandstone.

American coal.—The American coal bed is 40 feet above the Curry, from which it is separated by shale and sandstone. It is thin in this quadrangle except near Ensley, where it has been exposed and shows a thickness of about 3 feet. It is well exposed below a sandstone along the Blossburg branch of the Southern Railway, just west of Jefferson station.

Nickel Plate coal.—Thirty feet above the American coal is the Nickel Plate bed, which is about 2½ feet thick in the region north of Blossburg and from Fivemile Creek to Mount Olive Church and east to the Birmingham-Morris road. It occurs in much of this region in isolated patches on the hills. Between it and the American bed is generally a heavy sandstone and some shale.

Pratt coal.—The Pratt coal is in general 40 feet above the Nickel Plate, or 475 to 500 feet above the Mary Lee. The space between the Nickel Plate and the Pratt is occupied by coarse, thick-bedded sandstone. The Pratt coal is 2½ to 4 feet thick, with one or more thin partings. It is a valuable coal throughout the area underlain by it in this quadrangle and has been the chief bed mined in the Coalburg syncline up to the present time.

The Gillespie, Curry, American, Nickel Plate, and Pratt beds constitute the Pratt group of coals.

Strata overlying the Pratt coal.—The Pratt coal is overlain by about 170 feet of stiff sandy shale and thin sandstone, which in turn is succeeded by about 40 feet of sandstone and a smaller amount of shale, and then comes the Camp Branch sandstone, next to be described.

Camp Branch sandstone member.—The Camp Branch is a thick-bedded, coarse sandstone lying 210 feet above the Pratt coal. It is named from Camp Branch, along the south bluff of which it is well exposed. The sandstone is gray, medium grained, and generally thick bedded. It is persistent, but its lower limit can not easily be fixed with precision, for in places it merges into sandstone occupying a lower horizon. Its thickness is about 40 feet. The Camp Branch is a conspicuous stratum along Village Creek and to the north on the hills to Murray.

Cobb coal.—The Cobb coal immediately overlies the Camp Branch sandstone throughout the area in which it is present. The coal is generally only a few inches thick and of no account. On the road 1½ miles south of Republic are exposed two thin coals 5 feet apart, separated by shale. They may represent the upper and lower Cobb coals as they are developed on Rock Creek southwest of this quadrangle. No other evidence of two Cobb coals in this quadrangle was obtained. Several determinations give the distances of the Cobb coal above the Pratt bed as 250 to 300 feet.

Razburg sandstone member.—Overlying the Cobb coal is 120 feet of shale, and this is followed by about 20 feet of sandstone, which is here named the Razburg sandstone member, from the post-office of that name to the southwest of this area, where it is well developed and exposed. The Razburg sandstone is persistent over a large area to the southwest in the Brookwood quadrangle, and just catches the top of the ridge south of Camp Branch in the Birmingham quadrangle. It is gray, generally thick bedded, rather coarse, and 20 to 30 feet thick. The horizon of the Gwin coal is close above the Razburg sandstone, but the coal does not appear to be present at any point in this quadrangle, the stratigraphically highest Carboniferous rocks of the area probably lying just below its horizon.

Pottsville in the Cahaba Field.

General statement.—The part of the Cahaba coal field included in this quadrangle occupies a strip 3 to 3½ miles wide lying east of and parallel to Blackjack Ridge and Shades Mountain. Its eastern boundary, which passes through Henryellen, is an overthrust fault of about 10,000 feet displacement, by which the Lower Cambrian Rome formation has been pushed up on the east into contact with the upper part of the Pottsville. The rocks of the Cahaba field therefore lie in a structural trough, and in the part of the field here described they are inclined at angles varying from 10° to vertical. As a result of this attitude it has been necessary to compute their thickness from the dip and width of outcrop. An average result of 5100 feet has been obtained from five sections across the field, as follows: Along Black Creek, along the highway east from Trussville, along the Central of Georgia Railway, along the Southern Railway, and along the Birmingham-Leeds highway.[a] The writer feels a certain degree of skepticism as to the accuracy of this result and is inclined to the belief that it considerably exceeds the actual thickness. However, the method of measurement adopted is the only one possible and the results appear to be the best that can be obtained. There are no indications of duplication of beds by faults and folds except in the Birmingham-Leeds highway section, in which allowance has been made for a fault.

Names and correlations of coal beds.—The names of many of the coal beds in the Cahaba field were originally applied along the Louisville and Nashville Railroad between Brock Gap and Helena, and that section may be taken as the type. This is the type locality of the Gould, Nunnally, Harkness, Wadsworth, Buck, Black Shale, Little Pittsburg, Thompson (Conglomerate), and Helena beds, and the effort has been made to identify these beds and apply the corresponding names in the northern part of the field. The identification is certain up to the Harkness bed and highly probable for the Wadsworth, but as to the beds above the Wadsworth much doubt exists, and the application of a particular name expresses only the writer's guess as to identity and should be taken to signify no more than that, in his opinion, the bed so designated lies near the horizon of the bed of that name in the type locality.

Brock coal.—The Brock coal bed is taken as the base of the coal measures or Pottsville formation in the Cahaba coal field. It apparently was deposited upon the Parkwood formation without any break in sedimentation, as it appears to lie conformably upon that formation. It indicates the beginning of coal accumulation in the region, and, moreover, it is a persistent bed which has been traced continuously along the western margin of the Cahaba field. The Brock coal should therefore clearly be included in the Pottsville, but there are no known reasons for including any lower rocks and any effort to place the boundary lower would lead to inconsistent results, for there is no lower horizon that can with certainty be identified throughout the field.

The Brock coal is generally 1 foot thick or less. At Brock and Genery gaps, south of this quadrangle, it is thicker, but it is nowhere of sufficient thickness to be of value. It is named from Brock Gap. Some sections show two coal beds 30 feet apart, the lower one being some 60 feet below the base of the Shades sandstone member, next to be described.

Shades sandstone member.—The Brock coal is generally overlain by 50 feet or so of shale, above which is the Shades sandstone member, named from Shades Mountain, that ridge and its northern continuation, Blackjack Ridge, being due to the presence of the sandstone. The Shades sandstone member is thick bedded, rather coarse, and generally somewhat conglomeratic

[a] See columnar-section sheet; also see Bull. U. S. Geol. Survey No. 316, 1907, pp. 76-115, for individual profile and columnar sections.

in the lower part. It is 200 feet thick. Its outcrop is confined to the crest and eastern slope of the Shades-Blackjack ridge, along which its basal 40 feet or so extends as a cliff almost the entire length of the Cahaba field.

Campbell coal.—The Campbell coal, lying almost immediately on top of the Shades sandstone, is named from Mr. Campbell, who lives east of Argo, the coal being penetrated in his well and showing on the surface in the neighborhood. The coal is thin and valueless. A thin coal about 50 feet above the Shades sandstone on the Birmingham-Leeds road is probably the Campbell. This coal appears to be persistent in the quadrangle.

Roper coal.—About 200 feet above the Campbell is the Roper coal, named from Roper station, on the Seaboard Air Line Railway. It shows on the summit of Grassy Ridge, in the highway one-fourth mile east of the station, and in a ravine on the boundary between secs. 15 and 22, T. 16 S., R. 1 E. At the last-named point it is opened in shale close below the Pine sandstone member, next to be described, and is 1 foot thick. It also appears in two thin layers on the Southern Railway 1 mile west of Lovick. It is everywhere thin and worthless, though it appears to be persistent. The interval between the Campbell and Roper coals is occupied by shale.

Pine sandstone member.—Immediately or closely overlying the Roper coal is the Pine sandstone member, named from the ridge known as Pine Ridge south of this quadrangle but as Flat Ridge east of Birmingham and Grassy Ridge farther north. The Pine sandstone member is quartzose, coarse, and thick bedded at the base but finer grained and more flaggy at top. It is 250 feet thick. In this quadrangle it outcrops along the crest and east slope of the Flat-Grassy ridge. The presence of the sandstone has produced the ridge, the softer shales above and below it having been eroded away, leaving the sandstone standing in relief. The sandstone and the ridge are persistent the entire length of the Cahaba field.

Tidmore (?) coal.—In one section a coal about 1 foot thick, with partings, occurs about 100 feet or possibly less above the Pine sandstone. This coal was seen at only two points in sec. 22, T. 16 S., R. 1 E., one of which is on the Seaboard Air Line Railway, on the line between secs. 21 and 22. It is regarded as the equivalent of the Tidmore coal of the Warrior field.

Gould group of coals.—About 200 feet above the top of the Pine sandstone begins the Gould group of coals. The name is taken from the Gould coal, which was one of the early coals mined in the field, near the Louisville and Nashville Railroad 12 miles south of Birmingham. The group comprises in places at least four coals within a vertical interval of 50 feet, as shown in the road on Chestnut Ridge, 1 mile east of Roper. In this section the next to the upper coal is 2 feet thick, and this bed, or one of the others of the group, is a little over 2 feet thick at the Ratliffe mine, 1 mile south of Lovick. The coals show in a railroad cut half a mile west of Parsons station, where none are over 8 inches thick. They are thin north of Parsons.

Chestnut sandstone member.—Immediately over the Gould group of coals is a persistent quartzose sandstone 100 feet thick, making Chestnut Ridge, which is an easily recognizable feature almost the whole length of the Cahaba field. This sandstone is named the Chestnut sandstone member.

The three ridge-making sandstones, the Shades, Pine, and Chestnut, make up the "Millstone grit" of the Cahaba field. They differ from the higher sandstones in being coarser, conglomeratic, cleaner, and of a purer quartzose composition.

Nunnally group of coals.—About 450 feet above the Chestnut sandstone is the bottom of the Nunnally group of coals. The name is taken from the Nunnally place, on the Louisville and Nashville Railroad between Brock Gap and Cahaba River. The Nunnally coal group is essentially the same as the Five group of Squire.[a]

The space between the Chestnut sandstone and the Nunnally group is occupied by shale. At Lovick and for several miles to the south the middle part of this shale is black and fossiliferous, containing marine invertebrates, brachiopods, and gastropods. The shale is utilized at Lovick for brick. The Nunnally coal group occupies about 450 feet of space vertically in the section showing along the Birmingham-Leeds highway just west of the Cahaba River bridge. Here six coal beds are exposed, only one of which, near the bottom, appears to be of minable thickness. From this point the coals can be traced continuously to the type locality of the Nunnally coal group on the Louisville and Nashville Railroad, so there is no doubt of their identity. On the Southern Railway just east of Lovick two coals are exposed, the lower one 3 feet thick and mostly dirty. On the highway east of Trussville thin coals show in a section 100 feet thick on the west slope of Owens Mountain. The upper coal is here 2 feet thick. These coals appear also at other points on the west slope of Owens Mountain farther north. On Black Creek, just under the Seaboard Air Line Railway bridge, in a space of 10 feet there are four thin coals that are the only representatives of the group exposed in the section. The coals lie mostly in shale.

[a] Squire, Joseph, Report on the Cahaba coal field, Alabama Geol. Survey, 1890.

Harkness coal and associated strata.—Overlying the Nunnally coal group is a thin-bedded sandstone that in this quadrangle is of considerable thickness and makes the pronounced ridge Owens Mountain, which can be traced from the Birmingham-Leeds road northeastward to the margin of the quadrangle. This sandstone is overlain by 200 feet or so of shale showing one to two thin coals. At the top of this shale, 300 feet above the top of the Nunnally coal group, is a thick coal bed supposed to be the Harkness, named from the Harkness place, on the Louisville and Nashville Railroad west of Helena and south of this quadrangle. The identity of this bed is made reasonably certain by its position relative to the Nunnally group of coals, which, as has been said, is traceable from the type locality into this area. In this quadrangle the Harkness coal is generally a thick minable bed. It has been prospected thoroughly and can be traced by openings from the southern margin of the quadrangle to Parsons. It averages 6 feet in thickness but contains a considerable amount of impurities in the form of partings. The outcrop of the bed is shown on the economic geology map. East of Cahaba River, on the Birmingham-Leeds road, the outcrop is repeated by faults and folds.

Wadsworth coal and overlying beds.—At 300 feet above the Harkness coal, and separated from it by shale and sandstone, is a bed of coal that is correlated with the Wadsworth coal of the Louisville and Nashville Railroad section. It shows in the vicinity of Parsons station and near the Birmingham-Leeds road at Cahaba River as a bed 15 to 28 inches thick.

In the 500 to 600 feet of shale and sandstone immediately overlying the Wadsworth coal in this quadrangle no coal beds have been seen. This space probably includes the horizons of the Schute, Coke (Pump), Adkins, and other thin beds of the Louisville and Nashville Railroad section.

Buck coal.—The bed here regarded as the possible representative of the Buck bed of the type section at Helena lies 175 feet above the Wadsworth. It was seen on Black Creek a short distance east of the Central of Georgia Railway bridge and on the Trussville road in sec. 33, T. 16 S., R. 1 E. It is 2 feet thick.

Black Shale coal.—A bed about 200 feet above the Buck coal in this area and separated from it by shale is identified as the Black Shale coal. The intervening shale carries a thin coal bed. The Black Shale bed was seen on the Trussville road and on the Central of Georgia Railway three-fourths of a mile west of Henryellen. It is $3\frac{1}{2}$ feet thick on the railroad.

Little Pittsburg coal.—The Black Shale coal is overlain by 175 feet of shale, above which is a 2-foot coal that may be the Little Pittsburg of the Louisville and Nashville Railroad section at Helena. It was opened on Black Creek and was seen in the Trussville road and on the Central of Georgia and Southern railways. At the east end of the Southern Railway bridge over Cahaba River it is 21 inches thick and lies just under a heavy sandstone.

Thompson (Conglomerate) coal.—At 200 feet above the Little Pittsburg, just under a conglomerate, is a coal bed that was called by Squire the Double bed, as it is in places separated into two benches by a considerable thickness of shale. The presence of the conglomerate over the coal leads the writer to suspect that it is the same as the Conglomerate bed of the type section at Helena, otherwise known as the Thompson coal. Other reasons for this correlation have been fully stated in Bulletin 316 of the Survey (pp. 84–85) but are not repeated here because the intervening territory is not mapped in this folio.

In this area the Thompson bed, with its overlying conglomerate, is shown on the road east from Trussville just west of the Central of Georgia Railway. It appears as two benches in a cut on the railroad just south of the Trussville road. It is also exposed, 3 feet thick, on the Central of Georgia Railway half a mile west of Henryellen, and its conglomerate is not far above it. On the Southern Railway the coal outcrops just east of the station at the junction of the siding to Henryellen No. 6 mine. It is here over 2 feet thick and lies immediately under a coarse sandstone conglomerate. The conglomerate next above the Thompson coal is only 5 to 10 feet thick at the north end of this area, but toward the south it thickens to over 20 feet. At the north its pebbles are small and scattering, but on the head of Hogpen Branch they are larger and more plentiful. It is assumed that this conglomerate is the same as that which in the Blocton Basin, in the south end of the Cahaba field, begins just above the Thompson or Underwood coal and extends as a conglomeratic sandstone nearly or quite to the top of the coal measures in that region. Throughout its extent it is a coarse sandstone with conglomerate lenses. In places south of the Birmingham quadrangle these lenses become veritable pudding stones, being a mass of pebbles commonly 2 to 3 inches in diameter, with here and there one of larger size. One such bed near the base of the conglomerate is well exposed at several points in the vicinity of Helena.

Mammoth coal.—The Mammoth coal lies about 150 feet above the Thompson, the interval being occupied by the conglomerate described above and by shale. The Mammoth bed is 10 feet thick on Black Creek. On the Southern Railway it is split into two benches by about 10 feet of shale, and it is reported to maintain that condition to Hogpen Branch, where its outcrop terminates in a fault. For the same reasons as those stated in the discussion of the Thompson coal, the Mammoth coal is correlated with the Helena coal, which lies next above the conglomerate in the Louisville and Nashville Railroad section at Helena.

Yeshic (?) coal.—About 400 feet above the Mammoth coal, east of the junction of the Southern Railway with the siding to Henryellen No. 6 mine, is a bed of coal apparently 6 feet thick, which, if the Mammoth is the same as the Helena, would lie at the horizon of the Yeshic bed of the south end of the field. Apparently this same bed has been opened about 1 mile northeast of Henryellen and one-eighth mile or so east of Henryellen No. 4 mine, and it is possible that the same bed is represented by one or more of three thin beds outcropping in the Trussville road just east of the crossing of Black Creek. The rocks between the Mammoth and Yeshic beds consist of shale.

Rocks and coal beds above the Yeshic coal.—Above the Yeshic coal, best shown in the Trussville road east of Black Creek, are about 900 feet of shale and coarse, thick-bedded sandstone containing thin coals. At 400 feet above the Yeshic are two thin or much parted beds, and at 750 feet above it are two thin beds that outcrop in the Trussville road on the crest of the ridge east of Black Creek. If the correlations assumed by the writer for the Mammoth and Yeshic beds are correct, the coals above the Yeshic would include the Montevallo coal below and the Dogwood coals above. The intervals correspond very closely, the Montevallo in the southern part of the Cahaba field being 300 to 400 feet and the lower Dogwood 830 feet above the Yeshic.

Pottsville of the Coosa Coal Field.

General statement.—The Birmingham quadrangle embraces only a small triangular portion of the Coosa field southeast of Oak Mountain, in the extreme southeast corner of the quadrangle, lying in what is known as the Howard Basin. The total thickness of Pottsville rocks in the basin is computed to be 2800 feet.

Shades sandstone member.—At the base of the coal measures in the Coosa field lies the Shades sandstone member, 400 feet thick, coarse grained, and siliceous. Its outcrop makes Oak Mountain on the west of the field.

Pine sandstone member.—The Pine sandstone member is separated from the Shades sandstone member by 300 feet of shale. It is a good conglomerate 300 feet thick on the east flank of Oak Mountain, where its outcrop makes a hogback. It also makes Coosa Mountain, just off the southeast corner of the quadrangle.

Beds above the Pine sandstone member.—The 1800 feet of rocks above the Pine sandstone member comprise alternating beds of shale and sandstone, some of the sandstone strata being of sufficient thickness and persistence to make ridges. The Chestnut sandstone member of the Cahaba field can not be recognized. About 1300 feet above the Pine sandstone is a thin coal bed, probably the Howard, the only one that was noted in this part of the field.

General Correlation of the Coal Beds.

As there is no direct connection between the different coal fields, it is necessary to depend on fossils for correlating the coal beds. Considerable collections of fossil plants have been made, from an incomplete study of which David White concludes that the Black Creek coal of the Warrior field and the Harkness coal of the Cahaba field lie near the same geologic horizon. He is also inclined to associate the Rosa and Mary Lee beds of the Warrior field with the Gould and Wadsworth beds, respectively, of the Cahaba field. (See fig. 7, p. 8.) The Mary Lee bed, in his opinion, lies at nearly the same horizon as the Soddy coal of Tennessee. White has classed the Pottsville of the southern Appalachian region as lower and middle Pottsville. The lower Pottsville extends to the horizon of the Soddy coal, just above the conglomerates of the Cumberland Plateau and Lookout Mountain. The same plane is therefore approximately represented by the Mary Lee and Newcastle coals of the Warrior field and by the Wadsworth bed of the Cahaba field. All the Alabama coal measures fall in the lower and middle Pottsville.

QUATERNARY SYSTEM.

The deposits of the Quaternary system comprise certain high-level gravels and the alluvial deposits in the present valleys. The former are probably Pleistocene and the latter are of Recent age.

PLEISTOCENE DEPOSITS.

TERRACE GRAVELS.

Character and distribution. — Here and there, at slightly varying levels high above the present streams, are patches of gravel composed of quartz, quartzite, and chert. The pebbles are well rounded and range from 6 inches in diameter downward but are mostly less than 3 inches in diameter. They are associated with sand and loam. The deposits show no evidence of much thickness and range from about 10 feet down to scattered pebbles. These deposits lie on the tops of the hills or on terraces at considerable heights above the streams. As shown on the areal geology map, they are most extensive at and near Tidmore, where they lie at altitudes of 450 to 500 feet, or 100 to 150 feet above the river. The patch at Seloca is 200 feet above the river and those between Indio and Bradford are a little over 600 feet in altitude and 300 feet above the river. The deposits along the west side of Cahaba Valley south of Leeds lie on benches or terraces on the side of Pine Ridge at elevations of 650 to 700 feet. Just west of Chalkville, at an altitude of over 800 feet, is a deposit containing many quartz pebbles overlain by red loam, as in the typical Lafayette deposits farther southwest. The elevation of this deposit is the same as that of the highest Lafayette 40 miles to the west, and it is possible, though not positively asserted, that the deposit is a remnant of the Lafayette, a thin mantle of which may once have covered this region. The materials of the other deposits described may have been derived from the Lafayette mantle and have been worked over in the progress of post-Lafayette erosion and redeposited in their present positions in Pleistocene time. The ultimate source of the materials is the region of crystalline rocks northeast of Alabama.

Age of deposits.—The most conspicuous of these deposits lie on the high ground along the gorge of Little Warrior River, and as they are stream deposits in the present state they were deposited on the flood plains of the river or tributary streams when those streams ran on the rocks on which the deposits now lie. Subsequently the streams eroded their present comparatively narrow gorges 100 to 300 feet below the level of the deposits. These deposits are all of Quaternary age; the higher ones are probably Pleistocene, but those on the lower terraces nearest the river are probably Recent. The age of the Lafayette deposits, from which these gravels were probably derived, is regarded as Pliocene (latest Tertiary). The gravels near Chalkville included under this heading may be Lafayette and therefore of Pliocene (?) age.

RECENT DEPOSITS.

ALLUVIUM.

The most recent deposits of the region are the areas of alluvium along the present streams. These deposits consist of fine gravel and silt that have been laid down in the most recent times by the present streams as they overflowed their banks.

STRUCTURE.

METHODS OF REPRESENTING STRUCTURE.

There are two ways of representing structure—by structure sections and by structure contours. In the first method the structure is shown as it would appear from the edges of the cut strata in a deep trench extending across a region at right angles to the strike of the rocks. This method is very instructive, but it has the disadvantage of not being good far from the particular line of the section. It is the best method where the rocks are greatly folded and faulted.

By the contour method structure is represented by lines supposed to be drawn on the top or bottom of some bed identifiable over a large area through points having the same distance above or below sea level. The surface of the stratum chosen is called the reference surface and the lines of equal elevation are called contour lines. Thus the absolute elevation and horizontal contour of the reference surface are shown, and as all the other rocks of a regularly stratified series are approximately parallel to the reference surface the structure or lay of the mass is delineated.

The elevation of points on the reference surface is determined in a number of ways. If the reference surface outcrops at the surface, the elevation is determined directly. If the reference surface is buried beneath other strata, the elevation of points on it is determined by subtracting the thickness of the rocks between the reference surface and some higher bed whose elevation is determined by direct observation. Thus the elevation of the Mary Lee coal bed at many points has been calculated from the elevation of the Pratt coal bed, which has been determined at the surface and in mines. If the reference surface has been eroded, its original elevation is obtained by adding to the elevation of some other bed at any point the thickness of the rocks between the observed bed and the reference surface. Thus the height of the Mary Lee coal bed before it was eroded is determined at many points from the known elevation of the Black Creek coal bed.

STRUCTURES IN THE QUADRANGLE.

General statement.—In its general outlines the structure of the quadrangle is that of a number of anticlines and synclines passing diagonally across the area from northeast to southwest. There are also a number of faults following the same direction along which the rocks on one side have been thrust up over those on the other side. There are also minor faults crossing these main structures. Between the anticlines in the northwest

part of the quadrangle are extensive areas of nearly flat rocks. The description of the units of the structure proceeds from the northwest to the southeast. The sections on the structure section sheet illustrate graphically the structures to be described.

Structure of the northwest corner.—In the northwest corner of the quadrangle the rocks are nearly flat. The structure here is shown on the economic geology map by contours at vertical intervals of 50 feet representing the top of the Black Creek coal.

Arkadelphia syncline.—The Arkadelphia syncline is a low trough, the axis of which lies $1\frac{1}{2}$ miles southeast of Arkadelphia. As shown on section B–B, it is deepest at the southwest end.

Sequatchie anticline.—The Sequatchie anticline is a remarkably straight and narrow fold extending from Tennessee to the vicinity of Scrap, in the Brookwood quadrangle, lying to the southwest of this area. In the Birmingham quadrangle the axis pitches strongly southward. From the vicinity of Reid Gap northward the fold is unsymmetrical, the rocks on the northwest dipping much more steeply than those on the southeast, as shown by the difference in the width of outcrop of the same beds on opposite sides of the axis. (See sections A–A and B–B.) The dip to the northwest reaches 70° or 80°; on the southeast it is 10° to 15°. On the axis of this fold rocks as low as Clinton are exposed at Blount Springs. South of Reid Gap the fold is more symmetrical, the northwest and southeast dips running generally 8° to 12°. A dip of 80° NW. was observed in a narrow strip on the west side of the axis 1 mile east of Little Vine Church.

Coalburg syncline.—The Coalburg syncline extends diagonally across the quadrangle between the northeast and the southwest corners. Its shape is shown on the economic geology map by structure contours on the top of the Mary Lee coal. The contours converge northward, showing that the trough is canoe-shaped. In the southwest quarter of the quadrangle the trough is comparatively flat-bottomed, with gently sloping west rim but a steep east rim that stands vertical or in places is overturned with a dip of 40° southeast. The main axial line appears to be nearer to the east side in this southwestern part. Two subordinate axes are indicated—a low anticline running through Mineral Springs and a low syncline running through Brookside. West of Birmingham this trough is affected by a number of short normal faults approximately at right angles to its southeast margin. These faults are shown on the map. They vary in throw from 10 to 110 feet. The fault planes are generally inclined at 70° or more, but a single one is reported with an inclination of 45°. As shown by structure section D–D, the rocks on the southeast rim of the Coalburg syncline are in places overturned and from Cunningham Gap southward their outcropping beds are either vertical or dip to the southeast, apparently passing under older rocks but really changing their attitude below the surface to a northwest dip and passing beneath the coal measures of the syncline. The Coalburg syncline holds the largest area of coal measures and the most valuable coals of the quadrangle.

Opossum Valley fault.—The Coalburg syncline is terminated on the southeast, from the vicinity of Greene southward, by an overthrust fault, presumably with a southeast dip of unknown amount, along which the Conasauga limestone has been pushed up into contact with younger rocks from Knox to Pottsville.

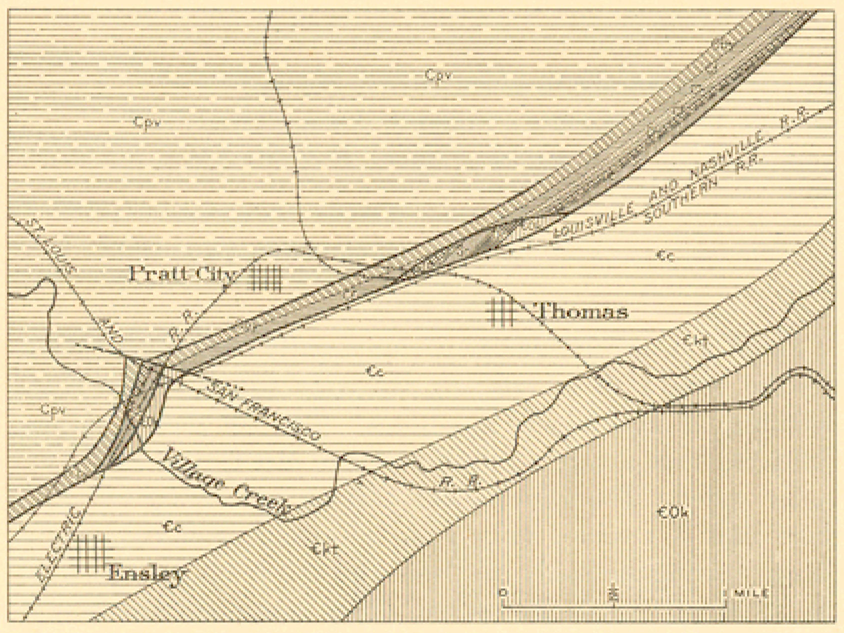


FIGURE 8.—Map of faulted areas in the vicinity of Pratt City and Thomas.

Cpv, Pottsville formation; Cby, Boyles sandstone member; Cf, Floyd shale; Ch, Hartselle sandstone member; Cfp, Fort Payne chert; Dc, Chattanooga shale and Frog Mountain sandstone; Sc, Clinton formation; Oc, Chickamauga limestone; €Ok, Knox dolomite; €kt, Ketona dolomite member: €c, Conasauga limestone.

From Pratt City to Wylam the basal Conasauga or perhaps older rocks are in contact with the Carboniferous, most of the way with the basal Pottsville. The total displacement involved is not less than 7000 feet. At some points the fault is compound, as in the vicinity of Wylam, Pratt City, and Thomas. At Wylam there is apparently a fault in the Pottsville formation parallel to the Opossum Valley fault, for the Boyles sandstone member is nearly in contact with the Pratt coal, and the outcrops of the Mary Lee and Black Creek coals are faulted out, as shown in section E–E on the structure section sheet. At Pratt City and Thomas compound faulting has resulted in the formation of small wedges of strata out of their normal relations, as shown on the sketch map, figure 8. To the north of Tarrant Gap also there is a split in the main fault. The Opossum Valley fault appears to terminate in the vicinity of Greene. If it continues farther north, it affects only the Knox on the surface and its presence can not be detected. With the exception of the cross fault at Pinson, shown on the map, by which the outcrop of the formations is offset, the structure is regular along the east side of the Coalburg syncline.

Pinson anticline.—In the vicinity of Greene station is apparently the beginning of a low anticline which extends northward. This fold is here named the Pinson anticline. It is shown on section C–C. South of Greene the dip of the Conasauga limestone is uniformly eastward, and if the Pinson anticline extends down Opossum Valley it has been overturned, so that all the rocks dip to the southeast. The more common view is that the northwest limb of the anticline has been mostly faulted out, leaving only the southeast limb with its normal southeasterly dips.

Murphrees Valley fault.—From Village Springs to the east margin of the quadrangle, along the east side of Murphrees Valley, is a fault of great magnitude. This fault differs from the Opossum Valley fault in the following respect: Along the Opossum Valley fault older rocks on the east are in contact with younger rocks on the west, whereas along the Murphrees Valley fault the reverse is true, and younger rocks on the east are in contact with older rocks on the west. It is commonly held that the movement producing the faults and folds of the Appalachian Valley has been from the southeast toward the northwest. In most of the faults, as in the Opossum Valley fault, the older rocks on the east side are shoved up over the younger rocks on the west, and such a displacement is called an overthrust fault. In the Murphrees Valley fault, however, the older rocks are on the west and appear to have been overthrust up on the younger rocks on the east. These relations would also result if the rocks on the east had been pushed downward and forward under the older rocks on the west, a displacement which has been called by E. A. Smith an underthrust fault.

The rocks adjacent to the Murphrees Valley fault on the east are overturned and in places have a dip of 45° W., as shown in section A–A of the structure section sheet. This conforms with the first explanation, that of an overthrust from the west upturning and crumpling the strata on the east. On the west of the fault the rocks dip regularly westward, and apparently all of the east limb of an original anticline has been faulted out.

Blount Mountain syncline.—The Blount Mountain syncline is probably a continuous trough extending from Birmingham northeastward through the middle of Birmingham Valley and along Blount Mountain. In the Blount Mountain area the synclinal fold is much deeper than it is farther south and holds rocks as high as Pottsville. (See section A–A.) From Blackoak Mountain northward the rocks pitch visibly northward along the axis of the syncline to Blackburn Fork, north of which the bottom of the syncline is apparently almost flat. From Blackoak Mountain southward the structure is revealed only by the outcrop of lower rocks on each side of the syncline in Opossum and Jones valleys. Along Enon Ridge in Birmingham the syncline is shown by the opposing dips on opposite sides of the ridge. There is probably a broad, flat anticlinal area connecting Jones and Opossum valleys between Kingston and North Birmingham, as shown by the flat-lying area of Ketona dolomite separating the chert ridge to the north from Enon Ridge, which is also composed of cherty dolomite overlying the Ketona.

At the south end of Blount Mountain the structure is considerably complicated by faults, as shown on section B–B. The wedgelike area between the two western faults, including Mills Mountain, appears to have dropped down between the faults and offset to the west the outcrop of the included rocks, which dip northeast. At the eastern fault, between Foster and Meridian mountains, the rocks are downthrown on the east.

A fault extends along the east base of Enon Ridge and then turns to an east-west course through Birmingham to the vicinity of Avondale, then turns northeastward and dies out in the vicinity of Eastlake. Along this fault the Conasauga limestone is thrust up into contact with the cherty Knox of Enon Ridge and with the narrow outlier of the same rocks lying to the west of Avondale and Woodlawn. This fault extends southward in the Bessemer quadrangle to the vicinity of Walnut Grove.

Birmingham anticline.—The Birmingham anticline passes through the city of Birmingham and extends northeastward along Jones Valley through Chalkville, Clay, and Ayres. It appears to be symmetrical, with low dips on the axis.

Cahaba Mountain syncline.—South of Trussville the rocks dip regularly to the east beneath the Cahaba trough, but north of that place the easterly dip is interrupted by a shallow trough and the west limb of an anticline. The flat trough is named the Cahaba Mountain syncline, from Cahaba Mountain, which lies near its axis. The axis rises toward the north, and the syncline therefore has a canoe shape, the outcrops of successively lower formations converging northward and passing around its north end. Southeast of Ayres there is an offset in the axis. The wide areas of the Clinton formation north of Trussville are due to the low dip in this syncline, and the large area of Knox dolomite to the east of the syncline forms the west limb of an anticline whose east limb has been faulted out. Immediately north of Trussville the structure is considerably complicated and not fully understood. The Cahaba syncline probably terminates in the broad area of Bangor limestone west of Trussville.

Red Gap fault.—Red Gap, between Gate City and Irondale, is traversed by a cross fault with steep dip. The fault lies on the course of the highway through the gap and the upthrown side is on the north. This fault may be a broken cross fold or direct shear, the rocks on the south side being offset to the west. Immediately above the road on the north the Fort Payne chert outcrops, while beneath the railroad cut just south of the highway the Fort Payne is more than 100 feet below the bottom of the cut.

Argo fault.—A fault beginning about a mile northeast of Trussville and extending northeastward near Argo to the east margin of the quadrangle is here named the Argo fault. At Argo and for a mile to the south the Fort Payne chert on the east is in contact with the Knox dolomite on the west. The rocks bordering the fault on the east are sharply upturned and vertical (see section B–B), indicating an overthrust from the northwest.

Cahaba syncline.—From the Birmingham anticline south of Trussville and the Argo fault north of Trussville the rocks dip continuously southeastward into the Cahaba trough. The unsymmetrical character of this syncline is shown in section C–C. The rocks dip at angles ranging from 10° to 30° toward an axial line that lies near the southeast margin of the trough. East of the axis the rocks are steep and in places vertical or overturned. The continuity of the fold is broken by the Helena fault, described later, which cuts out the eastern limb of the syncline in places, and by cross faults and low cross folds, which break up the main syncline into a number of independent synclines, or basins, as they are commonly termed. In this quadrangle are two of these basins, named the Henryellen and Little Cahaba basins.

Henryellen syncline. — The Henryellen syncline or basin includes all that part of the Cahaba trough north of the Southern Railway and the west limb of the trough south of the Southern Railway to the waterworks. Its axis is faulted out about 1 mile south of Henryellen.

Little Cahaba syncline.—About 3 miles southwest of Henryellen is the north end of the Little Cahaba syncline or basin, named from Little Cahaba River, which crosses the basin south of the Birmingham quadrangle. This is a distinct U-shaped basin bounded on both sides by faults. It is somewhat unsymmetrical, its southeast limb being steeper than its northwest limb.

Faults south of Henryellen.—About 1 mile south of Henryellen begins a fault that passes southwestward along the line of Hogpen Branch, from which it is named. The continuance of this fault has been established with a good degree of certainty as far south as the pump station 3 miles south of the quadrangle. It forms the boundary between the Little Cahaba and Henryellen basins.

The Helena fault is named from the town of that name to the south of this quadrangle. It is an overthrust fault of probably at least 10,000 feet displacement, the Lower Cambrian Rome formation having been thrust up into contact with the upper part of the Pottsville of the Cahaba coal field. This fault is commonly spoken of as the boundary fault. It extends the entire length of the Cahaba trough and may be continuous with the Rome fault to the northeast.

Three miles southwest of Henryellen a north-south fault connects the Hogpen Branch and Helena faults, the three faults cutting out a wedgelike block including all the formations from Knox to Pottsville. The outcrop of these rocks forms a triangular area inclosed by the faults.

Coosa syncline. — In the extreme southeast corner of the quadrangle is a small part of the Coosa syncline. In this area it is a simple unsymmetrical trough, the dip being much steeper on the southeast limb. This part of the Coosa syncline has been called the Howard Basin in reports of the Alabama Geological Survey. About 1 mile northeast of Leeds is a minor syncline in the Floyd shale.

HISTORICAL GEOLOGY.

The purpose of this section is to give an account of the events recorded in the rocks of the Birmingham region from the time of the deposition of the oldest rocks to the present. The processes by which the rocks were formed, the structures produced, and the mountains and valleys made are explained in the general description on the inside pages of the covers of the folio. Only the history deduced from the records afforded by the rocks outcropping in this area will be described here.

CAMBRIAN PERIOD.

General statement.—The geologic history of the Birmingham district, so far as the records of the rocks exposed at the surface are concerned, may be said to have begun with the deposition of the Rome ("Montevallo") formation. It has been concluded from evidence obtained in other parts of the Appalachian region where older rocks are exposed that at the beginning of Rome time a land mass extended along the east border of North America from Newfoundland to Florida, and perhaps far southeastward. Its western shore lay to the east of the Birmingham district, but how far east is unknown. On the west lay the great central mass of North America, extending from Greenland to northern Mexico. Between the two land masses was a narrow trough extending from the Gulf of St. Lawrence to the Gulf of Mexico, occupied by marine waters. This is known as the Appalachian Strait. East of the eastern land mass lay the Atlantic basin and south of the western continental land mass lay the deeps of the Gulf of Mexico. This was apparently a time of very wide extent of land and great contractions of epicontinental waters. The expansion and contraction of the Appalachian Strait and its ultimate filling up by the sediment washed in from the eroded lands constitute the earlier events of this history.

ROME EPOCH.

During the Rome epoch fine sediment was being discharged into the Appalachian Strait by the streams of the bordering lands. This fine sediment by induration subsequently became shale of the Rome formation. The prevailing absence of coarse sediments, such as become sandstone or conglomerate, suggests that the bordering lands were of low relief, and the absence of limestone probably indicates proximity to the shore, most sandy or muddy sediments being laid down within 100 miles of the shores of the land from which they are derived. The presence of ripple marks and trails in these rocks is indicative of shallow-water deposition. The common red color of the shale further indicates a deeply weathered land surface, on which the mantle of decayed material, soil, etc., has been stained by the long-continued oxidation of iron and accumulation of the oxide.

At times while the deposition of the Rome sediment was going on the conditions were favorable to life, but generally they appear to have been unfavorable, as is indicated by the general scarcity of fossils.

CONASAUGA EPOCH.

The Conasauga epoch appears to have been one of expanding water area, so that, in this part of Alabama at any rate, the prevailing sediment was calcareous and the Conasauga is predominantly limestone. The expansion of the Appalachian Strait may be assumed to have proceeded from the southwest northward, for the rocks of the same age in northeastern Alabama are much more shaly than those of the Birmingham region, indicating nearer shores and therefore mainly clastic sediment. At no time during the Conasauga epoch, however, did the recession of the shores remove them so far from this region that mud was not washed into it to make the shale beds which are everywhere intercalated between the limestone layers.

The source of the calcareous sediment of the Conasauga is unknown. It does not appear to have been produced by the growth of organisms in place, for it is generally without organic remains in this region. Possibly it was derived as limy mud from the more open waters of the Gulf of Mexico to the southwest.

CAMBRO-ORDOVICIAN TIME.

KNOX EPOCH.

The Knox epoch was one of continually expanding epicontinental seas, as is attested by the wide extent of the Knox dolomite or equivalent formations. By the end of Upper Cambrian time nearly all the interior of the United States was under water. The Birmingham district was so far out from shore that it received only pure calcareous sediment, accompanied during probably the later two-thirds of the epoch by the access of considerable silica, which composes the chert of the Knox. The belief that the Knox of this region was deposited at a considerable distance from land is based on the paucity or complete lack of clastic rocks such as shale or sandstone, which would naturally be deposited near a shore.

Many interesting questions that can not be certainly answered arise concerning the origin of the great mass of Knox dolomite. As shown on page 3, the Knox is, in part at least, a nearly pure dolomite and is throughout highly magnesian. It is an unusual kind of rock, and this, together with its great thickness—3000 feet and over—and wide territorial extent, make the question of its origin of much interest and importance. It is safe to say that there is no other such mass of dolomite known on the earth.

The immediate source of the Knox was the sea water, which probably has always contained in solution the constituents of dolomite—lime and magnesium, as carbonates, sulphates, and chlorides; carbon dioxide in various carbonates; and silica. These substances can all be precipitated from solution by evaporation or chemical reaction, and some of them can be extracted by various organisms to form their hard parts, such as coral and the shells of mollusks, which are of lime carbonate, and the spicules of sponges and skeletons of radiolarians, which are of silica. Dolomite may be formed through either one or both of the two processes—precipitation or extraction by organisms—but no large body of dolomite is known to have been formed by precipitation.

Examples are known, however, of originally pure limestone, such as coral-reef rock, which now contains up to 41 per cent of magnesium carbonate, nearly the ratio of that substance in dolomite. In such rock there is clearly an accession of magnesium carbonate, and it is possible that the Knox dolomite originated as limestone which was gradually transformed into dolomite by combination with magnesium from concentrated solutions of magnesium salts. The limestone may have been of organic origin in place, possibly through the agency of lime-secreting algæ, or it may have been transported as an impalpable mud from some region where organisms grew in abundance. If formed largely by lime-secreting plants, the absence of organic remains would be explained, for such plants are minute and fragile and their remains could not be preserved.

The silica from which the chert of the Knox has been derived was probably disseminated in the limy sediment at first. This silica, very likely of organic origin and of the hydrous and soluble variety, was in the course of time segregated into the nodules, stringers, and reefs of chert by solution and exchange of position with portions of the dolomite and was finally changed to crystalline quartz, the form in which the chert exists at the present time.

ORDOVICIAN PERIOD.

POST-KNOX EROSION INTERVAL.

About the close of Knox time there was an uplift along Birmingham Valley, followed by the erosion of the previously deposited Knox. The Knox was probably completely removed in Jones Valley just south of Birmingham, for in that vicinity the next succeeding strata of Ordovician age in this locality, those of the Attalla conglomerate member, rest unconformably upon the Conasauga limestone. In the time represented by this unconformity the Beekmantown limestone or its equivalent was deposited 4000 feet thick in east-central Pennsylvania. Beds of Beekmantown age are absent in Birmingham Valley. Either they were never deposited here on account of the elevation of the region before the close of the Knox epoch, or, if any such deposits were made, they were uplifted and eroded before the deposition of the Attalla conglomerate member and the next succeeding beds of the Chickamauga limestone, the lower part of which corresponds approximately to the Chazy, which succeeds the Beekmantown in eastern New York.

CHICKAMAUGA EPOCH.

The beginning of the Chickamauga epoch was marked by the transgression of the sea over the surface that had been exposed to erosion during all or part of Beekmantown time. The basal deposit of the epoch was the Attalla conglomerate member. This was probably a beach deposit, and its irregular distribution is very likely due to the irregularity of the shore lines as the water overflowed the dissected land surface. The situation can be understood by conceiving the present surface of this region to be submerged. The water would first occupy the valleys, leaving ridges between, and the shore line would be very ragged. As the water crept over the land into the valleys angular fragments of chert and finer rock waste from the land would be washed in to form a conglomerate or breccia. The well-rounded pebbles of quartz and quartzite which are common in the conglomerate may have been washed along the beaches from some distant source, for there is no parent rock near this locality from which they could have been derived. As the water rose only the higher parts of the land would remain as islands and comparatively small quantities of the finer soil would be washed into the expanding bays and lagoons to form shale such as composes the basal beds of Foster Mountain. (See fig. 4.) At the same time animal life would invade the region, flourish in the most favored spots, and furnish the material of limestones such as follow the shale and conglomerate and are to some extent interbedded with them.

Finally the whole region was submerged and the comparatively pure Chickamauga limestone accumulated. There are reasons for believing, however, that a land barrier existed throughout most of Chickamauga time between the Birmingham Valley and Cahaba Valley regions, the principal reason being the difference in the fossils in the limestone in the two localities. They have but few fossils in common, such as it seems likely they would have had if there had been free communication between them.

POST-CHICKAMAUGA EROSION INTERVAL.

In the Birmingham district the Clinton formation follows the Chickamauga limestone. At two localities, however, rocks of intermediate age are known. These are at the top of Butler Mountain and on the west side of Red Mountain at Lone Pine Gap and for about a mile to the south along the Louisville and Nashville Railroad. At the last-named locality there are shale and calcareous sandstone beds up to 40 feet thick carrying a fauna of Upper Ordovician age, roughly corresponding to part of the Lorraine of New York. At the top of Butler Mountain loose slabs of the same kind of rock containing the same Upper Ordovician fauna occur immediately above the Chickamauga.

With the exception of the occurrences just described there are not known in this region any rocks of ages from Trenton to Medina, inclusive, of New York, or of the ages of the Sevier shale and the Bays and Clinch sandstones of Tennessee. The aggregate maximum thickness of these formations is over 3000 feet, so that in the Birmingham region there is an unrecorded interval of time sufficient for the accumulation of more than 3000 feet of rock in other regions.

These fragmentary sediments of Upper Ordovician age were probably deposited in embayments or lagoons on the eroded surface of the Chickamauga limestone after an interval of emergence. Later the sea again withdrew and land conditions probably prevailed until the beginning of Clinton time.

SILURIAN PERIOD.

CLINTON EPOCH.

The Clinton epoch was of the greatest importance to this region, for in that distant age was laid the foundation of Birmingham's industrial greatness. The dry-land conditions just described gave way to a period of submergence along Birmingham Valley and westward to an unknown distance. On the east land probably stood between the Cahaba and Coosa coal fields, for the Clinton formation, which extends to the fault bounding the Cahaba field on the east, does not appear in the section on the west side of the Coosa trough, the Devonian there lying upon the Chickamauga.

The time of denudation intervening between the Chickamauga and Clinton epochs probably brought about conditions favoring the accumulation of the iron ore, which is the distinctive feature of the Clinton. Throughout most of that time not only the area now occupied by the Clinton in this region but probably also the area east of the Appalachian trough was dry land. That this land mass had been subject to long-continued erosion and deep denudation is proved by the enormous quantity of sediment that was probably derived from it to form the great mass of clastic rocks which in the northern Appalachian region intervene between the beds equivalent to the Chickamauga and the base of the Clinton. As stated above, these rocks aggregate over 3000 feet in thickness. As a result of this long-continued erosion the eastern land probably was reduced to a peneplain and deeply covered with decayed rock and a highly oxidized residuum from previous erosion. It is probable that a considerable concentration of iron as ferric oxide had taken place, as appears to be usual in regions long subject to slow erosion. From this lowland on the east gentle streams carried into the Clinton sea the muds forming the shales of the Clinton and at times the sand and fine quartz pebbles of the sandstones. The water at the same time carried much iron in solution, probably as sulphate or carbonate, which as ferric oxide so largely impregnates the Clinton rocks at the present time.

The precise manner in which the richer deposits of iron constituting the workable ore beds were accumulated is a debated matter. There are two views—that the iron was deposited at the same time as the beds in which it now occurs and that it was introduced into those beds subsequent to their deposition. The first may be called the original-deposition theory, the second the replacement theory.

The richer ore bodies are highly calcareous and the impressions of the fossil brachiopods, bryozoans, etc., from which the carbonate was derived are abundant in much of the ore. According to the original-deposition theory, iron was precipitated by the lime carbonate from solution. The iron in the shale and nonfossiliferous sandstones was probably precipitated by the agency of evaporation or chemical reactions other than that with lime carbonate.

The richer and thicker ore deposits, such as the Big seam of Red Mountain, were probably accumulated in more or less sheltered embayments or lagoons, from which for the time clastic sediment, mud, etc., were more or less completely excluded. At the same time lime-secreting organisms flourished and their shells, skeletons, etc., accumulated in the shallow water and perhaps along the flat beaches, where they were to some extent broken up by waves. Gradually these remains formed a layer of shells similar to the coquina of the present Florida beaches. In the interstices of this mass of comminuted shells and on their surfaces iron was precipitated. Much iron was also, by alternate wetting and drying, precipitated around sand grains or other nuclei to form the oolitic or flaxseed ore, just as calcareous oolites form on coral beaches at the present day. Subsequently there was doubtless much interchange of iron and lime, so that the organic remains were replaced by iron and the lime segregated by itself, yielding as a final product the limy or hard ore as it is found at the present time.

The advocates of the replacement theory would probably grant that limestone beds were accumulated in sheltered situations, as described above. According to that theory, however, the iron was dissolved by percolating meteoric waters from the superjacent rocks and carried down to the limestone beds. These were then partly dissolved and removed by the water and iron deposited in place of the lime carbonate.

Among the reasons advanced in support of the replacement theory are the following: Deposits of iron are known to be made by replacement of limestones; the decrease in the metallic content of the ore with increase in depth was considered to show that replacement of limestone had not been so complete at the greater depths because the circulation of water had been less free; the original-deposition theory involves very rapid deposition of iron to form the richer ore beds. Against the replacement theory it is urged that the enrichment of the superficial ore has been due to the leaching out of the lime carbonate in the zone of weathering, with proportional increase of the insoluble parts, including the iron oxide, and that the hard or limy ore does not decrease materially in metallic content below the lower limit of weathering; that good ore beds occur immediately beneath limestone beds, and it does not seem probable that a solution of iron would be carried through one limestone to be deposited in another just below it; that particles of iron oxide are found inclosed by lime, showing the deposition of lime carbonate subsequently to that of iron oxide; and that there are all gradations from the richer limy ores to ferruginous sandstones. It is generally agreed that the iron in the sandstones is an original deposit, and a probably correct inference is that it was also an original deposit in the contiguous limestone layers.

A circumstance favoring replacement not usually considered may be mentioned. During the later part of the Silurian period and most of the Devonian period the Clinton formation in Alabama was probably under only a thin cover of overlying rocks and circulating meteoric water would have had free access to the beds of that formation, so that there was ample time and opportunity for replacement to have occurred before the Clinton was buried under later deposits.

POST-CLINTON EROSION INTERVAL.

In Alabama there are no rocks corresponding in age to the Salina formation and Manlius limestone of the late Silurian and the Helderberg of the early Devonian, which in New York and Pennsylvania intervene between the Clinton and the Oriskany sandstone. In central Pennsylvania these rocks are over 1500 feet thick. No record of this time is preserved in Alabama nor in the most southern parts of the Appalachian region, so that what took place there during those periods is purely conjectural. It can only be said that neither uplift nor erosion could have been very great, for if it had been the Clinton formation would have been swept away.

DEVONIAN PERIOD.

ORISKANY EPOCH.

The Frog Mountain sandstone is undoubtedly of Oriskany age. The Oriskany epoch was one of widespread transgression of the sea in the northern part of the Appalachian province. The water reached the Birmingham region, but that it probably invaded only the low places of the Clinton surface, forming embayments and lagoons, is indicated by the patchy character of the Frog Mountain sandstone. In many places only the Chattanooga shale lies between the Clinton and Fort Payne. Along the east side of the Coosa trough, however, the Frog Mountain sandstone is continuous, indicating complete submergence.

The Frog Mountain is generally a coarse quartz sandstone and is very coarse and thick in the type locality near Rome, Ga. It indicates an uplift of the region whence it was derived, with a revival of the drainage, so that the streams could transport coarser material than before. The land was that already described as lying along the Atlantic coast east of the Appalachian Gulf.

CHATTANOOGA EPOCH.

In parts of the Birmingham quadrangle the Chattanooga shale is no more than a foot thick and is the sole representative of the late Silurian and Devonian rocks, which in central Pennsylvania aggregate 8500 feet. In other words, in Pennsylvania the Clinton and Pocono are separated by at least 8500 feet of rocks, but in the Birmingham district the Clinton is separated from the Fort Payne, which is broadly equivalent to the Pocono, by only 1 to 20 feet of Chattanooga shale. To all appearances the thickness of the shale decreases uniformly from 20 feet at Blount Springs to 1 foot at Birmingham. So far as exposures in this region show, the bedding of the shale is parallel with the underlying Clinton and the overlying Fort Payne, and without a knowledge of other sections one might never suspect that deposition was not continuous from Clinton to Fort Payne time.

The distribution of the Chattanooga shale shows that during a part of the Devonian period water covered this region and fine carbonaceous sediment was deposited. The position of the shore lines and the source of the sediment are unknown, though it is a plausible supposition that the old land to the southeast, again worn down to a peneplain, supplied the fine mud which may have been transported far through low swampy areas, supporting vegetation from which was derived the carbonaceous matter that gives to the shale its black color.

The Birmingham region apparently remained practically at sea level before and after the deposition of the black shale, neither receiving deposits nor losing material by erosion. It seems improbable that there could have been much erosion after the deposition of the Chattanooga, else it would be much less uniformly distributed than at present.

CARBONIFEROUS PERIOD.

FORT PAYNE EPOCH.

At the close of Devonian time there was another widespread transgression of the epicontinental sea and the whole interior of the United States was submerged. The old eastern land mass seems to have persisted and to have been connected through New England and northeastern New York with the Canadian land mass north of the Great Lakes. The Alabama region appears to have been covered by the advancing water at a somewhat later date than the central Mississippi Valley, for the Kinderhook of the latter region, forming the basal Mississippian, is apparently lacking in the vicinity of Birmingham.

The Fort Payne chert appears to correspond to the Burlington and Keokuk limestones of the Mississippi Valley and shows the complete submergence of the region at that time. Clear seas prevailed, for the rocks are mainly chert and limestone, and very little clastic material was being received. The source of the silica in the chert is unknown. It may have been either clastic silica or organic silica from silica-secreting organisms mixed with the calcareous matter. It probably was originally disseminated and subsequently it segregated and underwent a change to crystalline quartz in the process. The nearly pure chert on the outcrop is perhaps due to leaching of the calcareous contents of the rock, for specimens brought up from considerable depth in deep borings show the silica in nodules and irregular plates and stringers in limestone.

BANGOR EPOCH.

The Bangor epoch includes the time of the deposition of the Bangor limestone and the lower three-fourths of the Floyd shale. During this epoch submergence of the region continued, but the conditions which permitted the deposition of sediment like the Fort Payne far to the southeast of Birmingham changed, and the muddy sediment of the Floyd shale extended northwestward, so that by the middle of the epoch clastic sediment predominated as far northwest as a line roughly drawn through Trussville and Sayreton Gap. Northwest of this line clear water prevailed and limestone deposition was uninterrupted. For a time, however, coarse quartz sand was washed in and spread widely over the calcareous sediment to form the Hartselle sandstone member. The Floyd, the Hartselle, and the mud making the partings and occasional layers of clay in the Bangor limestone were all derived from the southeastern land mass. The Floyd is supposed to be a near-shore deposit laid down at the same time that the calcareous sediment of the Bangor limestone was accumulating in the clear water farther from the shore.

The conditions in this region during the Bangor epoch were particularly favorable to animal life and innumerable individuals of a great variety of forms lived in the waters of both the Bangor and the Floyd areas.

PENNINGTON EPOCH.

The Pennington epoch includes merely the time during which the Floyd type of sediment spread over the western region in which the Bangor limestone had formerly been deposited. After the Bangor limestone deposition ceased in this region only clastic deposits were laid down.

PARKWOOD EPOCH.

The coarse sandstones and sandy shales of the Parkwood formation indicate a great increase of erosional activity, possibly due to climatic changes with increased precipitation, or to an elevation of the land whence the sediments were derived. At the same time there must have occurred a comparatively rapid sinking of the sea bottom to permit the accumulation of so great a thickness of comparatively shallow-water rocks. Conditions were unfavorable to life and the sea bottom was generally destitute of living beings. At widely separated times some brachiopods and pelecypods lived in places, but they were few in species and the individuals were few and small.

EROSION INTERVAL.

Either during or after the Parkwood epoch there must have been strong warping of the earth's crust in this region. This conclusion is based on the distribution of the Parkwood and the stratigraphic relations of the succeeding Pennsylvanian rocks. Two alternative hypotheses may be entertained. The Parkwood may have been deposited over the Warrior Basin in continuity with the area east of Shades Valley, and afterward the Warrior area may have been uplifted and eroded before the deposition of the coal measures (Pottsville formation). Another hypothesis is that the warping began early in Parkwood time, the Warrior area rising above the sea, so that no sediments were deposited in it, and the area east of Shades Valley subsiding with continuous deposition. It is certain that the Pennington was deposited horizontally over the entire area, for it can be recognized between the Bangor and the coal measures of the Warrior field and at the base of the Parkwood in Blount Mountain and on the west side of the Cahaba coal field.

POTTSVILLE EPOCH.

The trough along the Cahaba-Coosa axis that began to form perhaps in Parkwood time continued and may have deepened throughout Pottsville time. A deep and comparatively narrow depression extended along the western margin of the old land mass from eastern Pennsylvania to Alabama, and in it were deposited the earliest coal-bearing rocks—the rocks of the anthracite field in Pennsylvania, of the New River and Pocahontas fields in West Virginia, of the Cumberland field in Tennessee, and of the Alabama coal fields. The coarse sediments, including in places great quantities of large quartz, quartzite, and chert pebbles, indicate an elevated land to the east, with consequent steep slopes, affording currents strong enough to bear the coarse sediment to the sea. Possibly the climate was humid and precipitation copious, affording abundant water and strong currents, by which the transportation of the coarse sediments was easily effected.

The distinguishing feature of the Pottsville is its coal. This makes it equal to the Clinton in economic importance to the Birmingham district. Coal consists of the metamorphosed remains of plants. The abundant vegetation of the Pottsville indicates a humid climate.

Coal beds have been formed for the most part by the accumulation of vegetal matter on the spot where it grew, in a manner similar to the accumulation of peat. The vegetal matter was derived from plants growing in marshes or on the low shores bordering marshes. The stems and leaves of plants, including trees of large diameter and great height, falling to the ground, were more or less completely covered by water and preserved from decay. After these were accumulated in thick and possibly very extensive deposits they were slightly submerged and a deposit of sand and mud was spread over the area. In time the bottom was built up to the water level, marsh conditions were restored, and another coal bed accumulated.

Many repetitions of this process occurred in this region during Pottsville time. That the Birmingham area lay near sea level throughout the epoch is attested by the occurrence of marine fossils at a number of horizons from top to bottom of the coal measures in the Warrior field. These fossils afford conclusive evidence of the recurrent invasion of the area by sea water. The plants that formed the coal could not live in salt water, however, so the area must have been above sea level most of the time. Still, it could never have been much above, for if it had been the previously formed coal beds would have been cut up by stream channels or largely eroded away. Moreover, any considerable uplift above sea level would have involved a correspondingly great downward movement to permit the frequent incursions of the sea with its marine organisms, and it is not likely that such extreme movements took place. The facts can probably be all explained by assuming constant but intermittent subsidence. A coal bed was formed and then subsidence ensued, with advance of the sea and marine life, gradual silting up to water level, the accumulation of another coal bed, a second subsidence, etc. Temporary submergence occurred at times during the accumulation of the coal beds and fine mud was washed upon the vegetal matter, forming the partings of clay or shale in the coal beds.

The great thickness of the Pottsville in the Cahaba field shows very rapid deposition of sediment, 6000 or 7000 feet accumulating in that area, while only half as much, or even less, was laid down in the Warrior field. The greater thickness and coarseness of the rocks of the southern part of the Cahaba field and the still greater thickness of the coal measures of the Coosa field farther southeast suggest that the source of the Alabama Pottsville lay in that direction.

POST-POTTSVILLE HISTORY.

No consolidated rocks younger than the Pottsville remain in this region, and it is probable that it has been dry land during most of post-Pottsville time. It is known from the rocks of the Pennsylvania-Ohio-West Virginia region and the Mississippi Valley that subsidence and submergence, with the deposition of sediment, continued in the northern part of the Appalachian province until the end of Permian time. The absence of rocks of later age than Permian shows that in post-Carboniferous time uplift has prevailed in the Appalachian province instead of subsidence and the region has been dry land undergoing erosion. In connection with the general uplift of the region along the Appalachian Valley there was extreme folding and faulting of the originally flat rocks. These movements were subsequent to the Permian epoch, for Permian rocks were involved. In this period of folding and faulting were produced the varied inclinations of the strata and the great thrusts or faults, such as bound the Warrior and Cahaba coal fields on the east and the Blount Mountain field on the west. These deforming movements resulted from lateral pressure in the crust, probably caused by shrinkage of the interior of the earth in cooling. The rocks yielded to the pressure and were folded and faulted along a belt extending from Alabama to Canada, and it is believed that there was a general crustal movement from southeast to northwest extending to considerable depth. Along such a fault as that bounding the Warrior field the total thrust may have been several miles, so that the rocks of the west side of the Cahaba field are that much nearer the Warrior field than at the time of their deposition.

CUMBERLAND (CRETACEOUS) PENEPLAIN.

Adjustment of the earth's crust in the Appalachian province and of the forces tending to deformation was finally accomplished, and a long time ensued in which the crust moved neither up nor down. Erosion of the stationary surface continued as it had been going on in the past, the effect being to lower the general level and reduce the inequalities of the surface of nearly the whole Appalachian province. The coal measures and lower rocks were worn away from the crests of the anticlines, leaving the detached coal fields of the present time. Much of the surface was ultimately worn down nearly to a plain probably near the level of the sea. This was the Cumberland peneplain, described on page 1. Slight subsidence after the surface was worn down very low caused the sea to creep landward over the peneplain, upon which sediment was deposited. In this region were laid down the clay and sand which now constitute the Tuscaloosa formation, of Upper Cretaceous age. There is none of the Tuscaloosa formation in this quadrangle now, but its northeast margin is only 25 miles down the valley southwest of Birmingham, in the vicinity of Tannehill, and it may have once extended into the Birmingham quadrangle and have been removed by erosion. The Tuscaloosa of course lay unconformably upon the rocks forming the surface of the peneplain.

Attention may well be directed here to the strongly meandering character of Warrior and Cahaba rivers. It is possible that their courses were established on the Cumberland peneplain, for the tendency of streams to develop meanders on flat lands with very low gradient is well known.

It is shown by the above account that the uplift, folding, faulting, and erosion of this region down to the formation of the Cumberland peneplain took place between the end of the Permian epoch and the middle of the Cretaceous period. These are the only two geologic dates in the post-Pottsville history of the region that it is possible to determine with any certainty.

HIGHLAND RIM PENEPLAIN.

Subsequent to the formation of the Cumberland peneplain there was a regional uplift, carrying the surface of the peneplain to more than 1000 feet above the sea in the Cumberland Plateau region. Then there was another period of repose, in which the Highland Rim peneplain (possibly of the same age as the Harrisburg peneplain of Pennsylvania) was eroded. This plain is especially well developed west of the margin of the Cumberland Plateau, where it now stands 1000 feet above the sea. The uplift was of the nature of a tilt, the Cumberland region being elevated much and the Birmingham region but little, or possibly not at all, whence it resulted that the Highland Rim and Cumberland peneplains converge southward and in the Birmingham region are not separately distinguishable. The date of the Highland Rim peneplain is supposed to be early Tertiary, though there is but little ground on which to base a judgment as to its age.

COOSA PENEPLAIN.

The period of repose during which the Highland Rim peneplain was developed was apparently succeeded by another uplift and halt, followed by erosion along streams nearly to base-level and the formation of the Coosa peneplain, described on page 1.

TERTIARY PERIOD.

LAFAYETTE EPOCH.

In the latest part of the Tertiary (Pliocene) or perhaps in the earliest part of the Quaternary period gravel and loam of the Lafayette formation were spread over all the coastal plains of the Gulf and the Atlantic. The source and the manner of transportation and distribution of the Lafayette, as well as its age, are mooted questions. There is so little, if any, undisturbed Lafayette remaining in the Birmingham quadrangle that these questions will not be discussed here.

QUATERNARY PERIOD.

After the deposition of the Lafayette, and probably in the Pleistocene epoch, gravels were deposited along the streams when their channels were higher than the present water level; these now form the higher terrace gravels. Slight uplift with rejuvenation of the streams, probably in the Recent epoch, caused the erosion of the deep-stream gorges of the present time. In thus intrenching themselves the streams maintained the meandering courses previously established, possibly on the Cretaceous peneplain. Thus are also explained the courses of the streams through the ridges described on page 2. It is probable that the mantle of Lafayette that once covered the quadrangle has been mostly washed away, leaving if any only scattered patches. Also in Recent time the lower terrace gravels along Warrior River and some of the larger creeks have been deposited, the material having been derived from the Lafayette deposits. More recently was laid down the alluvium of the existing flood plains, which is still being deposited at each overflow.

ECONOMIC GEOLOGY.

General statement.—The mineral resources of the Birmingham quadrangle consist of coal, iron, dolomite and limestone, shale and clay, road metal, chert, building stone, sand, lime and cement, soil, and water. The most important 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 factor of prime importance in the profitable conduct of the iron-making industry is the proximity of the deposits of coking coal, iron ore, and dolomite or limestone to each other. Red Mountain forms the western edge of the ore-bearing area; Sand Mountain, 5 miles distant, constitutes the eastern edge of the Warrior coal field; and in the valley between is the dolomite. The raw materials are therefore cheaply assembled for iron smelting.

COAL.

The areas of the Alabama coal measures (Pottsville formation) are naturally grouped in four different fields—the Warrior, Plateau, Cahaba, and Coosa fields. This quadrangle includes parts of all these fields, the part included in the Warrior field being by far the most important, since the eastern part of that field contains the best coking coal of the Birmingham district. In the portion of the Warrior field lying in the quadrangle there are two coal areas—that in the vicinity of Arkadelphia, named the Bremen district, and that of the Coalburg syncline, called the Pratt Basin. These areas, though separate in this quadrangle, are united a short distance to the southwest. The Warrior and Plateau fields are continuous along the Coalburg syncline, and the boundary between them is arbitrarily fixed here at a line crossing the syncline where it is narrowest, say on a line passing from Chepultepec through Tidwell to Tumlin Ford. The areas of the Rosa and Berry Mountain coals, which are worked in the region, lie to the northeast of this line.

In this quadrangle, as in the Alabama coal fields generally, the coal is of the high-grade bituminous variety, all of it being excellent for steam and domestic purposes and much of it for coke and gas making. The coal along the east side of the Warrior field is regarded as the best coking coal in the State. As shown by the analyses of 23 samples of these coals collected in the standard manner and analyzed as they came from the mine (see table on p. 20), they range in composition from 1.65 to 3.40 per cent moisture, 25.47 to 30.81 per cent volatile matter, 54.08 to 65.29 per cent fixed carbon, 2.77 to 15.64 per cent ash, and 0.57 to 4.24 per cent sulphur, the average composition being approximately 2.4 per cent moisture, 28.4 per cent volatile matter, 59 per cent fixed carbon, 10.2 per cent ash, and 1.74 per cent sulphur.

COALS OF THE WARRIOR FIELD.

The coals of the Warrior field have been fully described and mapped by McCalley,[a] and the writer expresses here his indebtedness to this report for much information. In this quadrangle the workable coal beds of the Warrior field, from below upward, are the Black Creek, Jefferson, Jagger, Blue Creek, Mary Lee, Newcastle, Nickel Plate, and Pratt coals. The Gillespie, Curry, American, and Cobb coals are of little importance and, so far as the writer could determine from actual observation, hardly deserve to rank as workable.

The coals of the Warrior field are more or less distinctly separated into groups, which were recognized and named by McCalley as follows: The Black Creek coal group, including the Black Creek, Jefferson, and Lick Creek coals; the Mary Lee coal group, including the Jagger, Blue Creek, Mary Lee, and Newcastle coals; the Pratt coal group, including the Gillespie, Curry, American, Nickel Plate, and Pratt coals; and the Cobb coal group, including the Cobb upper and lower coals. The following description begins with lowest workable coal and proceeds upward.

[a] McCalley, Henry, Report on the Warrior coal basin, Alabama Geol. Survey, 1900.

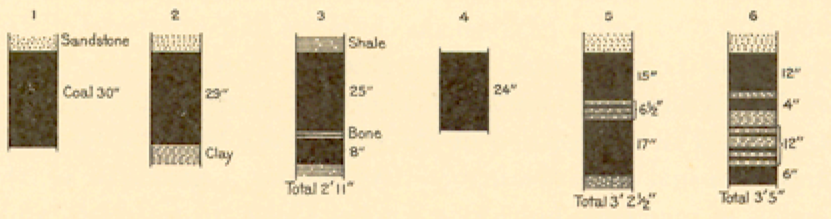
Coals below the Black Creek bed.—There is no evidence to show that any of the coals below the Black Creek are workable on a commercial scale in the Warrior field. In favorable situations a little coal can be obtained for local use from lower beds, as from the Rosa coal in Berry Mountain and Dry Creek Mountain, but the coals are not sufficiently important to merit detailed description.

BLACK CREEK COAL GROUP.

Black Creek coal.—The Black Creek coal is probably workable over a larger area than any other coal in the Warrior field. It is known to be 2 feet or more thick along its entire outcrop from Black Creek station, on the Louisville and Nashville Railroad, south of Newcastle, to Lehigh, at the northern extremity of the outcrop, and thence to the vicinity of Littleton, where the outcrop crosses the quadrangle boundary. South of Black Creek station to Pratt City there is uncertainty in distinguishing the Black Creek from the Jefferson bed. South of Pratt City the outcrop is apparently faulted out. The Black Creek is also workable in the Bremen district.

The coal bed is generally about 2 feet thick and consists of clean coal without partings. In apparently small areas it is less than 2 feet thick and in others it has partings and is thicker. Its character under the Pratt Basin is unknown, but it may fairly be assumed to run 2 feet thick on the average. If this assumption should prove true, the Black Creek bed contains more coal than any other in the quadrangle except the Mary Lee. The quality of the Black Creek coal is of the very best.

FIGURE 9.—Sections of the Black Creek coal.



1. One mile north of Creel.
2. Two miles northwest of Arkadelphia.
3. Three miles east of Bremen.
4. One mile north of Sayre.
5. Coaldale.
6. Pratt City.

Scale: 1 inch=5 feet.

A few selected sections which illustrate the make-up of the bed in the Bremen district are shown in figure 9 (Nos. 1 to 3) and others are given below.

(*a*) *Section of Black Creek coal bed in the SW. ¼ sec. 23, T. 13 S., R. 4 W., 2 miles southeast of Arkadelphia.*

	Ft.	in.
Shale	8	
Coal	2	4
Clay.		

(*b*) *Section of Black Creek coal bed on the east side of sec. 10, T. 13 S., R. 4 W., 1½ miles northeast of Arkadelphia.*

	Feet.
Shale.	
Clay	1
Coal	2
Shale	20

(*c*) *Section of Black Creek coal bed in the SW. ¼ sec. 24, T. 12 S., R. 4 W., 3 miles southeast of Bremen.*

	Feet.
Sandstone, massive	50
Coal	1
Clay	2
Sandstone.	

(*d*) *Section of Black Creek coal bed in the NE. ¼ sec. 26, T. 12 S.; R. 4 W., 2 miles southeast of Bremen.*

	Ft.	in.
Sandstone	8	
Coal	2	4½
Clay	1	

(*e*) *Section of Black Creek coal bed in the SE. ¼ sec. 15, T. 12 S., R. 4 W., 2 miles east of Bremen.*

	Ft.	in.
Sandstone	15	
Shale	1	
Coal		6
Bone	1	
Coal		2½
Shale	1	3
Coal (amount seen)		9
Total coal bed	3	8½

In the vicinity of Creel the Black Creek bed is the only one of importance, though the Jefferson may be locally workable in the isolated areas on the hilltops. The coal of the Bremen district is near the hilltops, the largest body being on Arkadelphia Mountain. It is well protected by a bed of sandstone, in places about 100 feet thick, called the Bremen sandstone member, which commonly in this district makes the roof of the coal.

Generally in the Bremen district the Black Creek coal is 2 to 2½ feet thick, without partings of consequence. At a few points it is only 12 to 18 inches thick (section *c*, above), but such thicknesses are exceptional and probably the coal is not so thin over any considerable areas. On the north end of Arkadelphia Mountain the coal bed is more complex, as shown by sections *e*, above, and 3, figure 9. In section *e* it is not certain that the full thickness of the bottom bench of coal was exposed and measured.

In the Pratt Basin the Black Creek appears to be workable for nearly the full length of its outcrop, though in places it may be of less than workable thickness. Sections 4 to 6 in figure 9 and the sections given below exhibit its general condition.

(*f*) *Section of Black Creek coal bed in sec. 28, T. 14 S., R. 3 W., west of Watts.*

	Ft.	in.
Shale	5+	
Coal	2	2
Shale.		

(*g*) *Section of Black Creek coal bed at Lehigh No. 2 mine, Lehigh.*

	Feet.
Shale	2
Coal	2
Fire clay	2

(*h*) *Section of Black Creek coal bed at Bradford No. 1 mine, Bradford.*

	Ft.	in.
Shale	2	
Coal	2	4

(*i*) *Section of Black Creek coal bed in the SW. ¼ sec. 17, T. 16 S., R. 2 W., at old Newcastle slope, Newcastle.*[a]

	Ft.	in.
Shale	15	
Coal	1	4
Black shale		¼
Coal		11
Black shale		¼
Coal		4
Shale	1	6
Total coal bed	4	1½

(*j*) *Section of Black Creek coal bed in sec. 11, T. 17 S., R. 3 W., 1 mile north of North Birmingham.*

	Ft.	in.
Shale.		
Coal		11
Clay		1½
Coal		2
Clay		1
Coal	1	7
Clay	2	
Total coal bed	2	10½

Along the western outcrop the bed appears to hold a nearly uniform thickness of 2 feet, so far as could be judged from the rather meager data obtainable. All over the region around Watts and Warrior the Black Creek runs from 20 to 32 inches, in most places solid coal. The thickness in the Wolf Den mine at Warrior is reported to be 18 to 30 inches. At Coaldale the bed contains a parting 4 to 6 inches thick and varies considerably within short distances but usually has at least 2 feet of solid coal. Between Coaldale and Lehigh the thickness is 2 to 3 feet. On the east side of sec. 4, T. 14 S., R. 2 W., it is 40 inches. South of Gurley Creek and along Self Creek the coal is shown by borings made by the Louisville and Nashville Railroad Company to be 30 to 38 inches thick and, so far as shown by the records, without partings. In the Indio shaft it is reported 2 feet 6 inches to 3 feet 4 inches thick, and in an old shaft near Morris it is 2 feet 6 inches thick underlain by 3 feet of clay. Sections *i* and *j*, above, and 6, figure 9, show about all that is known of the coal from Turkey Creek to Pratt City.

The roof of the Black Creek coal is usually good; it is sandstone in some places and shale in others. A heavy sandstone overlies the coal on Gurley Creek and is well exposed at Smith Mill, which is built upon it. Along the western outcrop and along the eastern outcrop as far south as Turkey Creek the dip is light, but farther south it is generally steep. Northwest of Pinson, in sec. 26, T. 15 S., R. 2 W., the rocks inclosing the coal are much disturbed and stand vertical over a small area, as shown by the structure contours on the economic geology map. From this point to Newcastle the rocks adjacent to the outcrop are more or less folded and warped. On the Louisville and Nashville Railroad 1 mile north of Newcastle the rocks are vertical for a short distance. It does not appear that this attitude extends over any considerable area, though steep dips exist immediately east of the vertical rocks. The rocks appear to flatten out a few rods west of the vertical strip. The vertical rocks are commonly spoken of in the region as marking a fault, but it is equally probable that their position is due only to a sharp fold or pucker of local extent. As shown on the map, the outcrop of the Black Creek coal terminates just east of Pratt City in a fault, and it does not reappear between that point and the vicinity of Virginia, in the Brookwood quadrangle, 13 miles to the southwest. The condition southwest of Pratt City is shown in the structure section through Wylam on the structure section sheet.

Jefferson coal.—The Jefferson coal is much less generally workable than the Black Creek. It is workable along its outcrop on Locust Fork, from the vicinity of Warrior to the point where it passes beneath the river in sec. 4, T. 15 S., R. 3 W., and it may be workable in the same region over a wider area, as indicated by the mapping of the outcrop with dash lines. It is of good thickness under Morris, as shown by an old shaft on the Moss property, and at Indio, but it does not appear to be of workable thickness on its outcrop northeast of Warrior, in T. 14 S., R. 2 W., nor from Bradford to Pratt City. In the township just named many observations show only 4 to 15 inches of coal. It is a reasonable assumption that a workable body of the coal extends from its western outcrop along the river southwest of Seloca to Indio, but the full extent of this workable area is not known. On the Southern Railway a short distance west of Littleton, in the Jasper quadrangle, a coal 2 feet 5 inches thick has been cut that appears to be in the position of the Jefferson, and a coal apparently of good thickness to the west of Sayre also may be the Jefferson bed. At an opening on this bed in the SW. ¼ sec. 20, T. 15 S., R. 4 W., the coal is reported to be 3 feet thick.

The sections in figure 10 and the others given below illustrate the physical make-up of the bed.

(*a*) *Section of Jefferson coal bed in sec. 31, T. 14 S., R. 3 W., at mouth of Painter Creek.*

	Feet.
Shale	5
Coal	1
Clay.	

(*b*) *Section of Jefferson coal bed in sec. 28, T. 14 S., R. 3 W., 1½ miles west of Watts.*

	Ft.	in.
Coal		8½
Bone		1½
Coal		10
Clay		½
Coal		6
Clay.		
Total coal bed	2	2½

(*c*) *Section of Jefferson coal bed at Seloca mine, Seloca.*

	Ft.	in.
Coal	1	3
Bone		2
Coal	1	8
Shale		6
Coal		8

(*d*) *Section of Jefferson coal bed in shaft on Moss property, half a mile southeast of Morris.*

	Ft.	in.
Sandstone	35	
Coal	4	3
Clay	3	

(*e*) *Section of Jefferson coal bed at Smith Mill.*

	Ft.	in.
Shale	15	
Coal		10
Clay	2	
Sandstone.		

The sections at Seloca and Kimberly show the Jefferson in its normal condition in the northwestern part of its workable area. Between Seloca and Warrior, however, the bed apparently splits into two or in one place into three benches separated by 10 to 20 feet of shale. It is not unlikely that the partings of clay and bone at Kimberly and Seloca thicken toward the north and separate the benches of the coal bed as they are in the vicinity of Warrior. The upper bench of the bed also becomes in part black band ore, and at its extreme northern outcrop at the old Hoene mines is said to approach within 2½ feet of the Black Creek coal bed. These conditions and relations are shown in the sections 4 to 6, figure 10, and in the sections given below.

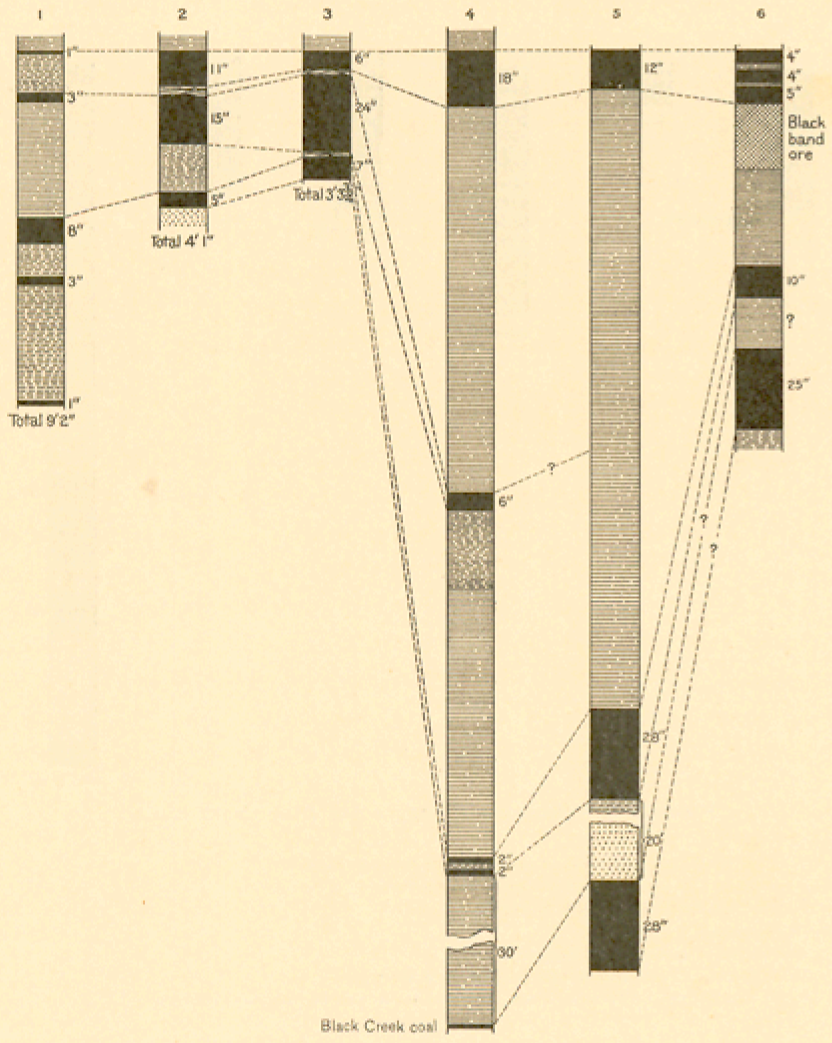


FIGURE 10.—Sections of the Jefferson coal.

1. Black Creek station, Louisville and Nashville Railroad.
2. Indio shaft.
3. Kimberly mine No. 1.
4. One mile southwest of Warrior.
5. Pierce, new shaft, Warrior.
6. Hoene drift.

In sections 4, 5, and 6 the relation of the Jefferson to the Black Creek coal below is shown.

Scale: 1 inch=5 feet.

(*f*) *Section on road just above west end of river bridge at Warrior.*

	Ft.	in.
Shale	40	
Jefferson:		
Coal { Coal, 7 inches; Clay, 6 inches; Coal, 2 inches }	1	3

[a] McCalley, Henry, Report on the Warrior coal basin, Alabama Geol. Survey, 1900, p. 15.

	Ft.	in.
Clay	2	
Shale	20	
Coal { Coal, 8 inches; Parting, 1 inch; Coal, 10 inches }	1	7
Clay	2	
Shale	25	
Concealed	15	
Coal (Black Creek).		
	106	10

(g) Section in the NE. ¼ sec. 13, T. 11 S., R. 3 W., in Wolf Den Hollow, just east of Warrior.[a]

	Ft.	in.
Coal	1	9
Black band	1	2
Shale and sandstone	33	
Coal with partings (Black Creek)	3	10
	39	9

(h) Section at Coaldale shale pits.

	Ft.	in.
Shale	20	
Jefferson:		
Coal	1	
Shale	30	
Coal	1	3
Shale	5	
Sandstone	20	
Shale	5	
Coal (Black Creek).		
	82	3

Lick Creek and Ream coals.—No evidence has been obtained by this Survey that the Lick Creek and Ream coals are of workable dimensions in this quadrangle.

MARY LEE COAL GROUP.

Jagger coal.—The Jagger coal is persistent but of varying thickness in the Birmingham quadrangle. So far as could be learned, it is not workable on a commercial scale except possibly in small areas. It is closely associated with the Lick Creek sandstone member, being beneath the top bench of that member southwest of Whites and Trouble creeks and above the bottom bench northeast of Crooked Creek. It was noted under conglomerate along the Southern Railway just west of Littleton. On Trouble Creek a bed supposed to be the Jagger underlies a conglomerate and is reported by a man who helped open it to be 2½ to 3½ feet thick. Two openings about half a mile apart were visited, but the coal could not be seen. On the south bluff of the river one-fourth mile west of the mouth of Whites Creek the coal is as shown in section 1, figure 11. From this point it thins eastward to Crooked Creek, as shown in sections *a* and *b*, below, and section 2, figure 11, but preserves its physical make-up of two benches of coal separated by a parting of bone and clay.

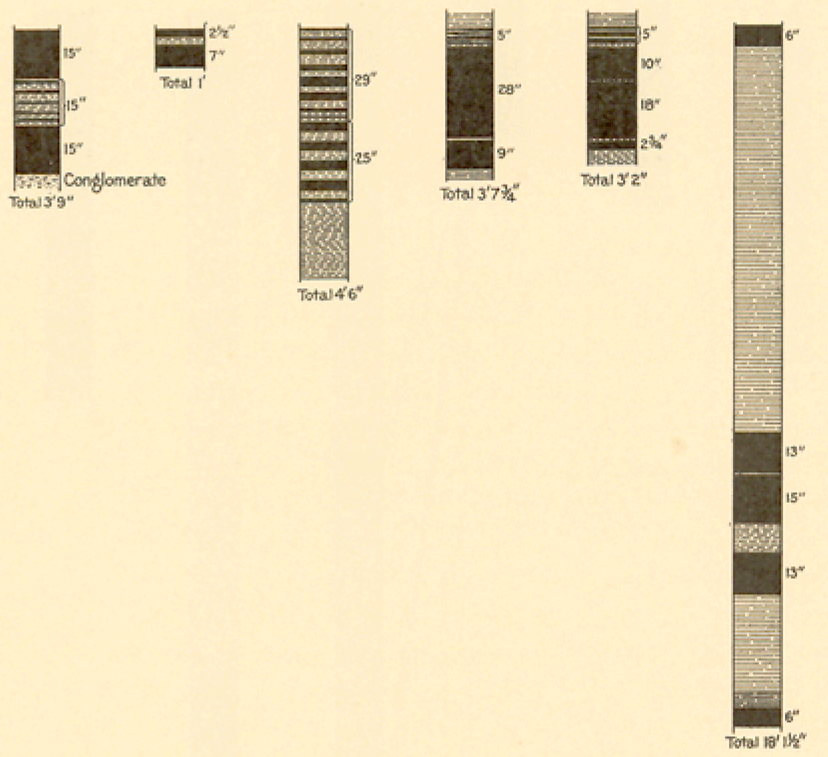


FIGURE 11.—Sections of Jagger and Blue Creek coals.

Jagger coal:
1. River bluff just southwest of the mouth of Whites Creek.
2. Crooked Creek just above bridge of Morris road.
3. Near Kimberly mine No. 2, Kimberly.

Blue Creek coal:
4. Two miles southwest of Kimberly.
5. On Turkey Creek, half a mile southwest of Morris.
6. On Log Branch of Turkey Creek, 1¼ miles southwest of Oakgrove Church.

Scale: 1 inch=5 feet.

At Kimberly, at Seloca, and at the Turkey Creek bridge a mile or so northwest of Morris the coal is a thick, dirty bed, more of a carbonaceous clay than a coal. Its character is shown by the following section:

Sections of Jagger coal bed at Kimberly No. 2 mine.

	Ft.	in.
Clay with streaks of coal up to 4 inches thick	2	5
Coal and clay alternating in 3-inch layers	2	1
Clay	1	9
Total coal bed	4	6
(See section 3, fig. 11.)		

In this region the relations of the Jagger, Blue Creek, Mary Lee, and Newcastle beds are about as shown in the following section along the road west of the Turkey Creek bridge, west of Morris, beginning at the bridge and going to the top of the hill:

Section west of Morris.

	Ft.	in.
Shale	60	
Coal (Newcastle).		
Shale	10	
Coal, Mary Lee.		
Sandstone (mostly)	60	
Coal, Blue Creek	2	11
Shale and sandstone	60	
Coal, Jagger.		
Conglomerate, Lick Creek sandstone member (under bridge)	20+	
	212	11

The interval between the Jagger and Mary Lee is 120 feet. Northwest of Morris and Kimberly and along the northeastern outcrop of the Jagger southward to Log Branch it thins and becomes less dirty. It is doubtful whether the coal is workable on a commercial scale anywhere east of the mouth of Whites Creek in sec. 13, T. 15 S., R. 4 W.

Very little is known of the Jagger coal along its eastern outcrop south of Turkey Creek. In the cut of the Louisville and Nashville (North Alabama) Railroad, just west of the Black Creek junction, is a coal bed regarded as the Jagger, which has the section shown in *e*, below. The bed here is overlain by almost 20 feet of shale, and the shale in turn by 30 feet of conglomeratic sandstone.

The foregoing statements are illustrated by sections 1 to 3 in figure 11 and by the sections given below.

(a) Section of Jagger coal bed in the SW ¼ sec. 18, T. 15 S., R. 3 W., near the head of Whites Creek.

	Ft.	in.
Sandstone.		
Shale	5	
Coal		3
Bone and clay		3½
Coal		7
Clay		1
Coal		8+
Total coal bed	1	10½

(b) Section of Jagger coal bed in the NW. ¼ sec. 18, T. 15 S., R. 3 W., at the head of Whites Creek.

	Inches.
Shale.	
Coal	4½
Parting	3
Coal	5
	12½

(c) Section of Jagger coal bed on wagon road in the NE. ¼ sec. 34, T. 14 S., R. 3 W.

	Ft.	in.
Coal		6
Shale	2	
Coal	1	
Clay	1±	
Total coal bed	3	6

(d) Section of Jagger coal bed in sec. 15, T. 15 S., R. 2 W., on road just east of Turkey Creek.

	Ft.	in.
Shale	5	
Coal	1	6

(e) Section of Jagger (?) coal bed on Louisville and Nashville Railroad one-eighth mile west of Black Creek station.

	Ft.	in.
Coal		8
Shale	6	
Coal	1	2
Clay	2	
Total coal bed	1	2

Blue Creek coal.—So far as known the Blue Creek coal is of economic importance in this field only across the Coalburg trough along Turkey Creek and to the north of that stream. A stratum of sandstone lies close above the bed over a large part of this region and in some places, as at Fedora, is in contact with it. Generally the coal has a shale roof a few feet thick and a clay floor. The thickness and make-up of the bed vary, and it is generally rather dirty where thickest. Sections 4 to 6 in figure 11 and the sections given below illustrate its character.

(a) Section of Blue Creek coal bed in the SE. ¼ sec. 34, T. 14 S., R. 3 W.

	Ft.	in.
Shale		4
Coal	2	8
Shale.		

(b) Section of Blue Creek coal bed on east bank of Turkey Creek at Fedora.

	Ft.	in
Sandstone.		
Coal	1	4
Parting		½
Coal		1½
Clay, sandy		2
Coal		4
Clay	2	
Total coal bed	2	

(c) Section of Blue Creek coal bed in the SE. ¼ sec. 7, T. 15 S., R. 2 W., on railroad to Indio mine.

	Ft.	in.
Shale.		
Coal	1	
Clay		7
Shale, carbonaceous		3
Clay		3
Coal		¾
Clay		½
Coal		1¾
Clay		6
Bone and clay in ½-inch layers		4¾
Coal		10¾
Clay, sandy	3±	
Total coal bed	4	1½

(d) Section of Blue Creek coal bed in the NW. ¼ sec. 9, T. 15 S., R. 2 W.

	Ft.	in.
Shale.		
Coal	2	2
Bone		7
Shale.		

(e) Section of Blue Creek coal bed in the E. ½ sec. 19, T. 16 S., R. 2 W., on the Louisville and Nashville Railroad just east of Newcastle No. 4 mine.

	Ft.	in.
Shale.		
Coal		6
Clay		3
Coal		1
Shale	5	
Coal	1	
Clay	2	

On the head of Trouble Creek, in the NW. ¼ sec. 24, T. 15 S., R. 4 W., the coal bed is represented by streaks of black band, bony coal, and carbonaceous shale, as in the following section:

Section of Blue Creek coal at head of Trouble Creek.

	Ft.	in.
Shale	15	
Black band		4
Bony coal		8½
Shale, carbonaceous	1	
Shale	2	
Total coal bed	2	½

The occurrence of black band at the horizon of the Blue Creek has been noted by McCalley as common. Nowhere to the southwest of Trouble Creek is the coal known to be of value. The most western point at which minable coal regarded as the Blue Creek was observed is 1½ miles west of Kimberly, in sec. 34, T. 14 S., R. 3 W. The section of the bed at this point is shown in section *a*, above. Sections *b* and *c*, above, and 4 to 6 in figure 12 show the character and variations of the bed along Turkey Creek to Log Branch. On the hills north of Morris and Indio are small blooms at many points that are apparently in the position of the Blue Creek bed, but no good measurements were obtainable. At Morris a thickness of 18 inches is indicated, but along Turkey Creek to the south and west of Morris the bed is much thicker. At a locality on Log Branch half a mile north of the point at which section 6, figure 12, was measured, the coal has an abnormally thick development, as shown in the section below.

Section of Blue Creek bed in the NW. ¼ sec. 27, T. 15 S., R. 2 W.

	Feet.
Coal with partings	5
Shale	3
Coal with partings	3
	11

The coal and partings in this section vary so greatly in number and thickness within a few feet that no detailed measurements were attempted. The proportion of shale and clay in the coal, however, is so great as to seriously impair the value of the coal. Moreover, the thickness shown by the section persists but a short distance along the outcrop. At another opening a few rods away the coal is only 4 to 5 feet thick, and a little farther north along the outcrop test pits showed no coal.

On the high hill 1 mile southwest of Bradford, in the southern part of sec. 11, T. 15 S., R. 2 W., the Blue Creek bed outcrops in the road and a thickness of 2 feet is indicated.

The bed was not seen south of Log Branch north of the point at which section *e*, above, was measured, and it is probably worthless along most of its eastern outcrop.

Mary Lee coal.—The Mary Lee coal, commonly also called the Big seam, is the most important coal bed in the quadrangle. In places it reaches a thickness of over 10 feet, including partings, and it is persistent and probably workable over the entire region included within its outcrop, except possibly in a small area west of Pratt City and Wylam.

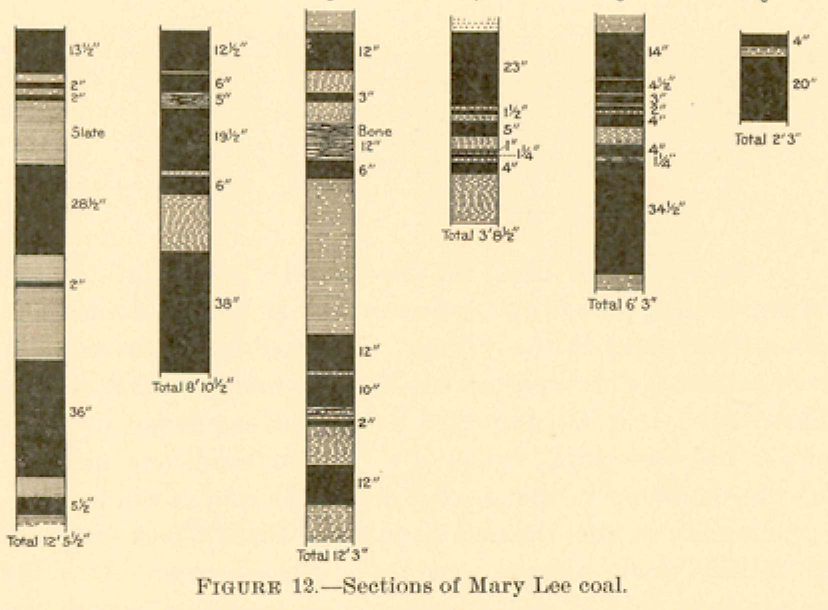


FIGURE 12.—Sections of Mary Lee coal.

1. Bore hole in Sleepy Hollow, 1 mile north of Graysville.
2. Sayre mine, second left heading, Sayre.
3. Half a mile northeast of Indio.
4. On Louisville and Nashville Railroad, three-fourths mile north of Black Creek station.
5. Sayreton mine, in manway near entry.
6. Half a mile northeast of Pratt City.

Scale: 1 inch=5 feet.

The Mary Lee is nearly everywhere a "dirty" bed—that is, it is composed of alternating layers of coal and bone, clay, and shale, as shown in the sections of figure 12. Where these layers are comparatively thick and few in number the coal can be

[a] McCalley, Henry, op cit., p. 19.

separated from the dirt in mining. This is the condition of the bed at Littleton and Sayre, as shown in section 2, figure 12, and sections *b* and *c*, below. On the east side of the Coalburg trough the bed in places consists of a single bench of clean coal, as shown in sections *k* and *l*, below. In most of its extent, however, the intermixture of coal and dirt in the bed is so intimate that washing is necessary to make it fit for use.

A study of the sections of figure 12 will show that the bed is thick from the bore hole at Murray to the vicinity of Trouble Creek, thinner and more broken around the north end of its outcrop and along the east side to Newcastle, thicker from Newcastle to a point south of the Sayreton mine, where it begins to thin, and thinner thence southward to the point where its outcrop is lost in the fault at Pratt City, as shown in section 6 of figure 12 and section *n*, below.

(a) Section of Mary Lee coal bed (at 541 feet in depth) in bore hole at Murray.

	Ft.	in.
Coal	4	
Slate	1	
Coal	2	6
Total coal bed	7	6

(b) Section of Mary Lee coal bed in Thomas mine, Littleton.

	Ft.	in.
Shale.		
Coal	1	10
Black shale		5
Coal	1	7
Bone		¼
Coal		5½
Clay	1	7
Coal	2	2¼
Shale		1½
Coal		8½
Shale		4
Coal		5½
Total coal bed	9	9½

(c) Section of Mary Lee coal bed in the S. ½ sec. 22, T. 15 S., R. 4 W.

	Ft.	in.
Shale.		
Coal	1	2
Clay		1½
Coal		8
Clay	1	3
Coal	2	10
Clay		½
Coal		9
Total coal bed	6	10

(d) Section of Mary Lee coal bed in the center of sec. 13, T. 15 S., R. 4 W.

	Ft.	in.
Shale.		
Coal	1	½
Clay		3
Coal		6
Clay	1	6
Coal (amount seen)	1	
Total coal bed	4	3½

(e) Section of Mary Lee coal bed in the SE. ¼ sec. 3, T. 15 S., R. 3 W., 1½ miles northwest of Morris.

	Ft.	in.
Shale (?).		
Coal		3
Clay		3
Coal		4
Clay		6
Coal		4
Total coal bed	1	8

(f) Section of Mary Lee coal bed near the center of sec. 16, T. 15 S., R. 3 W., near Crooked Creek.

	Ft.	in.
Shale.		
Coal		8½
Parting		½
Coal		2½
Parting		¼
Coal	1	2
Parting		1½
Coal		¼
Parting		1½
Coal		1½
Parting		¼
Coal		½
Parting		1½
Coal		11½
Clay	1	
Shale.		
Total coal bed	4	9½

(g) Section of Mary Lee coal bed near the center of sec. 16, T. 15 S., R. 3 W., near Crooked Creek.

	Ft.	in.
Shale.		
Coal		6
Clay and bone		1½
Coal		3
Clay and bone		5
Coal		11
Total coal bed	2	2½

(h) Section of Mary Lee coal bed on Louisville and Nashville Railroad at Fedora.

	Ft.	in.
Shale.		
Coal		5
Clay		2½
Coal		3
Clay		1
Coal	1	4
Clay		¾
Coal		4½
Clay		½
Coal		3
Clay		7
Total coal bed	3	7¼
Birmingham.		

(i) Section of Mary Lee coal bed in the NE. ¼ sec. 4, T. 15 S., R. 2 W., 2 miles north of Indio.

	Ft.	in.
Shale and bone	5	
Coal	1	1
Clay		2¼
Coal	3	1
Clay, slaty	2	
Total coal bed	4	4¼

(j) Section of Mary Lee coal bed in the southeast corner of sec. 17, T. 15 S., R. 2 W., 1 mile south of Indio.

	Ft.	in.
Shale	3	
Coal		10
Clay		6
Coal, dirty		8
Clay		2
Coal, dirty (reported 1 foot 10 inches)		4+
Clay or shale.		
	2	6

(k) Section of Mary Lee coal bed in the W. ½ sec. 34, T. 15 S., R. 2 W.

	Ft.	in.
Coal	2	6

(l) Section of Mary Lee coal bed on siding to Newcastle No. 4 mine, a few rods southeast of Newcastle No. 2 mine.

	Ft.	in.
Sandstone.		
Coal	2	6
Shale.		

(m) Section of Mary Lee coal bed in mine at Lewisburg, at bottom of main slope in manway.

	Ft.	in.
Coal, bony		3
Coal, clean		5
Dirt		½
Coal		3½
Rash (pyrites)		½
Coal		6½
Slate parting		6
Coal, bony		10
Coal, clean, best of seam	3	2
Total coal bed	6	½

(n) Section of Mary Lee coal bed in the SE. ¼ sec. 16, T. 17 S., R. 3 W.

	Ft.	in.
Coal	2	
Clay		2
Coal	1	5
Clay		2
Coal		5+
Total coal bed	4	2

South of Pratt City the Mary Lee bed does not outcrop, lower rocks having been thrust up over it, as shown in the cross section through Wylam, on the structure section sheet. There is evidence that in the Wylam locality and to the south the bed splits up and becomes worthless. It is unknown how far west this condition may exist, but as the bed is good at Murray and on its outcrop on Locust Fork west of Short Creek, 6 miles west of the Birmingham quadrangle, it may fairly be assumed to be workable as far south as an east-west line drawn through Pratt City. So far as the writer's knowledge permits a judgment, the best part of the Mary Lee bed lies between a line passing in the vicinity of Newcastle No. 4 mine and the mouth of Trouble Creek on the north and a line passing through points about 1 mile south of the Sayreton mine and 1 mile south of Adamsville on the south.

The Mary Lee coal makes excellent coke, and so far as this quadrangle is concerned it will be the main dependence for coke after the Pratt bed has been exhausted. The chemical composition of the coal is shown in the table of analyses, Nos. 15–20 inclusive (p. 20).

The Mary Lee bed and the next overlying bed, the Newcastle, appear to coalesce on the northern outcrop, west of Morris, as is indicated in the following sections:

Section on highway in the SE. ¼ SE. ¼ sec. 4, T. 15 S., R. 3 W.

		Ft.	in.
Coal, 3 inches; Clay, 6 inches; Coal, 1 foot 11 inches; Clay	Newcastle (?)	2	8
Concealed		10	
Coal, 3 inches; Clay, 3 inches; Coal, 4 inches; Clay, 6 inches; Coal, 4 inches	Mary Lee (?)	1	8
		14	4

Section on the same road as the preceding, on the west side of sec. 3, T. 15 S., R. 3 W.

	Feet.
Shale	20
Sandstone	5
Shale	40
Coal, thin, Newcastle (?).	
Shale	10
Coal, thin, Mary Lee.	
Shale and sandstone	60
Coal, Blue Creek.	
	135

These two sections show two coal beds near the Mary Lee horizon; they represent either the Mary Lee and Newcastle beds, the latter having approached the former by thinning of the 40 to 50 feet of shale usually separating them, or the Mary Lee bed alone, the Newcastle bed having disappeared. The 65 feet of shale and sandstone overlying the top bed in the last section is continuously exposed, and no coal is present in it that might represent the Newcastle bed. No bed was observed in the usual position of the Newcastle around the northern outcrop of the Mary Lee group, the top bed of the group occupying the position of the Mary Lee. Moreover, aside from the Ream bed, the Mary Lee group of this region contains only three beds—the Jagger, the Blue Creek, and the one just mentioned as occurring in the position of the Mary Lee. The thick bed shown in section 3, figure 12, may be regarded as made up of the Mary Lee and Newcastle. No separate bed in the position of the Newcastle was seen by the writer along the east side of the Coalburg trough between Turkey Creek and Newcastle, where the Newcastle bed is well developed, as shown below.

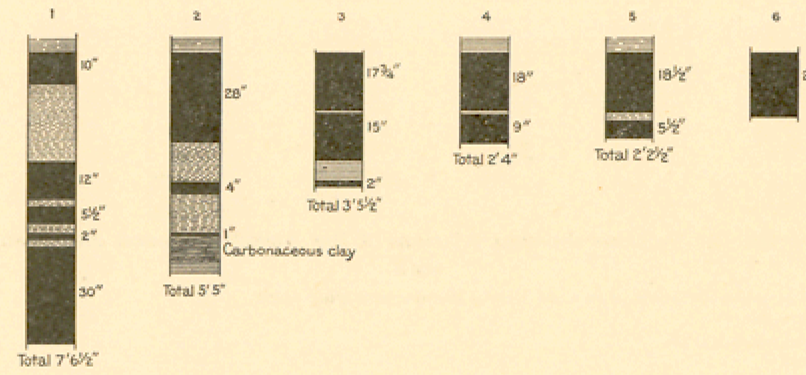


FIGURE 13.—Sections of Newcastle and Nickel Plate coals.

Newcastle coal:
1. Newcastle mine, Newcastle.
2. Graves mine, three-fourths mile southwest of Lewisburg.

Nickel Plate coal:
3. Pratt mine No. 16, No. 1 entry, Stumptown.
4. Newfound mine, Brookside.
5. Mount Olive Church.
6. One mile north of Jugtown.

Scale: 1 inch=5 feet.

Newcastle coal.—The Newcastle coal is a workable bed a few miles along its outcrop from Newcastle southward. It is best at Newcastle, where its section is much like that of the Mary Lee at other points. (See section 1, fig. 13.) Its thickness decreases southward, as shown in section 2, figure 13, and sections *a* and *b*, below. It is reported at the Sayreton mine, 40 feet above the Mary Lee, and it has been opened by test pits in the SE. ¼ sec. 16, T. 17 S., R. 3 W. A mile still farther southwest, on the Birmingham-Republic road, in the SE. ¼ sec. 20, T. 17 S., R. 3 W., the coal does not appear, though there is a complete exposure of the rocks for a thickness of 200 feet or so above the Mary Lee. It probably is absent from the section from Pratt City southward.

(a) Section of Newcastle coal bed on highway 1 mile north of Lewisburg.

	Ft.	in.
Coal	1	5
Clay		8
Coal		6
Shale	40±	
Total coal bed	2	7

(b) Section of Newcastle coal bed west of highway one-eighth mile south of Mary Lee mine, Lewisburg.

	Ft.	in.
Shale.		
Coal	2	6
Clay	1	
Coal		7
Shale	20±	
Total coal bed	4	1

PRATT COAL GROUP.

Gillespie coal.—The Gillespie coal, about 300 feet above the Newcastle, is the lowest bed of the Pratt group. It appears to be persistent but is less than a foot thick over most of the Coalburg trough. Northwest of Newcastle it is locally 18 to 30 inches thick. At an opening in the SE. ¼ sec. 7, T. 16 S., R. 2 W., it is 2 feet 6 inches thick, and at an old pit in the northeast quarter of the same section it was, as reported, 18 inches thick. At no other point in the quadrangle was so great a thickness observed.

Curry coal.—The Curry coal is, like the Gillespie, thin but persistent. McCalley, on his map of the Warrior Basin, shows a thickness of 22 inches in the NE. ¼ sec. 3, T. 16 S., R. 3 W.

Nickel Plate coal.—From 70 to 80 feet above the Curry is the Nickel Plate or Cardiff bed, which is mined over a considerable area in the Blossburg-Brookside-Mineral Springs region. A question of identification and correlation arises in connection with the Nickel Plate bed which demands some notice here.

From 15 to 20 feet below the Nickel Plate in the region outlined is another bed 8 to 10 inches thick so far as measured. This bed shows at a number of points in the vicinity of the Jet mines, in the railroad cut at Jefferson station, on the Southern Railway west of Cardiff, and along the branch to Blossburg, just west of Jefferson. Along the eastern outcrop of these coals, at the Pratt No. 7 mines, on Black Creek, where apparently the same coals are only about 15 feet apart, as shown in section 6, figure 14, the name Double seam is applied to them.

It appears from McCalley's report on the Warrior field[a] and the accompanying map that he regarded the Nickel Plate as the same as that which he called the Fire Clay seam, to the west of this region. The coal under the Nickel Plate bed McCalley regarded as the American bed, which is typically developed only in the region west of this quadrangle.

[a] McCalley, Henry, Report on the Warrior coal basin, Alabama Geol. Survey, 1900, plate opp. p. 29.

McCalley may be entirely correct in his interpretation of the facts, but another interpretation is possible. In the road between Coalburg and Republic, in the center of sec. 32, T. 16 S., R. 3 W., is a thin coal 10 feet below the Pratt, as shown in the section below.

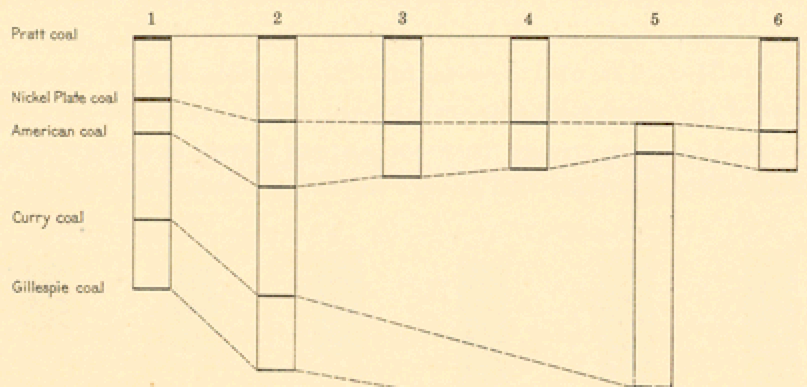


FIGURE 14.—Sections showing relations of the Nickel Plate and American coals.

1. Two miles southwest of Banner, west of Birmingham quadrangle.
2. Brookside.
3. Jefferson station.
4. Jet.
5. Just east of Clift station.
6. Pratt mine No. 7.

Scale, 1 inch = 100 feet.

Section on Coalburg-Republic road in sec. 32, T. 16 S., R. 3 W.

	Ft.	in.
Shale	50	
Coal, Pratt	2	7
Clay	1	6
Shale	8	6
Coal		11
Shale.		
	63	6

The 11-inch coal in this section may represent the Fire Clay seam. If the thin bed described above is the Fire Clay seam, it is possible to regard the Nickel Plate bed and the coal 20 feet below as the equivalent of the American bed farther west, as at Short Creek, where the American is 70 feet below the Pratt, in about the same position as the bed below the Nickel Plate. According to this view the American bed is separated into two benches by a 20-foot parting, the upper bench being the Nickel Plate. (See fig. 14.) To the southeast this parting appears to thin out and the two benches to come together and make a bed of considerable thickness, as shown in the following section measured at Ensley:

Section of American (?) coal at Ensley.

	Ft.	in.
Shale.		
Coal	1	2
Clay		0–8
Coal	1	4
Clay		6
Coal		6–8
Sandstone	5	
Total coal bed (average)	3	11

The same bed is exposed in the town of Wylam, where it has the following section:

Section of American (?) coal at Wylam.

	Ft.	in.
Coal	1	2
Clay		2
Coal		4
Shale	4	
Coal		3
Clay		3
Coal		8
Total coal bed	6	10

Whichever view as to the identification of the coal above described is accepted, it is certain that the workable bed in the Blossburg-Mineral Springs district is the upper of the two, or the one next below the Pratt—in other words, the Nickel Plate, as it is most generally known in the district.

Sections 3 to 6 in figure 13 and the sections given below illustrate the make-up of the Nickel Plate coal in its minable area, as outlined above.

(a) Section of Nickel Plate coal bed at Pinkney.

	Ft.	in.
Shale roof	4	
Coal	1	$4\frac{1}{2}$
Clay		$1\frac{1}{2}$
Coal	1	
Clay (amount seen)	1	
Total coal bed	2	6

(b) Section of Nickel Plate coal bed in Jet mine, No. 2 entry, Jet.

	Ft.	in.
Shale.		
Coal	1	7
Clay		2
Coal	1	7
Total coal bed	3	4

(c) Section of Nickel Plate coal bed in Kosmo mine, near Mineral Springs.

	Ft.	in.
Coal	1	$5\frac{1}{2}$
Parting		$3\frac{1}{2}$
Coal		$8\frac{1}{2}$
Total coal bed	2	$5\frac{1}{2}$

(d) Section of Nickel Plate coal bed near Clift mine, Clift.

	Feet.
Coal	2+

The bed varies from 26 to 38 inches in thickness and is generally separated into two benches by a parting of clay near the middle. In the vicinity of Clift the coal appears to vary much within short distances. A measurement 10 feet from that shown in section *d*, above, gave the following section:

Section of Nickel Plate coal bed near Clift mine, Clift.

	Ft.	in.
Coal		8
Clay		6
Coal (bottom not seen)		3
Total coal bed	1	5+

At Clift station there are two beds of coal, each 1 foot thick, separated by 10 feet of shale and sandstone. One or both of these beds may represent the Nickel Plate. On the ridge north of Jugtown the coal is present and reported about 2 feet thick, and the same condition appears to prevail along Snell and Bagley ridges and at Mount Olive Church. The bed is not far below the tops of the ridges. On the ridge north of Newcastle, on the west side of sec. 5, T. 16 S., R. 2 W., is a coal 22 inches thick 30 feet below the top of the ridge. This coal appears to be in the position of the Nickel Plate.

The chemical composition of the Nickel Plate coal is shown in analyses 11 to 14 in the table (p. 20). The coal is of about the same quality as the other coals of the region, as may be seen by a comparison of the analyses, though the bottom bench is rather sulphurous and high in ash at the points of sampling, and in analysis 12 the whole bed shows high ash and sulphur.

Pratt coal.—Judged by its quality and present development, the Pratt bed is the most important in the quadrangle and it supplies a large part of the coke used in this district. It contains less coal, however, than the Mary Lee bed. The Pratt bed underlies all the quadrangle southwest of Fivemile Creek from Coalburg westward, and there are a number of outliers on the hills to the north of that stream. The total area carrying the bed is about 50 square miles.

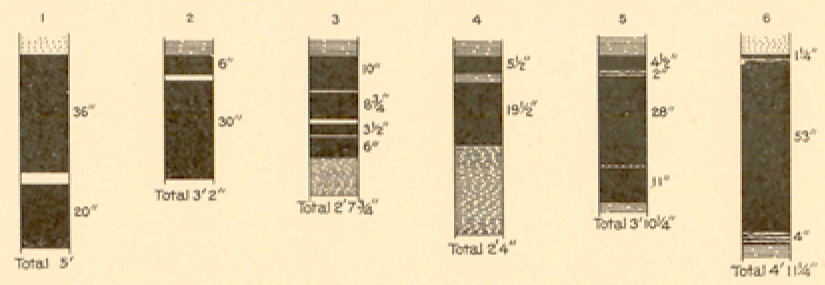


FIGURE 15.—Sections of Pratt coal.

1. Bore hole at Village Falls.
2. Two miles northwest of Union Grace Church.
3. Tutweiler mine No. 3, Pinkney.
4. Eldorado mine, half a mile west of Coalburg.
5. Warner mine, Republic.
6. Sandusky shaft, Sandusky.

Scale: 1 inch=5 feet.

The Pratt ranges in thickness from $2\frac{1}{2}$ to 4 feet but over most of its extent measures 3 to $3\frac{1}{2}$ feet. In general it has a thin parting above the middle, but in some localities, as at Blossburg, Pinkney, Republic, and the Thompson mines, it has two partings, as shown in section 3, figure 15, and sections *b* and *h*, below.

(a) Section of Pratt coal bed in Tutweiler No. 4 mine, Murray.

	Ft.	in.
Shale roof.		
Coal		7
Bone		3
Coal	2	
Total coal bed	2	10

(b) Section of Pratt coal bed in West Blossburg mine.

	Ft.	in.
Sandstone.		
Shale	3	6
Coal		6
Bone		$2\frac{1}{2}$
Coal	2	3
Shale	2–3	
Coal	1	6
Sandstone.		
Total coal bed	6	$11\frac{1}{2}$

(c) Section of Pratt coal bed in Pratt No. 16 mine, near Stumptown.

	Ft.	in.
Shale	4	
Coal		5
Bone		$2\frac{1}{2}$
Coal	2	11
Shale	5	
Total coal bed	3	$6\frac{1}{2}$

(d) Section of Pratt coal bed in Newfound mines, three-fourths mile east of Brookside.

	Ft.	in.
Shale roof	4	
Draw slate		8
Coal		$5\frac{1}{2}$
Bone		3
Coal	3	
Fire clay		4
Shale		3
Total coal bed	3	$8\frac{1}{2}$

(e) Section of Pratt coal bed in Goode mine, Mineral Springs.

	Ft.	in.
Slate roof	4	
Coal		4
Parting		2
Coal	3	
Clay	3–4	
Total coal bed	3	6

(f) Section of Pratt coal bed at pit mouth in Clift mine, 2 miles east of Mineral Springs.

	Ft.	in.
Shale roof.		
Coal		6
Bone		3
Coal	2	$\frac{1}{4}$
Shale and sandstone floor.		
Total coal bed	2	$9\frac{1}{4}$

(g) Section of Pratt coal bed in D mine, North Coalburg.

	Ft.	in.
Shale.		
Coal		$4\frac{1}{2}$
Shale		$2\frac{1}{2}$
Coal	2	4
Total coal bed	2	$11\frac{1}{2}$

(h) Section of Pratt coal bed in Thompson mine, $1\frac{1}{2}$ miles northwest of North Birmingham.

	Ft.	in.
Coal		7
Shale, carbonaceous		3
Coal	2	9
Clay		3
Coal		2
Clay	2	6
Total coal bed	4	

(i) Section of Pratt coal bed in Pratt No. 4 mine, Wylam.

	Ft.	in.
Sandstone	6	
Coal		$8\frac{1}{2}$
Slate parting		$1\frac{1}{2}$
Coal	3	8
Slate, clayey		10
Total coal bed	4	$6\frac{1}{2}$

(j) Section of Pratt coal bed in bore hole in center of sec. 27, T. 17 S., R. 4 W.

	Ft.	in.
Coal	3	7
Shale		6
Coal	1	6
Total coal bed	5	7

Borings along Village Creek in the central part of T. 17 S., R. 4 W., show the bed in excellent condition, as indicated in sections 1, figure 15, and *j*, above. Analyses 1 to 10 inclusive (p. 20) show the composition of the Pratt coal.

COBB COAL GROUP.

According to all the evidence collected by the writer or published by McCalley in his report on the Warrior Basin, the Cobb coal beds, if indeed there are two distinct beds to be so designated, are worthless in this quadrangle.

COALS OF THE PLATEAU FIELD.

Rosa coal.—There is only one bed of importance in the Blount Mountain region. This is mined at Swansea, where it is $3\frac{1}{2}$ feet thick. A mile northeast of Swansea it is somewhat thicker but is more broken up by partings. Openings on this coal have been made near the road in secs. 11 and 14, T. 14 S., R. 1 E., but were not open to inspection. The coal is probably of workable thickness throughout the area included by its outcrop. It lies 100 to 200 feet above the Boyles sandstone member, and is in the position of the Rosa or Berry Mountain coal, with which it is correlated. It also lies near the horizon of the Gould coal of the Cahaba field. (See p. 10.)

Sections of the Rosa bed in Blount Mountain are given below.

Section of Rosa coal northeast of Swansea, in the NE. $\frac{1}{4}$ sec. 33, T. 13 S., R. 1 E.

	Ft.	in.
Shale	8	
Coal	2	7
Clay		3
Coal		11
Clay		$\frac{1}{2}$
Coal		5
Clay.		

Section of Rosa coal in Red Star mine, Swansea.

	Ft.	in.
Shale.		
Coal	2	6
Rash		1
Coal		11

The Rosa coal is about 18 inches thick at Rosa and Berry Mountain and is mined on a small scale for local consumption.

COALS OF THE CAHABA FIELD.

General statement.—In the Cahaba field there are only two coal beds—the Harkness and the Mammoth—that are thick enough to be of importance, though there are others that are known to reach locally a thickness of 2 feet or a little more. The area underlain by the Mammoth bed is small, but that of the Harkness is considerably greater, and that of the Gould, which is the lowest bed of workable thickness at any place, is the greatest of all.

Gould coals.—As previously stated, there are a number of coals at the Gould horizon. One of these is worked at the Ratliffe mine, 1 mile southwest of Lovick. At this mine the coal has the following section:

Section of Gould coal at Ratliffe mine.

	Ft.	in.
Coal		6
Parting		1
Coal	1	9

The composition of the coal at this mine is shown in the table of analyses (p. 20, No. 23).

On the road to the east from Trussville, 1 mile southeast of Roper station, four coals of the Gould group are exposed, and the third one from the bottom is solid coal 2 feet thick. It is assumed that the Gould group carries 2 feet of workable coal along the outcrop in this quadrangle as far north as this point southeast of Roper.

Nunnally coals.—The Nunnally group of coals lies next above the Gould group. Several of the Nunnally coals are of good thickness to the south of this quadrangle, but none of them are known to be workable in this area. On the Birmingham-Leeds road just west of Cahaba River six coals are exposed, the best of which, the third from the bottom, has the following section:

Section of Nunnally coal bed on Birmingham-Leeds road west of Cahaba River.

	Ft.	in.
Coal		9
Clay	2	3
Coal	1	2
Total coal bed	4	2

On the Southern Railway half a mile east of Lovick a coal of this group is exposed. It is thick, very dirty, and of little value. The section is as follows:

Section of Nunnally coal bed on Southern Railway one-half mile east of Lovick.

	Ft.	in.
Shale	1	
Coal		4
Shale and clay	3	
Coal, dirty		2
Clay		5
Coal		4
Clay		7
Coal		11
Clay		1½
Coal		6
Total coal bed	6	4½

On the road east of Trussville, on the west slope of Owens Mountain, are four coals of the Nunnally group, the third from the bottom being as shown in the section below.

Section of Nunnally coal bed on Trussville road on Owens Mountain.

	Ft.	in.
Shale.		
Coal, dirty		5
Coal, pure	1	7

Still farther north, under the Seaboard Air Line Railway bridge over Black Creek, there are four coals, all less than 1 foot thick, in the vertical space of 20 feet. These probably represent the Nunnally group.

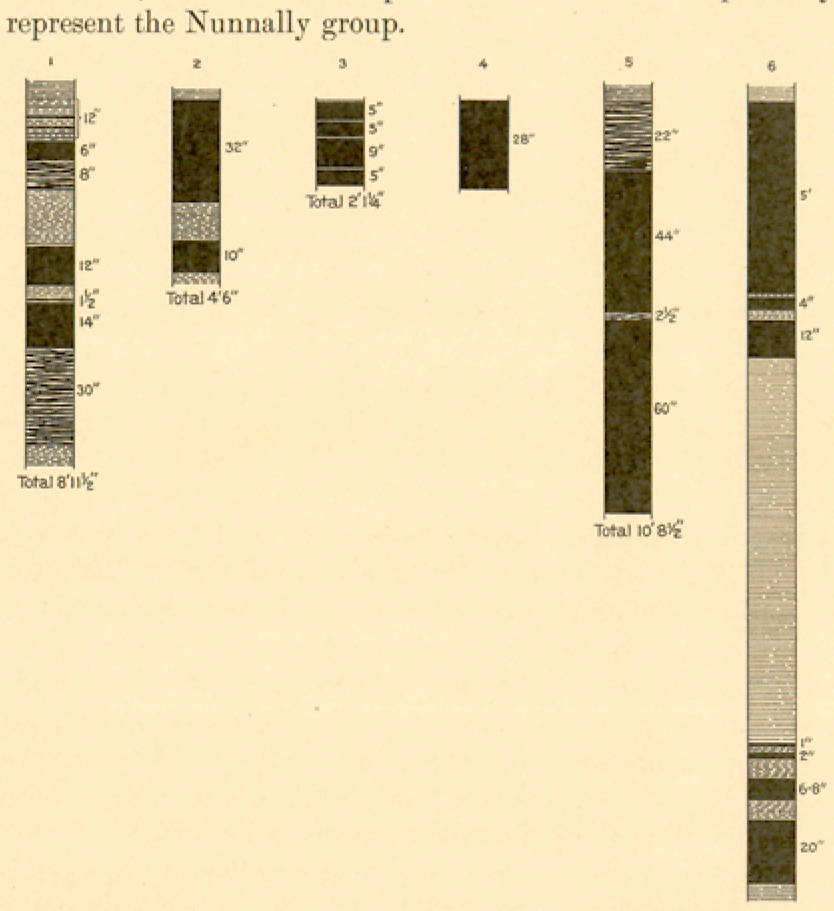


FIGURE 16.—Sections of Harkness, Wadsworth, and Mammoth coals.

Harkness coal:
1. Near Trussville road, half a mile northwest of Black Creek.
2. On Birmingham and Leeds road, 1 mile east of mouth of Hogpen Branch.

Wadsworth coal (?):
3. Just east of Parsons station.
4. Kanetuck Branch, half a mile southwest of mouth of Hogpen Branch.

Mammoth coal:
5. Junction of Middle and Little Black creeks.
6. Junction of siding to Henryellen mine No. 6 with Southern Railway.

Scale: 1 inch=5 feet.

Harkness coal.—The Harkness coal lies about 300 feet above the top of the Nunnally group. It is a thick, valuable bed along most of its outcrop in the quadrangle but is thin and of little value between the Southern Railway and Snake Branch. Except in this part of its outcrop, it is 4 to 6 feet thick, including partings, as shown in sections 1 and 2, figure 16, and the sections given below.

(*a*) *Section of Harkness coal bed in Margaret mine, 3 miles northeast of Parsons.*

	Ft.	in.
Clay	1	
Coal		7½
Clay		4½
Coal		7½
Clay		9
Coal	2	6
Clay	1	8
Total coal bed	4	10½

Birmingham

(*b*) *Section of Harkness coal bed on Southern Railway 1 mile east of Lovick.*

	Ft.	in.
Shale	3	
Coal		2
Clay	1	
Coal		6
Rash		8
Coal		9
Clay and coal		5
Coal		11
Clay floor.		
Total coal bed	4	5

(*c*) *Section of Harkness coal bed in the SW. ¼ sec. 13, T. 17 S., R. 1 W., south of Southern Railway.*

	Ft.	in.
Shale	1	
Clay		6
Coal	1	
Clay		6
Shale	2	6
Coal, dirty		3
Clay		6
Coal, dirty		3
Total coal bed		5

(*d*) *Section of Harkness coal bed in the center of sec. 23, T. 17 S., R. 1 W., on Snake Branch.*

	Ft.	in.
Sandstone	20±	
Clay and shale	1	
Coal, dirty		5
Clay		6
Clay with three ¼-inch streaks of dirty (?) coal		4
Clay		1–3
Coal		7
Clay		1
Coal		2
Clay and coal in 1-inch streaks		8
Coal		6
Clay.		
Concealed	1	8
Sandstone	10+	
Total coal bed (average)	3	5

(*e*) *Section of Harkness coal bed in the NE. ¼ sec. 33, T. 17 S., R. 1 W., on Cahaba River.*

	Ft.	in.
Clay	1	
Coal	1	8
Clay and dirty coal	1	7
Coal		9
Clay		5
Coal		1½
Total coal bed	4	6½

(*f*) *Section of Harkness coal bed in the SE. ¼ sec. 32, T. 17 S., R. 1 W.*

	Ft.	in.
Clay		7
Coal	1	10
Clay		3
Coal		3½
Clay		7
Coal		3
Shale.		
Total coal bed	3	2½

As indicated by sections 1, figure 16, and *a*, above, the coal bed is best along its northern outcrop, so far as its thickness and make-up are concerned. The chemical composition of the coal within the quadrangle is unknown, as there was no chance to procure an unweathered sample for analysis. Its character at the Margaret mine, a few miles to the northwest of the quadrangle, is shown in analysis 22 of the table (p. 20).

A peculiarity of the bed between the Trussville road and the Southern Railway is a bench of coal that has the appearance of having been crushed. The bench is shelly or hackly on the weathered outcrop. The same peculiarity exists in the Big Bone bed of the Blocton Basin, which appears to correspond to the Harkness. There is no reason to believe that this feature is due to crushing, for other benches of the bed at the same place and other beds in the same section show no such phenomena, although they must have been subject to the same forces as the bench in which the peculiar structure is developed. It seems not unlikely that this structure is due to the original constitution of the coal in the bench, which is bony.

On the Birmingham-Leeds road the outcrop of the Harkness coal is repeated by the Hogpen Branch fault, as shown in figure 17. There is thus set off a separate area of the Harkness coal in the north end of the Little Cahaba Basin, as shown by the section and by the mapping of the outcrop of the coal on the economic geology map.

Wadsworth coal.—Some 300 feet above the Harkness lies the Wadsworth bed. In the locality of Parsons one measurement of 15 inches and another of 26 inches were obtained. (See section 3, fig. 16.) On Cahaba River near the Leeds-Birmingham road the Wadsworth has been opened at two points, one by the riverside and one on Kanetuck Branch, a short distance south of the river. At the opening on Kanetuck Branch the coal is 2 feet 4 inches thick. (See section 4, fig. 16.) In this general locality the Wadsworth promises to be of moderate value, but it would be unsafe at present to make any definite statement as to the probabilities of its being of workable thickness and character farther north.

Coals between the Wadsworth and Mammoth beds.—Between the Wadsworth and Mammoth beds are a number of thin coals that at a few points are 2 feet thick or a little more. In the description of the Pottsville formation the statement was made that the Mammoth coal bed probably represents the Helena bed of the Helena and Acton basins south of this quadrangle. A more complete statement of the reasons for this identification is made in the writer's description of the northern part of the Cahaba coal field.[a] If this identification is correct, the thin coals mentioned above correspond to the coals between the Wadsworth and Helena in the type section on the Louisville and Nashville Railroad at Helena. In the 600 feet or so of rocks immediately above the Wadsworth bed no coals were seen in this area, but these rocks should contain the Schute, Coke (Pump) beds, etc., of the type section.

On Black Creek, in the SW. ¼ sec. 23, T. 16 S., R. 1 E., a bed of solid coal 2 feet thick has been opened. It is supposed that this bed lies near the horizon of the Buck coal. What is regarded as the same bed shows on the Trussville road on the east side of sec. 33, T. 16 S., R. 1 E. At this point the following section was measured:

Section of Buck bed near Trussville road on east side of sec. 3, T. 17 S., R. 1 E.

	Ft.	in.
Coal		4
Clay		4½
Coal		8
Clay		1
Coal, dirty	1	
Clay.		
Total coal bed	2	5½

A bed exposed on the Central of Georgia Railway in the southern part of sec. 7, T. 17 S., R. 1 E., may be the Black Shale coal. It has the following section:

Section of Black Shale coal on Central of Georgia Railway, in southern part of sec. 7, T. 17 S., R. 1 E.

	Ft.	in.
Coal		6
Clay		7
Coal		1
Clay		1
Coal	1	2
Clay		6
Coal		5
Total coal bed	3	4

There are prospect pits on Black Creek and Snake Branch apparently on the Black Shale bed, but they were either closed or not found and the coal was not seen.

A bed of solid coal 2 feet thick, supposed to be the Little Pittsburg or a coal near its horizon, is opened on Black Creek in the NW. ¼ sec. 26, T. 16 S., R. 1 E. On the Trussville road, on the west side of sec. 34, T. 16 S., R. 1 E., a coal having the following section may be the Little Pittsburg:

Section of Little Pittsburg coal on Trussville road on west side of sec. 34, T. 16 S., R. 1 E.

	Ft.	in.
Coal	1	5
Clay		3
Coal		5
Clay		8
Total coal bed	2	1

On the Southern Railway just east of the Cahaba River bridge the Little Pittsburg bed is 21 inches thick, consists of solid coal, and underlies a thick-bedded sandstone. On Snake Branch, in the SE. ¼ sec. 23, T. 17 S., R. 1 W., 2 feet 4 inches of solid coal at this horizon underlies 20 feet of sandstone.

At only one point in this field—on the Southern Railway just east of the junction of the siding to Henryellen No. 6 mine—does the Thompson bed show indications of being of workable thickness. The coal makes a good showing here, but no measurement could be obtained.

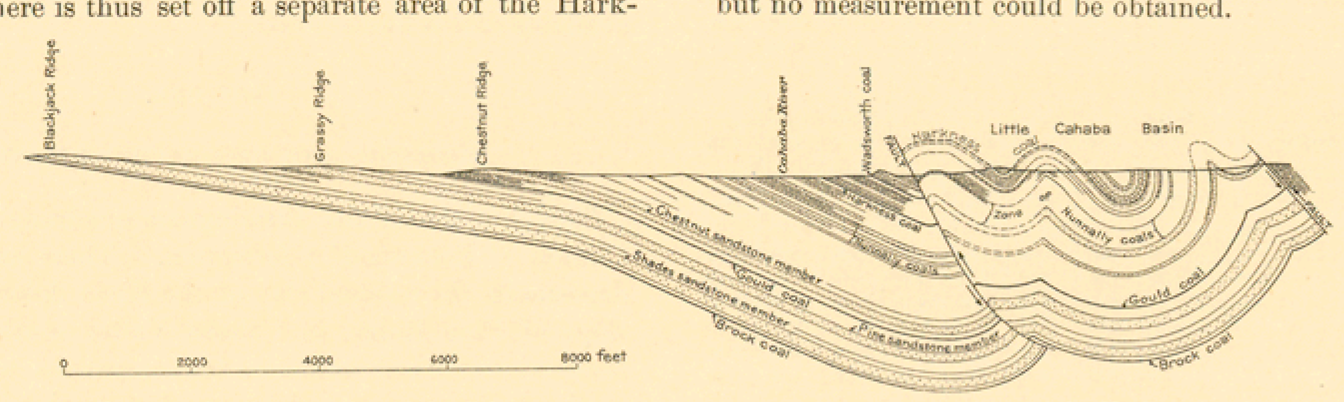


FIGURE 17.—Cross section of the Cahaba coal field, showing structure and repetition of the Harkness coal.

The outcrops of all these thin beds are probably faulted out by the Hogpen Branch fault, 2 miles or so south of Snake Branch. Although the thin beds just described will at some future time yield considerable coal, they are not considered minable on a commercial scale at the present day.

Mammoth coal.—The Mammoth is a thick bed along its entire outcrop in the Henryellen Basin. Its outcrop is cut out by the Hogpen Branch fault 3 miles southwest of Henryellen. As it outcrops near the east side of the basin, it underlies only a narrow triangular area of small extent.

[a] Bull. U. S. Geol. Survey No. 316, 1907, pp. 84-86.

The bed is about 10 feet thick on Black Creek, with a thick clay parting near the middle. On the Southern Railway and to the south the parting consists of shale and is apparently 10 feet thick. Both benches of the coal are more or less dirty. The lower bench south of Henryellen is said to be bony. The make-up of the bed is shown in sections 5 and 6 of figure 16 and the sections given below.

(*a*) *Section of Mammoth coal bed in the SE. ¼ sec. 33, T. 16 S., R. 1 E., on Black Creek.*

	Ft.	in.
Shale.		
Coal	3	6
Clay and coal	1	6
Coal	4	10
Clay.		
Total coal bed	9	10

(*b*) *Section of Mammoth coal bed in Henryellen No. 4 mine.*

	Ft.	in.
Sandstone	20±	
Shale	20±	
Clay, carbonaceous	1±	
Coal, hard	3	1
Coal, soft, friable	2	2
Clay.		
Total coal bed	5	3

The chemical composition of the upper bench of the Mammoth coal as mined at Henryellen No. 6 mine is shown in the table of analyses below (No. 21).

Yeshic and other coals.—Only one bed of minable thickness above the Mammoth was seen, and this at only one point, near the Southern Railway, in the northwest corner of sec. 19, T. 17 S., R. 1 E., where it is 6 feet thick, as shown in the subjoined section:

Section of coal bed in northwest corner of sec. 19, T. 17 S., R. 1 E.

	Ft.	in.
Coal	1	4
Clay		2
Coal		6
Clay	1	9
Coal	2	4
Total coal bed	6	1

This bed is regarded as the Yeshic bed of the type section.

A number of other coals occur above the Mammoth in the Henryellen Basin, especially along the Trussville road east of Black Creek, but none of them are known to be workable.

COALS OF THE COOSA FIELD.

Only one coal bed, probably the Howard, was found in the portion of the Coosa field lying in this quadrangle, and this was only about a foot thick. It is doubtful whether any workable coal exists in this part of the field.

GENERAL CHARACTER OF THE COAL.

All the coal of this region is bituminous, has a fuel ratio just below 2 and makes good coke. It is also a high-grade steam and domestic coal. In efficiency it ranks a little below the Pocahontas and New River coals of West Virginia and is just about the same as the Kanawha coals of the same State. The amount of impurities (clay partings and sulphur) in some beds makes washing necessary before the coal is coked. The composition of the coal is shown by the subjoined table of analyses. These analyses were made at the fuel-testing plant of the United States Geological Survey on samples collected by the standard method.

Proximate analyses of coal samples from the Birmingham quadrangle.

[Samples as received.]

	1.	2.	3.	4.	5.	6.	7.	8.
Laboratory No.	1755	1756	1933	1932	1917	1918	1768	1754
Moisture	2.51	2.68	2.07	2.27	1.83	2.88	2.27	2.66
Volatile matter	27.10	25.17	26.80	27.00	29.28	29.56	26.86	29.93
Fixed carbon	59.96	61.82	61.28	57.70	57.53	56.91	55.82	59.04
Ash	10.43	10.33	9.85	13.03	11.36	10.65	15.05	8.37
Sulphur	1.68	1.86	2.13	1.79	4.24	2.04	2.45	1.71
Calorific value:								
Calories	7,571	......	......	......	......	7,477	......	......
British thermal units	13,628	......	......	......	......	13,459	......	......
Loss of moisture on air drying	1.60	1.80	1.40	1.40	.90	1.60	1.10	1.60

	9	10.	11.	12.	13	14.	15.	16.
Laboratory No.	2436	2433	1794	1793	1920	1931	1919	1989
Moisture	1.63	1.86	3.35	3.10	2.86	1.76	3.14	3.40
Volatile matter	30.81	28.52	26.41	25.31	29.08	28.52	28.46	26.68
Fixed carbon	64.03	64.73	57.58	56.15	65.29	54.08	59.35	59.53
Ash	3.53	4.89	12.66	15.44	2.77	15.64	9.05	10.39
Sulphur	.57	2.27	1.84	3.11	.95	4.05	1.05	.65
Calorific value:								
Calories	......	......	7,247	......	......	......	......	......
British thermal units	......	......	13,045	......	......	......	......	......
Loss of moisture on air drying	......	......	2.10	1.90	1.30	1.00	1.60	2.00

	17.	18.	19.	20.	21.	22.	23.
Laboratory No.	1990	1930	2432	2431	3460	3484	3499
Moisture	2.89	3.35	2.49	2.16	2.51	3.39	1.98
Volatile matter	28.87	26.92	27.34	27.11	33.81	30.69	30.66
Fixed carbon	59.94	59.01	57.14	55.47	56.85	57.08	58.95
Ash	8.30	10.72	13.03	15.26	6.83	8.84	8.41
Sulphur	.63	.67	1.37	.93	.48	2.34	1.09
Calorific value:							
Calories	......	7,369	......	......	......	......	7,563
British thermal units	......	13,264	......	......	......	......	13,613
Loss of moisture on air drying	1.60	2.20	1.20	1.30	1.00	1.80	.80

1. Pratt seam, Warner drift, room 23, off twelfth right neading, Republic. E. E. Somermeier, analyst; Charles Butts, collector.
2. Pratt seam, Warner drift, twelfth left heading, room 19, Republic. E. E. Somermeier, analyst; Charles Butts, collector.
3. Pratt seam, Tutweiler No. 3 drift, seventh left heading, 900 feet from main entry, Pinkney. E. E. Somermeier, analyst; T. M. Campbell, collector.
4. Pratt seam, Tutweiler No. 3 drift, ninth right heading, 600 feet from main entry, Pinkney. E. E. Somermeier, analyst; T. M. Campbell, collector.
5. Pratt seam, Pratt No. 16 mine, third face heading at mouth of fourth left entry, 1 mile west of Cardiff. E. E. Somermeier, analyst; E. M. Dawson, jr., collector
6. Pratt seam, Pratt No. 16 mine, section 5, right heading, entry No. 3, 1 mile west of Cardiff. E. E. Somermeier, analyst; E. M. Dawson, jr., collector.
7. Pratt seam, Kosmo mine, room 3, off second right heading 600 feet from drift mouth, Mineral Springs. E. E. Somermeier, analyst; E. M. Dawson, jr., collector.
8. Pratt seam, Clift mine, main entry 800 feet from drift mouth, Clift station. E. E. Somermeier, analyst; Charles Butts, collector.
9. Pratt seam, No. 4 mine, sixth cross heading, room 1, Wylam F. M. Stanton, analyst; E. M. Dawson, jr., collector.
10. Pratt seam, No. 4 mine, room 5, Kelso entry, Wylam. F. M. Stanton, analyst; E. M. Dawson, jr., collector.
11. Nickel Plate seam, Tutweiler No. 3 drift, fourth right heading, Pinkney. E. E. Somermeier, analyst; T. M. Campbell, collector.
12. Nickel Plate seam, Tutweiler No. 3 drift, second left heading, Pinkney. E. E. Somermeier, analyst; T. M. Campbell, collector.
13. Nickel Plate seam, Pratt No. 16 drift, upper bench, fifth right heading of entry No 1, 1 mile west of Cardiff. E. E. Somermeier, analyst; E. M. Dawson, jr., collector.
14. Nickel Plate seam, Pratt No. 16 drift, lower bench, fifth right heading of entry No. 1, 1 mile west of Cardiff. E. E. Somermeier, analyst; E. M. Dawson, jr., collector.
15. Mary Lee seam, Thomas slope, ninth left cross heading, top bench, Littleton. E. E. Somermeier, analyst; T. M. Campbell, collector.
16. Mary Lee seam, Thomas slope, ninth left cross heading, middle bench, Littleton. E. E. Somermeier, analyst; T. M. Campbell, collector.
17. Mary Lee seam, Thomas slope, ninth left cross heading, bottom bench, Littleton. E. E. Somermeier, analyst; T. M. Campbell, collector.
18. Mary Lee seam, Thomas slope, tenth left cross heading, whole seam, Littleton. E. E. Somermeier, analyst; T. M. Campbell, collector.
19. Mary Lee seam, Lewisburg slope, bottom of main slope in manway, 60 feet from main slope, part of bed above bottom bench of 38 inches, Lewisburg. F. M. Stanton, analyst; E. M. Dawson, jr., collector.
20. Mary Lee seam, Lewisburg slope, bottom of main slope in manway, 60 feet from main slope, bottom bench, Lewisburg. F. M. Stanton, analyst; E. M. Dawson, jr., collector.
21. Mammoth bed, Henryellen No. 6 mine, 2 miles southwest of Henryellen. F. M. Stanton, analyst; Chester W. Washburne, collector.
22. Harkness bed, Margaret mine, main entry 800 feet from slope mouth, Margaret. F. M. Stanton, analyst; Charles Butts, collector.
23. Gould bed, Lovick. F. M. Stanton, analyst; W. F. Prouty, collector.

MINING CONDITIONS.

In the Warrior field the coals lie nearly flat, except around the margin of the field. The dip is low on the western margin and steep on the eastern margin from Lewisburg southward. In the Plateau field the dip is steep on the west side of Blount Mountain and moderate on the east side, being low or flat in the bottom of the syncline. In the Cahaba field the dip is uniformly eastward and comparatively steep throughout, with increasing steepness near the east margin. Near the fault bounding the field on the east the rocks appear to turn upward toward the fault, forming thus a narrow syncline, the axis of which is shown on the maps. On the eastern margin of the Warrior field are many normal faults of small throw, also shown on the maps. These faults are of course a considerable hindrance to mining.

All the coal beds seem to have an excellent roof, generally of shale. Neither water nor gas is sufficiently abundant to be very troublesome. The topographic conditions in the coal fields are such that points favorable for locating mines can easily be reached by railroads.

DEVELOPMENTS.

An examination of the economic geology map will show that coal-mining operations are confined almost entirely to the Warrior field. There is one active mine in the Henryellen Basin, the Henryellen No. 6 mine, and two mines in the Plateau field. Considerable coal has been taken from the Mammoth bed in the vicinity of Henryellen and a little from the Harkness bed at old mines in sec. 33, T. 16 S., R. 1 E. In the Warrior field, except for the Pratt bed, the workable beds have only been touched here and there on the edges and the great body of available coal is undisturbed.

IRON ORE.

GEOLOGIC AND GEOGRAPHIC RELATIONS.

The iron ore of the Birmingham quadrangle occurs in the Clinton ("Rockwood") formation. There are also limonite deposits in the residual clay of the Knox dolomite on the east slope of Pine Ridge, in Cahaba Valley south of Leeds, and these were worked formerly, but operations were abandoned, as the deposits are not rich enough to work with profit under present conditions.

The Clinton formation carries ore beds everywhere in the quadrangle, but only on Red Mountain south of Morrow Gap and on West Red Mountain north of Village Springs are the beds of sufficient thickness and persistence and of good enough quality to be worked with profit at present. Outside of the territory just outlined the beds of ore are in general comparatively thin and even where thick carry only a small proportion of good or indifferent ore, in streaks separated by ferruginous shale or sandstone. In many places the ore beds are only highly ferruginous sandstone, so lean as hardly to be ranked as ore. There is no doubt, however, that much ore of good quality exists in the areas at present outside the field of active operations, and it is probable that these areas will yield a considerable quantity of ore after the richer deposits of the region have been exhausted. The ores of this region have been fully discussed in Bulletin 400 of the Survey and it seems unnecessary to go more into detail concerning these less valuable deposits. The following statements are therefore devoted to the areas carrying ore at present workable.

The Clinton formation, in which the ore occurs, varies extremely in thickness and in the details of its stratigraphy, although the presence of beds of hematite somewhere within the formation is a remarkably persistent feature, not only throughout the length of the Appalachians but in rocks of equivalent age in Wisconsin and New Brunswick. In Alabama the formation is thickest at the north and there contains beds of limestone, which give way to sandstone with the thinning of the formation toward the south; the proportion of shale in the Clinton is also greatest in the northern part of the State. Within the district here considered the Clinton formation shows notable variations in composition from northeast to southwest, as is indicated by the four sections on Red Mountain, beginning northeast of Birmingham and continuing at irregular intervals for about 20 miles to the southwest, shown in figure 5 (p. 5). As the Clinton has been fully described on pages 5–6, further description will be omitted here.

ORE BEDS ON RED MOUNTAIN.

Hickory Nut seam.—The Hickory Nut seam, the uppermost of the series, comprises 3 to 5 feet of sandy ore or ferruginous sandstone, characterized by a great abundance of *Pentamerus oblongus*, fossils which resemble hickory nuts incased in partly open outer shells. The ore is of too low grade to be worked at present. The seam reaches its greatest thickness in the district between Birmingham and Bessemer, and where recognized it lies about 12 to 20 feet above the next lower seam.

Ida seam.—The Ida seam consists of 2 to 6 feet of rather siliceous ore associated with 14 to 16 feet of ferruginous sandstone. Ore at this horizon is more continuous and extensive than at the horizon of the Hickory Nut seam. It has been recognized at many of the workings from Bald Eagle Gap 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, with a corresponding range in silica of 32 to 42 per cent. The Ida seam occurs 20 to 50 feet above the top of the Big seam.

Big and Irondale seams.—The Big and Irondale ore beds are considered together, as they are very closely associated in space. The ore of the two beds, however, differs somewhat in quality, and the seams are so sharply separated by thin sandstone or shale that they may be mined independently.

The thickness of the Big seam varies from 16 to 30 feet. It extends as a traceable unit on Red Mountain for practically the whole length of the mining district. Notwithstanding its great thickness there is rarely more than 10 to 12 feet of good ore in a single bench, and at most places only 7 to 10 feet is mined. Probably the maximum thickness is attained between Red Gap (near Irondale) and Bald Eagle, although for a mile southwest of Red Gap the bed remains nearly as thick. Toward the southwest the total thickness of the ore-bearing sediments gradually decreases, without, however, altering greatly the thickness of the workable portion. About the middle of the district the seam becomes separated into two benches, either by a well-defined parting along the bedding plane or by a shale bed thin at first but thickening gradually to the southwest. The middle of the Big seam is the workable part in the northeast end of the district, but the upper bench is of most importance throughout the rest of the area. In the southwestern portion of the district, south of this quadrangle, the lower bench, which farther northeast is composed of ore that may eventually be mined, becomes a series of thin layers of lean ore and shale and is consequently of no possible value. Finally the upper bench itself becomes shaly and carries only ore of very low grade.

The Irondale seam is of most value on Red Mountain between Pilot Knob on the northeast and Lone Pine Gap on the southwest. Southwest of Lone Pine Gap the seam is composed in places of interbedded low-grade iron ore and shale, while elsewhere its identity is completely lost. Its soft ore, now nearly all mined out by either surface trenches or slopes, is the best in the district. Its hard ore is also of high grade and hitherto has been for the most part held in reserve, because ore could be produced from the thicker Big seam at a lower cost per unit of iron.

The structure and composition of the Big and Irondale seams are shown in the following five sections, measured by Burchard[a] at places 2 to 5 miles apart along Red Mountain, beginning in the northeastern portion of the mining district:

[a] Bull. U. S. Geol. Survey No. 400, 1909, pp. 47-49.

Character of Big and Irondale seams 1 mile northeast of Red Gap, near Irondale.

Strata.	Thickness. Ft.	in.	Character.
Sandstone.			
Big seam:			
Ore, sandy	1	8	Unweathered ore: Metallic iron, 16-20 per cent; insoluble, 40± per cent; lime, 18± per cent.
Ore, lean, with fine quartz pebbles.	5		
Ore, massive, cross-bedded, mined.	7		Hard ore: Averages metallic iron, 36 per cent; insoluble, 26 per cent; lime, 20 per cent.
Ore, similar in appearance to above but not mined at present.	6		Percentage of iron grades down from 35 at top to less than 20 at bottom; insoluble rises to more than 60 per cent.
Sandstone, ferruginous, lean ore, and shale	20		
Shale	0-6		
Sandstone, very hard	3		
"Gouge," calcareous		6	
Irondale seam:			
Ore, mined	5		Semihard ore: Averages metallic iron, 37 per cent; insoluble, 29 per cent; lime carbonate, 14 25 per cent.
Shale, hard.			

Character of Big and Irondale seams one-half mile south of Red Gap.

Strata.	Thickness. Ft.	in.	Character.
Sandstone, coarse, ferruginous.			
Big seam:			
Ore, containing much silica in coarse grains and fine pebbles.	22		Upper half, soft ore: Metallic iron, 22± per cent; insoluble, 64± per cent; lime, trace. Lower half, soft ore: Metallic iron, 32± per cent; insoluble, 47± per cent; lime, trace.
Shale		1	
Ore, mined	7		Soft ore: Metallic iron, 36± per cent; insoluble, 45± per cent; lime, trace.
Ore, not mined	10		Semihard ore: Metallic iron, 25± per cent; insoluble, 50± per cent; lime carbonate, 8.12 per cent.
Shale, soft	3		
Irondale seam:			
Ore, mined	4	4	Soft ore: Metallic iron, 50± per cent; insoluble, 15± per cent; lime, trace.

Character of Big and Irondale seams near Lake View, Birmingham.

Strata.	Thickness. Ft.	in.	Character.
Sandstone, thin bedded.			
Big seam:			
Ore, mined	10		Soft ore: Metallic iron, 40± per cent; insoluble, 39± per cent; lime, trace. Hard ore: Metallic iron, 34± per cent; insoluble, 26± per cent; lime, 20± per cent.
Shale		8	
Ore, not mined	7		Value decreases regularly downward. Soft ore: Metallic iron 15 to 25 per cent; insoluble, 50 to 60 per cent.
Shale	2		
Irondale seam:			
Ore	2	8	Hard ore: Metallic iron, 38± per cent; insoluble, 16± per cent; lime carbonate, 24± per cent Soft ore: Metallic iron, 47± per cent; insoluble, 26± per cent. Only hard ore mined at present.
Shale		9	
Ore	2	2	

Character of Big and Irondale seams near Lone Pine Gap.

Strata.	Thickness. Ft.	in.	Character.
Shale.			
Big seam:			
Ore, mined	10±		Hard ore: Metallic iron, 36± per cent; insoluble, 25± per cent; lime carbonate, 20± per cent. Soft ore: Metallic iron, 44± per cent; insoluble, 35± per cent. Semihard ore mined at present.
Shale	1+		
Ore, not mined	6	6	Value decreases regularly downward, top ore being poorer than the ore mined above.
Shale	2		
Irondale seam:			
Ore, not mined	6		Low-grade ore interbedded with shale.

Character of Big and Irondale seams at open cut, Green Spring mine, SW. ¼ sec. 11, T. 18 S., R. 3 W.

Strata.	Thickness. Ft.	in.	Character.
Sandstone, coarse, ferruginous.			
Shale, yellow.			
Big seam:			
Ore, massive, cross-bedded and jointed; mined.	8		Soft ore: Metallic iron, 42± per cent; insoluble, 31± per cent; lime, 2± per cent. Semihard ore: Metallic iron, 38± per cent; insoluble, 32± per cent; lime, 8± per cent. Mostly semihard ore mined at present.
Parting on bedding plane.			
Ore, rather a ferruginous sandstone or coarse grit; mined in only a few places.	8		
Shale		2	
Sandstone, ferruginous and shaly	1		
Shale, sandy		6	
Sandstone, ferruginous	1	3	
Shale		2	
Sandstone		4	
Shale		2	
Ore, sandy		5	
Shale		5	
Ore, sandy		3	
Shale		2	
Irondale (?) seam:			
Ore, very sandy	1	6	Not minable.
Shale		2	
Sandstone, fine grained, very ferruginous.	1	4	
Shale		2	
Sandstone, fine grained, very ferruginous.		10	
Shale		1	
Sandstone, very ferruginous		5	
Shale		1	
Sandstone, very ferruginous		10	
Shale.			

The sections made near Lake View and at Lone Pine Gap show that although the total thickness of the iron-bearing strata in this direction grows gradually less, yet the thickness of workable material remains fairly constant, and the last section illustrates the complete deterioration of the Irondale seam.

The question whether the iron-ore beds extend to the southeast under the Cahaba coal field is interesting and important. In this connection attention should be directed to the fact that the Clinton formation is present in the fault block 1 mile south of Henryellen. Furthermore, the formation carries good ore at this point, but nothing is known of the thickness of the bed or beds. These facts argue for the persistence of the formation, with good ore also, beneath the full width of the Cahaba field. The dip is continuously eastward at angles of 12° to 30° and the ore beds are thus carried to great depths. Roughly speaking, the ore horizon is 3000 feet below the Shades sandstone member on Shades Mountain, 4000 feet below the Gould coal, 5300 feet below the Harkness coal, 7000 feet below the Mammoth coal, and 8000 feet deep in the deepest part of the Cahaba trough. Whether the ore maintains its thickness and quality under this area is entirely unknown. The hard ore has not been found to change materially in quality with increase of depth up to the present time, though it has been tested at a depth of 1200 feet, and there is no well-established ground for expecting such a change. As the mining of this deeper-lying ore is a labor for somewhat remote generations, the matter demands no further discussion here.

ORE BEDS ON WEST RED MOUNTAIN.

On West Red Mountain the rocks dip at high angles and appear not to carry valuable seams of iron ore throughout the middle of the district. To the north of Village Springs, however, is a bed of some value which has been mined at Compton. This bed is reported to be 3½ feet thick just south of Blackburn Fork, 6 miles north of Compton. Its extension south of Compton is not known.

The seam at Compton ranges generally from 30 to 36 inches in thickness, with a thin parting of shale that is irregular in position. Locally the entire seam is pinched down to a very few inches or entirely cut out by downward bulging of the overlying shale, which at such places has a concretionary or concentric structure. Such structures, which result in the local absence of the ore bed, are termed "faults" by the miners, but there is no dislocation of the beds such as is required by a true fault, and the ore is usually picked up again if the workings are driven on.

CHARACTER OF THE ORES.

As described by Burchard[a] the Clinton iron ore, so named from its typical occurrence in sedimentary rocks at Clinton, N. Y., and in strata of equivalent age in other parts of North America, belongs to the class of iron oxides known as red hematite. It includes the structural varieties known as red fossil and oolitic ore. The mass of the ore is amorphous red hematite mixed with calcium carbonate, silica, alumina, magnesium carbonate, and other minerals in minor quantities.

STRUCTURE.

The structure and mineralogy of the Clinton ore are closely related features of the deposits. The ore with its associated minerals occurs in lenticular beds analogous to strata of sandstone, shale, and limestone, and interbedded with such rocks.

The fossil ore consists of aggregates of fossil organic forms such as bryozoans, crinoids, corals, and brachiopods. (See Pl. VIII.) These forms were evidently at one time principally calcium carbonate, and they have been replaced partly or wholly by ferric oxide. The fossil material, much of which consists of broken and waterworn fragments, evidently was gathered by the action of waves and currents into beds and subsequently cemented together by calcium carbonate and ferric oxide. More or less clay material has been likewise included in the beds during their formation, and this commonly exists as thin seams of shale.

The oolitic ore consists of aggregates of flat grains with rounded edges, somewhat of the size and shape of flax seeds. (See Pl. XI.) 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 instances 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 certain 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, while the oolitic ore may carry higher proportions of silica and alumina.

A characteristic of the Clinton ore that is secondary rather than original is that where weathered or acted upon by surface waters the lime carbonate is dissolved out of the beds, thereby increasing the content of iron oxide, silica, and other constituents proportionately. Such altered ore is popularly termed "soft ore," and appropriately, too, for where altered it is usually porous and friable as compared with the unaltered material, which is termed "hard ore." The alteration of the ore beds takes place along the outcrop and to distances of a few feet to 400 feet, depending on the attitude of the beds and on the thickness and permeability of their cover. The quantity of the soft ore is small as compared to that of the hard ore, and owing to its higher content of iron and its greater accessibility much of the soft ore has already been taken in mining, so that in the future the reserves of this variety of ore will steadily decrease in importance.

[a] Bull. U. S. Geol. Survey No. 400, 1909, pp. 26-27.

CHEMICAL COMPOSITION.

Conditions of blast-furnace practice determine the grade of material that may be regarded as an ore. For instance, a lower limit of metallic iron and a higher limit of impurities may be allowed in a limy ore than in one that contains but little lime. In localities where brown iron ores are available for mixing with Clinton ores an ore of the Clinton class can be used as a flux in many instances, although it runs so low in iron and so high in lime that it might not be regarded as acceptable in districts where no brown ore can be used. In general the hard and semihard ores used to-day in the Birmingham district range in percentages of major constituents as follows: Metallic iron, from 32 to 45 per cent; lime oxide, from 5 to 20 per cent; silica, from 2 to 25 per cent; alumina, from 2 to 5 per cent; magnesia, from 1 to 3 per cent; phosphorus, from 0.25 to 1.5 per cent; sulphur, from a trace up to 0.5 per cent; and water, from 0.5 to 3 per cent. The ore is therefore of non-Bessemer grade. Small quantities of manganese are found in the ore in places. The content of this mineral seldom exceeds 0.25 per cent. 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 following analyses show a typical hard ore (No. 1), a typical soft ore (No. 4), and intermediate or semihard grades (Nos. 2 and 3):

Analyses of Clinton iron ores, 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

These analyses represent ore samples 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 No. 1 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 metallic iron in this particular mine.

SPECIFIC GRAVITY.

The Clinton ore exhibits rather wide variation in specific gravity due to variations in composition and to variations in structure. By experiments with 1-inch cubes and lumps of ore the specific gravities of certain southern Appalachian Clinton ores have been found to range from 2.93 to 3.56. The above figures correspond roughly to weights of from 183 to 225 pounds per cubic foot and to volumes of 12.25 to 10 cubic feet per long ton.

LIMESTONE AND DOLOMITE.

General statement.—Both limestone and dolomite are economically important in the Birmingham district. Limestone is used for lime and cement, and both limestone and dolomite are used for flux in iron smelting. Indeed, the presence of dolomite for fluxing material is one of the three essential factors in the great industrial development and importance of the Birmingham district.

In this area there are three distinct limestone formations and one dolomite formation. These are, in order from youngest to oldest, the Bangor limestone, the Chickamauga limestone, the Knox dolomite, and the Conasauga limestone.

BANGOR LIMESTONE.

The Bangor limestone is of Carboniferous age and is named from Bangor, Ala., where it has been quarried. It is generally a semicrystalline, rather light-gray limestone, ranging from a few feet to 300 feet or more in thickness. Its chemical composition is shown below.

Analyses of Bangor limestone.[a]

	1.	2.	3.	4.
Silica (SiO_2)	2.05	4.45	2.80	1.05
Iron oxide and alumina ($Fe_2O_3+Al_2O_3$)	.76	3.30	.70	.82
Lime carbonate ($CaCO_3$)	89.64	86.35	94.59	96.74
Magnesium carbonate ($MgCO_3$)	8.15	-------	-------	.71

[a] Smith, E. A., Bull. Alabama Geol. Survey No. 8, 1904, p. 71.

1. Average sample of 150 feet of rock used as flux, Compton quarry, north of Dale. J. L. Beeson, analyst.

2 and 3. Stock house samples, Compton quarry. W. B. Phillips, analyst.

4. Average of eight analyses of limestone from Blount Springs quarry. Henry McCalley, J. L. Beeson, and J. R. Harris, analysts.

These analyses show considerably more silica and magnesia in the limestone of the Compton quarry than at Blount Springs. Only analysis 2, however, shows an injurious amount of silica, with a corresponding lower percentage of lime carbonate.

CHICKAMAUGA LIMESTONE.

The Chickamauga limestone has been quarried at Gate City by the Sloss Iron Company for use as flux, but it is no longer used in this region for that purpose to any extent. The subjoined analyses show its composition at this quarry.

Analyses of Chickamauga limestone at Gate City.[a]

	1.	2.
Silica (SiO_2)	5.70	3.30
Iron oxide (Fe_2O_3)	1.87	2.14
Lime carbonate ($CaCO_3$)	91.16	91.33

[a] Smith, E. A., Bull. Alabama Geol. Survey No. 8, 1904, p. 72.

1. Average sample from crusher. Henry McCalley, analyst.
2. Average of four samples. J. W. Miller, analyst.

The high percentage of silica shown by these analyses probably indicates the reason why the use of this limestone as flux has been discontinued. Much purer rock can be obtained in the region, as will be shown below.

The most favorable locality for quarrying the Chickamauga limestone in this region, so far as natural conditions are concerned, is at the south end of Blount Mountain, where the limestone lies nearly flat and forms high hills, such as Foster and Butler mountains. About 400 feet of limestone is here available, entirely above drainage level and exposed on all sides. This locality could be easily reached from the Louisville and Nashville Railroad by a spur 3 miles long, leaving the main track 2 miles north of Pinson and extending up Dry Creek to Foster Mountain.

KETONA DOLOMITE MEMBER.

The lower 500 to 600 feet of the Knox dolomite, which is free from the chert characterizing the upper 2700 feet of the formation, is known as the Ketona dolomite member. It outcrops along the east side of Opossum Valley, where are located the quarries of the Republic Company at Thomas and of the Sloss Iron Company at North Birmingham. The outcrop in Opossum Valley continues as a narrow belt up the west side of Birmingham Valley to Pinson. Along the east side of Birmingham Valley a narrow belt outcrops to a point within 1 mile of Chalkville. Besides the quarries mentioned above, the Spencer quarry of the Lacy-Buek Iron Company at Lardona, that of the Tennessee Company at Ketona, and the quarry at Dolcito are located along the western belt. The eastern and western belts of outcrop are connected between North and East Birmingham, where the dolomite lies nearly flat and makes a wide outcrop separating the chert ridge in Birmingham known as Cemetery Ridge from the chert ridge extending northeastward from East Birmingham to Blount Mountain. An outcrop of the dolomite in Murphrees Valley extends along the east side of Gravelly Ridge from Chepultepec to Remlap. It is well exposed on Blackburn Fork west of Swansea as a bluff about 100 feet high. The dolomite is also known to occur along the east side of the Cahaba trough at the west base of Pine Ridge, where on account of its vertical attitude its outcrop is narrow, though it probably extends for 10 miles diagonally across the southeast corner of the quadrangle.

The Ketona dolomite is generally gray in color and more or less crystalline in texture. As shown by the analyses below, it may be nearly free from silica, though thin plates of chert or silica in some other form are said to occur in the rock at various points. At the top it begins to show more or less abundant chert inclusions, such as nodules, stringers, and thin irregular sheets. This transition may be observed in the vicinity of the abandoned Dolcito quarry, where the overlying cherty beds of the Knox dolomite are fairly well exposed. The rock is as a rule thick bedded. In weathering much of the surface becomes granular, simulating closely a coarse-grained sandstone. The dip along the western belt, where the quarries mentioned above are located, is from 10° to 15° E.

From the Ketona dolomite member is obtained all the flux quarried in the quadrangle except that obtained from the Bangor limestone. As quarried by the Tennessee Company at Ketona and the Sloss Company at North Birmingham this rock is a nearly pure calcium and magnesium carbonate, as shown by the following analyses:

Analyses of dolomite from Ketona and North Birmingham.

	1.	2.
Silica (SiO_2)	1.31	0.70
Alumina (Al_2O_3)	.96	.63
Lime carbonate ($CaCO_3$)	55.80	56.41
Magnesium carbonate ($MgCO_3$)	42.47	43.00

1. Average of four analyses of average samples from Ketona quarry, made from August to October, 1903. Analyses furnished by Tennessee Company.
2. Average of ten analyses of carload lots from North Birmingham quarry, made from August, 1903, to June, 1905. Analyses furnished by Sloss Company.

These analyses indicate that the lime and magnesia in this rock are nearly in the proportions of the mineral dolomite and that it is properly called dolomite.

W. B. Phillips[a] has made a number of silica determinations from the dolomite in the vicinity of Dolcito. At the south end of the Dolcito quarry, which had a face of 17 feet at the time of sampling, samples taken from every foot of the face showed a range of 0.48 to 0.88 per cent of silica, with an average of 0.64 per cent. At the northeast end of the same quarry, presumably from the same beds as at the southwest end, though not so stated, the silica, in samples taken in the same way, ranged from 0.48 to 4.58 per cent, with an average of 1.69 per cent. This shows a considerable variation within a short distance. Two miles northeast of Dolcito, on Five-mile Creek, 29 samples taken at intervals from the top to the bottom of 116 feet of dolomite and analyzed by Phillips gave silica ranging from 0.96 to 7.28 per cent, with an average of 3.26 per cent. This shows a still greater increase in silica content to the northeast. It is possible that these samples were obtained at a horizon above that of the true Ketona dolomite, which north of Dolcito is apparently confined to the flat land along the valley and does not show in outcrop to any extent.

On account of the fact that the dolomite outcrops along the valley bottoms and but little above drainage level, the conditions for quarrying it are not very favorable, inasmuch as it is necessary to keep the quarries dry by constant pumping and the rock has to be raised from considerable depths. It is especially difficult to keep the quarries dry in heavy and prolonged rains, and at times work has to be suspended on account of flooding. The usual conditions of quarrying are shown in Plate XII on the illustration sheet.

The conditions for quarrying are most favorable in Murphrees Valley between Remlap and Chepultepec, where the dolomite outcrops well up on the east side of Gravelly Ridge. Although the rock here dips to the west at a considerable angle, large bodies of it could be quarried in such way as to be self-draining, and the expense of raising the rocks would be entirely avoided.

The suitability of this dolomite for flux has been amply demonstrated by its use in the furnaces of the region for the last ten years or more. The results obtained throughout this period prove that the dolomite is in every respect equal to the best limestone to be had in the region for fluxing purposes. One company reports its exclusive use in smelting iron for the manufacture of steel by the basic process. The abundant supplies to be had in proximity to the furnaces also favor its use.

CONASAUGA LIMESTONE.

No use has been made of the Conasauga limestone in this region so far as known. Below is an average of two analyses of samples from an old quarry near Wheeling, northeast of Bessemer.

Average analysis of Conasauga limestone from quarry near Wheeling.

[William E. Janes, analyst.]

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

This rock is suitable for flux and for lime, but it contains too much magnesia for cement making. It would, however, manifestly be unsafe to draw any general conclusions as to the general composition of this limestone from these two analyses.

The outcrop of the formation is always on low ground near drainage level and the dips are high, so that the conditions for quarrying are very unfavorable. There is little likelihood that the limestone will be utilized to any extent, as the region contains abundant material of as good or better quality and better situated for quarrying.

CLAY.

Both sedimentary and residual clays occur in this quadrangle. The sedimentary clay occurs either as a superficial deposit or as the underclay of coal seams.

So far as known, the only important superficial deposit of sedimentary clay lies along Turkey and Cunningham creeks south and east of Morris. This clay has been worked to a considerable extent for brickmaking at De Soto, on the Moss property, but the plant has not been in successful operation in recent years. The clay here is reported to be 10 to 12 feet thick and shows the following section:

Section of clay at Moss brickworks, De Soto.

	Ft.	in.
Gray sandy loam	1	
Sandy clay	3	9
Layer full of ferruginous and sandy fragments		6
Clay stained with iron to bottom	5	

The entire thickness of the deposit is used. The bricks made from this clay are of a good red color and are reported to be of excellent quality. They are said to shrink a good deal in drying. The clay in this locality is said to occur in irregular patches of unknown shape and extent as far down Turkey Creek as the bridge south of Morris. Clay was noted along the Louisville and Nashville Railroad half a mile east of Morris and at a point between Fedora and Indio. It seems not unlikely that the clay deposit is coextensive with the flat ground along Turkey Creek from Fedora to Indio and along Cunningham Creek for 2½ miles above its junction with Turkey Creek, though it probably varies much in thickness and quality in this area.

[a] McCalley, Henry, Report on the valley regions of Alabama, pt. 2, Geol. Survey Alabama, 1897, pp. 323–326.

This deposit of clay accumulated during the time that the creek waters were more or less ponded from some cause, for it is evidently composed of fine material that was washed down from the surrounding hills and slowly settled in still water. The cause of the ponding may have been a stratum of sandstone which crosses Turkey Creek near the bridge south of Morris and which retarded the downcutting of the creek bed and acted as a dam to the water above.

Residual clay from the Knox dolomite and the Conasauga limestone is utilized at a number of points in Birmingham and vicinity. This residual clay or red loam to the depth of 4 to 8 feet, together with a foot or more of top soil, makes an excellent common brick. The soil and red loam are mixed in the proportion of one-third soil to two-thirds loam, to prevent too great shrinkage. The loam can not be worked beyond a depth that would give too great a proportion of loam in the mixture. The materials are mixed with a wheel in open pits for about three hours, sufficient water being added to give the necessary degree of plasticity. The brick are molded by hand, air-dried for about a week, burned for twelve to fourteen days, and allowed four to six days to cool off.

The only underclay utilized in the quadrangle is that under the Black Creek coal bed at Coaldale and vicinity. It is a gray plastic clay and makes a buff brick. It has been mined near the Southern Clay Company's brickworks at Coaldale and at the Butterfly mine, about 1 mile east of Coaldale. At both points it is 4 feet thick. Its further extension is unknown, but there is evidently a considerable body of good clay in this locality. From both places mentioned above the clay has been shipped to Birmingham and Bessemer for fire brick and terra cotta. It is now being mined at the Butterfly mine by the Sibley-Menge Press Brick Company for use in its new works 1 mile north of Coaldale. It is used for dry-press face brick of buff color, is mixed with shale for gray brick, and by the addition of manganese is used for speckled brick.

A bed of clay 4 to 6 feet thick underlies the Nickel Plate or American coal seam at Baileys Quarters, northeast of Brookside, where it is exposed in a cut of the Louisville and Nashville (North Alabama) Railroad. The same clay also shows in a cut of this railroad at Clift station. Here there are three beds, two of which are each 2 feet thick and one 18 inches thick. A bed of clay 3 to 4 feet thick occurs at the same horizon at Short Creek, and clay of greater or less thickness has been noted under the same coal at other points in the region. It has not been utilized and nothing is known of its qualities.

A bed of very white, soft, plastic clay 2½ feet thick underlies the Pratt seam at the Thompson mine, northwest of Sayreton, but generally the coal seams of this region appear to be without underclays of economic importance.

SHALE.

The Alabama coal measures, reaching in the deepest part of the Cahaba trough nearly 7000 feet in thickness, are made up of alternating shale and sandstone, the shale forming about two-thirds of the whole. Most of the shale is probably suitable for brickmaking. Shales from different horizons in the Warrior Basin and from one horizon in the Cahaba trough are now being utilized for brick.

The highest bed of shale used for brick is that above the Mary Lee coal group in the Warrior Basin. This is generally a blue clay shale about 200 feet thick. It is a persistent stratum, extending throughout the Warrior Basin in this area where not removed by erosion. It is very uniform in appearance, though, as stated below, it may show considerable variation in composition at different points or at different levels. The vertical continuity of the shale is broken here and there by layers of sandstone up to 10 feet thick, or possibly more at some points. Shale from the bottom of this mass is extensively used for brick by the Graves Shale Paving Brick Company at Graves. Below is a section of the shale quarry at this place.

Section at shale quarry, Graves.

	Feet.
Yellow shale	6
Gray shale	10
Blue shale	28
	44

The shale dips from 10° to 15° W., into the hill. According to Ries,[a] the yellow shale is somewhat sandy and has a large content of ferric oxide. It vitrifies at 2250° F. and fuses at 2500°, yielding a brick that has a tensile strength of 40 pounds to the square inch. The gray shale is less sandy and ferruginous. It vitrifies at 2200° F. and fuses at 2500°, yielding a brick of good red color, with an average tensile strength of 105 pounds to the square inch. The brick are burned nine days in round down-draft kilns. Paving brick and chemical

[a] Ries, Heinrich, Bull. Geol. Survey Alabama No. 6, 1900, p. 185

brick are made. The latter are used principally for packing acid chambers in making sulphuric acid, a use for which they are well adapted because, on account of their density, they absorb almost no water. The daily capacity is 50,000 brick and the actual daily output is reported as 28,000 to 38,000.

At Coaldale shale from two horizons is used. The upper horizon is that of the Jefferson coal seam and the lower is about 150 feet below the Black Creek coal seam. Shale from the upper horizon is utilized by the Southern Clay Manufacturing Company for vitrified paving brick. The section at this company's quarry is as follows:

Section at Southern Clay Manufacturing Company's quarry, Coaldale.

	Feet.
Reddish, somewhat sandy shale	20
Dark clay shale with mica	15
Coal	1
Stiff gray, somewhat sandy shale	30
Coal	1

The shale dips at a low degree to the east, and as it outcrops near the top of the hill the conditions for quarrying are very favorable. The 20 feet of reddish shale may differ from the underlying 15 feet of dark shale only in being more weathered. Although the lower 30 feet of gray shale has been used, only that from the upper 35 feet is used at present, in the proportion of two-thirds red shale to one-third dark. A test, apparently of the red shale, showed that vitrification takes place at 2000° F. and viscosity at 2150° F. The brick are burned in round down-draft kilns for nine days and are red or brown. The capacity of this plant is 30,000 brick daily.

The shale lying 100 to 200 feet below the Black Creek seam is used for dry-press brick by the Sibley-Menge Press Brick Company, whose plant is about 1 mile north of Coaldale. The shale lies nearly flat and is at least 70 feet thick, but only rock from the bottom 20 feet is used at present. In its weathered condition this is a gray clay shale, apparently with very little mica and sand. It makes a fine dry-press face brick of a pleasing red color. As stated above, it is mixed with the underclay of the Black Creek coal for gray brick. The capacity of the plant is about 60,000 brick daily. Tests of brick made at this plant showed a crushing strength of over 100,000 pounds and an absorption of 3 ounces of water in six hours.

At Lovick, in the Cahaba coal field, shale lying between the Gould and Nunnally coal groups is being extensively utilized at the brickworks of L. L. Stevenson. The whole bed utilized has the following section:

Section at Stevenson brickworks, Lovick.

	Feet.
Reddish shale, probably weathered phase of gray shale below	10
Gray clay shale	18
Blue-black carbonaceous clay shale, with fossils	20

Shale from all these layers is mixed and used for pale-red common brick or brown vitrified brick. The time of firing is nine days—three days at low heat to expel the water and six days at red heat and finally at white heat. The capacity of the plant is 80,000 brick daily and the output is large. No analyses or physical tests have been made.

This shale body is traceable by a characteristic dark fossiliferous shale layer for 6 miles southwest of Lovick. It is particularly well shown along the Leeds-Birmingham road in the southwest corner of sec. 28, T. 17 S., R. 1 W. The shale extends northeastward along the west side of Owens Mountain to Parsons station and beyond. At Lovick this shale dips 8° E., but both to the north and the south the dip reaches 20°.

Since the field work for this folio was completed the Copeland-Inglis shale paving and building brick plant has been established at Alton, in Shades Valley. It uses shale from the middle of the Parkwood formation.

The shales of this region are well adapted to brickmaking not only at the points described above but also at many other points at the same or other horizons throughout the area. It appears, therefore, that there are unlimited quantities of shale in this region from which high-grade paving and building brick can be made. At many points the conditions as regards quarrying the shale, cheap fuel supply, and transportation facilities are favorable for the location of brickworks. The shale brick made in this region find an active market throughout the Southern States.

ROAD METAL.

The Birmingham region is abundantly supplied with road metal. The limestones and dolomite already described will afford exhaustless supplies of material for road making, for both foundation and surface purposes. The coal-measure and other sandstones 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 especially facilitating its use for this purpose is its minutely shattered or fractured condition, near its outcrop at least. 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, a few miles south of the quadrangle, 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 smooth, hard mass. Probably it contains also enough calcareous matter to act as a bond. It makes a very firm, smooth, white, clean road surface.

The Fort Payne chert has been exploited in this quadrangle only at Red Gap and the immediate vicinity. The supply easily accessible to transportation along the east flank of Red Mountain and in the region to the north of Trussville is inexhaustible. In fact, the formation will probably yield chert practically ready for the road at almost any place along its outcrop.

Chert from the Knox dolomite has been used to some extent for road dressing. It is taken from banks adjacent to the roads, where the finer portions of the residual chert have accumulated at the bases of slopes. The material is shoveled out like gravel and is mixed with more or less earth, which serves as a bond. Great quantities of this chert exist as bowlders scattered on the surface of the Knox outcrops. If crushed to a fine size and mixed with a sufficient proportion of finely crushed limestone to serve as a bond or cement, this chert would apparently make a superior material for surface dressing. It is so hard as seemingly to be indestructible. By itself, indeed, unless crushed very fine, it would hardly be suitable for road metal, as it would not make a compact mass, but with sufficient bonding material it would make an excellent road. The expense of crushing the hard bowlders might prove too great to permit its use. It has never been tried.

BUILDING STONE.

Abundant sandstone for rough masonry occurs in the coal measures, Hartselle sandstone, and Clinton formation. A little brown sandstone has been taken from the Clinton formation in the vicinity of Gate City for superstructural work. Very little stone of a quality suitable for such work can be obtained, however. At the base of the Chickamauga limestone in Murphrees Valley is a stratum of buff limestone that works freely and has been utilized to some extent for dimension stone in abutments for railroad bridges. The situation of this stratum at the base of West Red Mountain, under which it dips at a comparatively steep angle, renders it practically inaccessible for quarrying on any considerable scale.

SAND.

Sand for several purposes is obtainable in the Birmingham quadrangle. A mile northeast of Trussville sand is procured from the Hartselle sandstone member, which is coarse and friable, and also from a red loam on the slope below the quarry in the Hartselle sandstone. The loam may be residual from the Hartselle or it may be of Lafayette age, as it greatly resembles the Lafayette in other localities. The red loam is used as molding sand. Sand from the friable Hartselle, both in the Trussville locality and at a quarry at Irondale, is used extensively for sanding brick molds and for other purposes. Sand has also been obtained on a small scale by crushing the Boyles sandstone member at Sayreton Gap, North Birmingham. This sand has been used in the manufacture of sand-lime brick. The sand is about 98 per cent silica. The sand-lime brick industry does not appear to have been very successful, however.

LIME AND CEMENT.

The raw materials of lime and cement exist in great abundance in the region. About a mile north of Chepultepec the Chickamauga limestone is quarried and burned into lime on a considerable scale. At Leeds a large cement mill has been established. It obtains its limestone from the Chickamauga limestone and its shale from the Floyd shale to the east of Leeds. Much of the shale in the coal measures is probably suitable for cement manufacture. The Chickamauga and Bangor limestones are generally suitable for the same purpose, but the Knox dolomite and probably the Conasauga limestone carry too much magnesia for cement making.

SOILS.

The Birmingham quadrangle has a variety of soils. The shales and sandstones of the coal measures yield a soil varying 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 soil types 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 with rock fragments. 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 limestone and dolomite valleys have some of the best soil. The areas of Knox dolomite and Fort Payne chert carry a stony loam which is comparatively unfertile on the hills and ridges but of good fertility 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 full of chert bowlders, which are an impediment to cultivation, but in the lower grounds the chert fragments, though plentiful, are finer and less troublesome. The flat-lying areas of Bangor limestone, especially in Brown Valley and its coves, have a fertile clay loam resulting from the decomposition of the limestone. Wherever the limestone outcrop is crossed by streams from the sandy coal measures the limestone soil is modified by the accumulation of sandy material transported by the streams and a rich sandy loam is formed. 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 same statements apply to the Chickamauga limestone area of Cahaba Valley.

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

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

WATER SUPPLIES.

Underground water.—The Birmingham quadrangle is abundantly supplied with water, because it is situated in a region having a yearly rainfall of over 54 inches. Large springs of excellent water are common in the limestone and dolomite valleys, and these contribute largely to the flow of the larger streams, such as Cahaba River and Gurley, Fivemile, Village, and Valley creeks. Permanent wells of good water can be obtained almost anywhere at depths of 40 to 60 feet. At Schillinger's Brewery in Birmingham are three wells in the Conasauga formation, one of which is 150 and the other two 100 feet deep. These yield 250 gallons of water a minute each and have never shown any signs of exhaustion. The water is used for making ice.

The character of the underground water varies of course with the source. From the limestone and dolomite areas the water is "hard" from the calcareous matter in solution, while from the coal measures, which are composed of shale and sandstone, the water is "soft" or freestone water. No analyses are at hand showing the exact composition of either the hard or soft waters.

Surface water.—Great quantities of water are consumed in the coal washeries, smelting furnaces, and other manufacturing establishments located in Birmingham and vicinity. Supplies for these purposes are derived from the creeks or from Cahaba River, which also affords the water supply for the city of Birmingham. In rainy times the smaller streams in the vicinity of the furnaces, washeries, etc., furnish plenty of water, but in seasons of drought the supply is likely to run low and the water problem becomes serious. In the vicinity of Birmingham water is obtained largely from the waterworks company, but some of the larger consumers desire to have an independent supply, and to obtain such a supply that will be abundant and permanent it is necessary to resort to the lower courses of the larger streams of the region or to the distant rivers, like Blackburn Fork and Locust Fork.

The Tennessee Coal, Iron and Railroad Company is constructing a dam near Village Falls to impound the water of Village Creek for use in its iron and steel works at Ensley. The other streams heading in the dolomite area of Birmingham Valley—Fivemile, Turkey, Self, and Gurley creeks—afford equally good opportunities for a permanent and fairly abundant water supply. A dam 150 feet high across Blackburn Fork just above Swansea would raise the water high enough to run to all parts of the city of Birmingham. Locust Fork could be dammed, say below Watts mines, and raised to the 500-foot level, and the water would then have to be raised 200 feet to flow to most parts of the city; this would provide an inexhaustible supply for all time to come.

The present Birmingham water supply comes from Cahaba River, which is dammed several miles south of this quadrangle. The pumping plant is located near the dam and the water is pumped to the sand filtration plant and reservoirs on Shades Mountain 6 miles southeast of Birmingham, whence it runs by gravity to the city. Little Cahaba River has recently been dammed and its supply added to that of the Cahaba. An ample supply for the needs of the city seems to be thus assured for a long time to come.

Water power.—The streams of this area are capable of producing considerable water power during most of the year, and they are utilized to some extent for running gristmills, sawmills, and cotton gins. In exceptionally dry periods, however, the water power is almost nothing, even in the larger streams, such as Mulberry Fork of Black Warrior River. Measurements of the flow of Mulberry Fork at Cordova, 10 miles west of this quadrangle, and of the flow of Locust Fork at Palos, 2 miles west of the quadrangle, were made in the period from 1900 to 1905.[a] The months of September, October, and November, 1904, were unusually dry and the flow of the streams was probably as low as it ever becomes. Computed on the basis of mean flow during these months, the

[a] Water-Supply Paper U. S. Geol. Survey No. 65, 1901; No. 75, 1902; No. 127, 1905; No. 168, 1906; No. 204, 1907.

horsepower obtainable at Cordova per foot of fall was as follows: September, 7 horsepower; October, 4 horsepower; November, 27 horsepower. That is to say, the natural flow of Mulberry Fork at Cordova during this time over a 20-foot dam would have yielded during September 140 horsepower, during October 80 horsepower, and during November 540 horsepower. This power would have been yielded constantly day and night. As Mulberry Fork receives some large tributaries, such as Sipsey Fork, between this quadrangle and Cordova, its flow is probably twice as great at Cordova as within the quadrangle. The power per foot of fall in this area would therefore have been 3½, 2, and 13½ horsepower respectively, in September, October, and November, 1904. The total fall of Mulberry Fork in its passage through this area is about 75 feet, so that the total power that could have been obtained by utilizing all the water during September, 1904, would have been 262 horsepower, during October 150 horsepower, and during November 1012 horsepower.

These powers could have been developed from the total flow over a dam 75 feet high on the west margin of the quadrangle or from the flow over seven dams each 10 feet high distributed along the river.

Measurements on Locust Fork at Palos for the same period show 5.8 horsepower for September, 4.5 horsepower for October, and 11 horsepower for November per foot of fall. The total fall of Locust Fork within the quadrangle is 250 feet, and on the assumption that the flow for the whole length would average one-half that at Palos the stream would have yielded during September 600, during October 562, and during November 1375 horsepower.

It is not probable that the water power of these streams will ever be less than for the period taken for the computations above. In every other year for which there are statistics the mimimum has been much greater than for this period.

For fuller and more detailed information on these streams and the methods of computation the reader is referred to the Water-Supply Papers already cited.

No data have ever been obtained for the minor streams of the area. Some of these—as Turkey, Gurley, Fivemile, and Village creeks—are fed by springs and maintain a small flow even in the driest seasons. Calvert Prong and Blackburn Fork of the Little Warrior are good-sized streams. The fall of Blackburn Fork in the quadrangle is about 300 feet; that of Calvert Prong, 200 feet; Turkey Creek below Pinson, 300 feet; Gurley Creek below Village Springs, 300 feet; Fivemile Creek below Boyles Gap, 290 feet; and Village Creek below Ensley, 100 feet. It is obvious that all these streams and others as well could be made to yield much power during the greater part of years of normal rainfall.

It does not appear probable, however, that the water power of the area will be utilized on any large scale as long as coal can be had as cheaply as at present, but it can probably be utilized locally with profit on a small scale in exceptionally favorable situations for constructing dams and at points at which coal can not be delivered at a low cost. The possibilities in this direction are probably greater than is realized and the subject may well receive careful consideration.

Mineral waters.—At Blount Springs and at Leeds are mineral springs of considerable note. The water at Blount Springs issues from the top of the Clinton formation, on the crest of the Sequatchie anticline.

The Leeds mineral water is obtained from an open well in the Floyd shale, 1 mile northeast of Leeds, on the Southern Railway. The water is bottled and has considerable sale in the State. The composition of both these mineral waters is given in the next column.[a]

[a] Smith, E. A., The underground water resources of Alabama: Alabama Geol. Survey, 1907, p. 78.

Analyses of Blount Springs sulphur waters.

[Parts per million].

	1.	2.	3.
Potassium (K)	14.2	13.8	11.8
Sodium (Na)	234.3	232.0	217.8
Lithium (Li)	1.2	([a])	([a])
Magnesium (Mg)	24.3	24.9	23.1
Calcium (Ca)	51.4	53.2	50.6
Barium (Ba)	4.6	([a])	([a])
Strontium (Sr)	2.4	([a])	([a])
Iron (Fe)	.8	1.0	.8
Alumina (Al_2O_3)	1.5	1.5	1.3
Chlorine (Cl)	325.1	320.1	297.3
Bromine (Br)	1.9	([a])	([a])
Iodine (I)	Trace.	Trace.	Trace.
Sulphuric acid (SO_4)	Trace.	Trace.	Trace.
Carbonic acid (HCO_3)	279.1	276.2	257.3
Sulphureted hydrogen (H_2S)	56.5	54.2	53.1
Silica (SiO_2)	26.5	19.7	16.6
	1,023.8	996.6	928.9

[a] Present but not determined.

Analyses of Leeds mineral water: Hawkins well.

[Parts per million.]

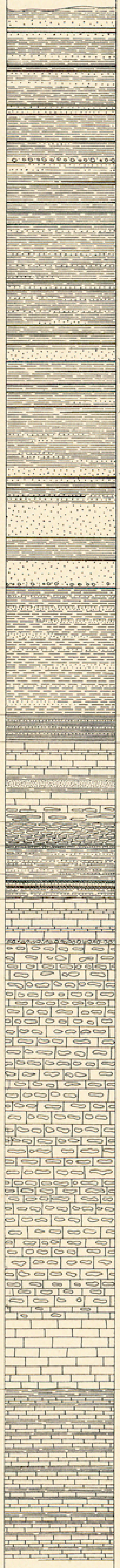
Potassium (K)	6.7
Sodium (Na)	20.5
Magnesium (Mg)	.9
Calcium (Ca)	2.5
Iron (Fe)	2.1
Aluminum (Al)	4.6
Chlorine (Cl)	20.5
Sulphuric acid (SO_4)	35.2
Carbonic acid (HCO_3)	34.5
Silica (SiO_2)	19.9
	147.4

March, 1910.

COLUMNAR SECTIONS

GENERALIZED SECTION FOR THE CAHABA COAL FIELD IN THE BIRMINGHAM QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

System.	Series.	Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Minor Divisions.	Character and Thickness of Divisions.	General Character of Formation.
CARBONIFEROUS	PENNSYLVANIAN	Pottsville formation.	Cpv		5100	Mammoth coal. Thompson coal. Little Pittsburg coal. Black Shale coal. Buck coal. Wadsworth coal. Harkness coal. Nunnally coal group.	10 feet thick with parting in middle. 2 feet thick locally. 2 feet thick. 2 feet thick. 1½ to 3 feet thick. 2 to 8 feet thick with many partings. Thin and of no value.	Predominantly shale with beds of sandstone, conglomerate, and coal. Thick strata of siliceous sandstone and conglomerate ("Millstone grit") at base.
			(Ccn)		(100)	Chestnut sandstone member. Gould coal group.	Thick and thin bedded siliceous sandstone.	
			(Cpi)		(300)	Pine sandstone member.	Thick and thin bedded siliceous sandstone.	
			(Cs)		(250)	Shades sandstone member. Brock coal.	Thick and thin bedded siliceous sandstone conglomerate.	
	MISSISSIPPIAN	Parkwood formation.	Cpw		300-3000			Prevailingly gray shale and sandstone. Fossils very scarce.
		Pennington shale.	Cp		30-300			Gray green, and red shale with a little chert, sandstone, and conglomerate. Highly fossiliferous.
		Bangor limestone.	Cb (Ch)		700 (100)	Hartselle sandstone member.	Prevailingly fine-grained firm sandstone; locally coarse grained and friable.	Prevailingly thick-bedded light-gray crystalline limestone. Hartselle sandstone member and some shale in the middle. Merges through sparingly cherty limestone into Fort Payne chert below. Highly fossiliferous.
		Fort Payne chert.	Cfp		200			Mostly thin-bedded chert; locally thick bedded at bottom and generally fragile. Fossiliferous.
		UNCONFORMITY						
DEV.		Chattanooga shale and Frog Mountain sandstone.	Dc		5-30			Black carbonaceous shale; sandstone with phosphate nodules and fossils locally below.
		UNCONFORMITY						
SIL.		Clinton ("Rockwood") formation.	Sc		250-500	Iron ore, "Big seam." Iron ore, "Irondale seam."		Gray and yellow shale and green, brown, and red highly ferruginous sandstone; beds of calcareous iron ore.
		UNCONFORMITY						
ORDOVICIAN		Chickamauga ("Pelham") limestone.	Oc		200-500			Thick and thin bedded dove-colored and blue limestone. Fossiliferous.
			Oa		(0-40)	Attalla conglomerate member.	Mostly angular chert conglomerate with some well-rounded pebbles of quartzite.	
		UNCONFORMITY						
? CAMBRIAN	UPPER CAMBRIAN	Knox dolomite.	€Ok		3300			Thick-bedded crystalline dolomite with dense compact chert in layers, stringers, and nodules. Ketona dolomite member, free of chert, at the base.
			(€kt)		(600)	Ketona dolomite member.	Noncherty, nearly pure thick-bedded crystalline dolomite. Much used for flux.	
		UNCONFORMITY						
	MIDDLE CAMBRIAN	Conasauga ("Coosa") limestone.	€c		1000-2000			Prevailingly thin-bedded blue limestone interbedded with gray or yellow shale.

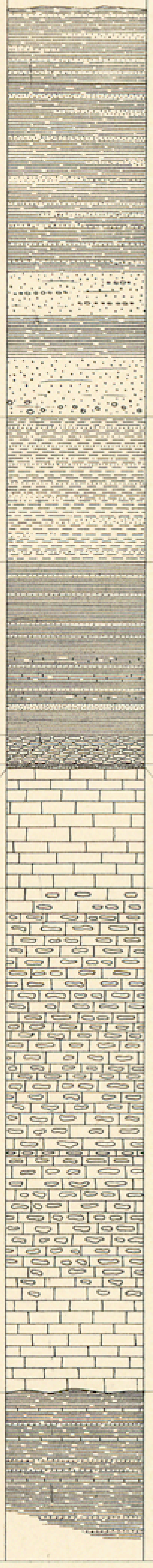
GENERALIZED SECTION FOR THE WARRIOR COAL FIELD IN THE BIRMINGHAM QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

System.	Series.	Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Minor Divisions.	Character and Thickness of Divisions.	General Character of Formation.
CARBONIFEROUS	PENNSYLVANIAN	Pottsville formation.	Cpv		2175	Cobb coal. Camp Branch sandstone member. Pratt coal group: Pratt. Nickel Plate or Cardiff. American. Curry. Gillespie. Mary Lee coal group...: Newcastle. Mary Lee. Blue Creek. Jagger. Lick Creek sandstone member. Ream. Black Creek coal group: Lick Creek. Jefferson. Black Creek. Sapp coal. Rosa or Swansea coal. Tidmore coal.	Generally thin and of little value. Thick-bedded sandstone. 3½ feet thick, mostly coal. Valuable bed. 2½ feet thick with parting in middle. Thin and of no value except possibly in southwest corner. Thin and of no value. Thin and of no value. 1 to 8 feet thick. Thick only locally and much parted. 3 to 8 feet thick, much parted. Very valuable bed. 1 to 3 feet thick. Locally thick and much parted. 1 to 3 feet thick. Generally very dirty and of little value. Thin and of no value. Thin, not workable. 2 to 3 feet thick. Locally a good bed. 2 to 4 feet thick. Generally clean coal and of superior quality. Thin and of no value. 1 to 3 feet thick. Thin and of no value.	Predominantly shale with beds of sandstone, conglomerate, and coal. Thick strata of siliceous sandstone and conglomerate ("Millstone grit") at base.
			(Cby)		(350)	Boyles (Pine?) sandstone member.	Thick-bedded siliceous sandstone conglomerate at base; local pockets of coal in or just below base.	
		UNCONFORMITY						
	MISS.	Pennington shale.	Cpn			For the description of the Pennington shale, Bangor limestone, and older formations that outcrop in this district see the section for the Cahaba coal field.		
		Bangor limestone.	Cb					

GENERALIZED SECTION FOR THE COOSA COAL FIELD IN THE BIRMINGHAM QUADRANGLE.

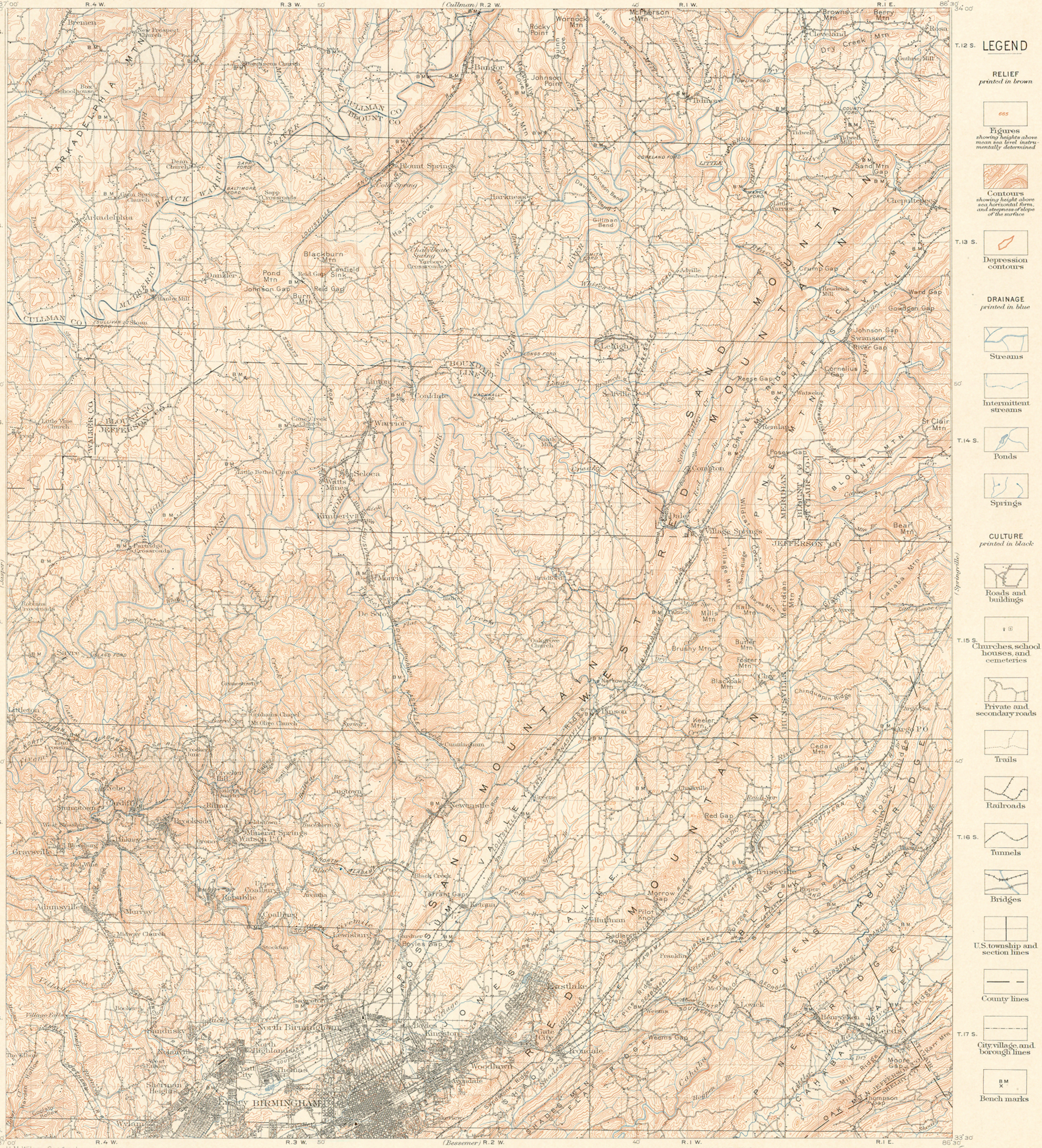
SCALE: 1 INCH = 1000 FEET.

System.	Series.	Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Minor Divisions.	Character and Thickness of Divisions.	General Character of Formation.
CARBONIFEROUS	PENNSYLVANIAN	Pottsville formation.	Cpv		2800	Howard ? coal.	1 foot thick.	Predominantly shale with beds of sandstone conglomerate and thin coals. Thick strata of siliceous sandstone and conglomerate ("Millstone grit") at base.
			(Cpi)		(300)	Pine sandstone member.	Thick-bedded siliceous sandstone, locally conglomeratic.	
			(Cs)		(400)	Shades sandstone member.	Thick-bedded siliceous sandstone.	
	MISSISSIPPIAN	Parkwood formation.	Cpw		1000			Sandstone and sandy shale.
		Floyd shale.	Cf		1200			Black and gray shale and a little sandstone, somewhat calcareous. Fossiliferous.
			(Ch)		(50)	Hartselle sandstone member.	Hard fine-grained sandstone.	
		Fort Payne chert.	Cfp		200			Mostly thin-bedded chert; locally thick-bedded at bottom and generally fragile. Fossiliferous.
		UNCONFORMITY						
DEV.		Chattanooga shale and Frog Mountain sandstone.	Dc		23			Black carbonaceous shale. Sandstone with phosphate nodules and fossils locally below.
		UNCONFORMITY						
ORDOVICIAN		Chickamauga ("Pelham") limestone.	Oc		1000			Very thick-bedded dove-colored, blue, and dark-gray limestone.
		UNCONFORMITY						
? CAMBRIAN	UPPER CAMBRIAN	Knox dolomite.	€Ok		3300			Thick-bedded crystalline dolomite with dense compact chert in layers, stringers, and nodules; Ketona dolomite member, free of chert, at the base. Prevailingly limestone with soft chert and dolomite layers in upper 500 feet.
			(€kt)		(600)	Ketona dolomite member.	Noncherty, nearly pure, thick-bedded crystalline dolomite. Much used for flux.	
		UNCONFORMITY						
	LOWER CAMBRIAN	Rome ("Montevallo") formation.	€r		1000			Variegated red, gray, and yellow shale, calcareous sandstone, and thin limestone.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

ALABAMA
BIRMINGHAM QUADRANGLE



H.M. Wilson, Geographer.
H.B. Blair, in charge of section.
Topography by H.B. Blair, Oscar Jones, and C.D.S. Clarkson.
Assistants, R.L. Harrison and Carroll Caldwell.
Control by Coast and Geodetic Survey, Oscar Jones, and C.B. Kendall.
Surveyed in 1904-1905.

APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

Edition of Aug. 1907, reprinted Dec. 1909

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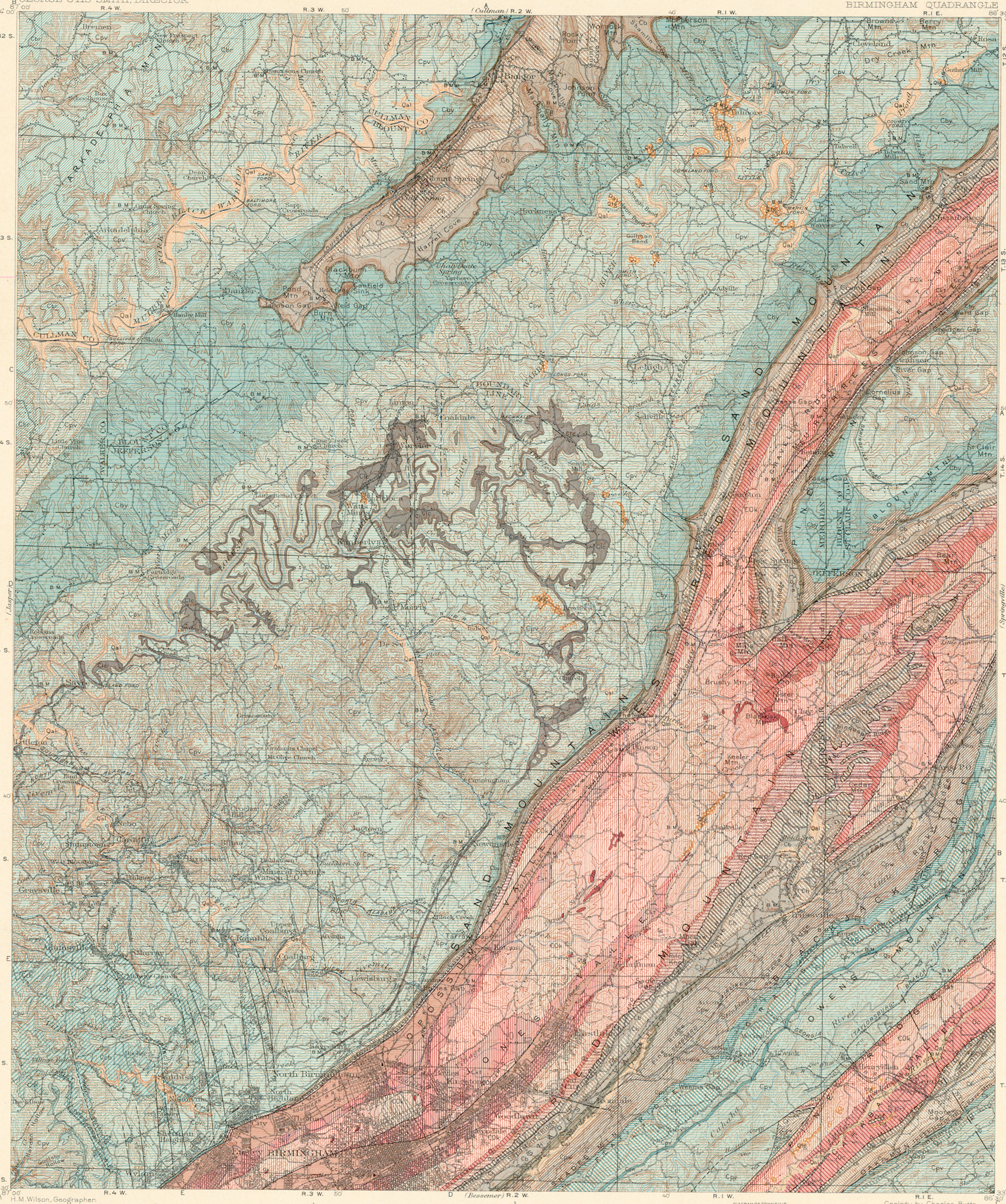
AREAL GEOLOGY

ALABAMA
BIRMINGHAM QUADRANGLE



LEGEND

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent

Qal — Alluvium
(flood plain deposits of present streams)

Pleistocene

Qrg — Terrace gravels
(gravel and sand of probable Pleistocene age on terraces or hills 100 to 300 feet above present streams)

CARBONIFEROUS

Pennsylvanian

Cpv, Cbr, Cby, Ccb, Clc, Ccn, Cpi, Cs, Cr — Pottsville formation
(sandstone, shale, and coal beds, and Shades, Cs, Boyles, Cby, Pine, Cpi, Chestnut, Ccn, Bremen, Cbr, Lick Creek, Clc, Camp Branch, Ccb, and Razburg, Cr, sandstone members)

Mississippian

Cpw — Parkwood formation
(gray shale and sandstone)

Cp — Pennington shale
(gray, green, red, and black shale, some sandstone, conglomerate, and chert)

Cf, Ch — Floyd shale
(black carbonaceous shale, greenish and gray shale, and thin Hartselle sandstone member; Ch)

Cb, Ch — Bangor limestone
(thick-bedded gray crystalline limestone with Hartselle sandstone member, Ch, and a little shale and chert)

Cfp — Fort Payne chert
(chert and limestone)

DEVONIAN

Dc — Chattanooga shale and Frog Mountain sandstone
(black shale and sandstone below, too thin to separate on map)

SILURIAN

Sc — Clinton (Rockwood) formation
(shale and sandstone with beds of iron ore)

ORDOVICIAN

Oc, Oa — Chickamauga ("Pelham") limestone
(thick to thin-bedded, dove and blue fossiliferous limestone; Attalla conglomerate member, Oa, chiefly chert pebbles, locally at base)

CAMBRIAN

€Ok, €kt — Knox dolomite
(heavy bedded cherty dolomite with chert-free Ketona dolomite member, €kt, at base)

€c — Conasauga ("Coosa") limestone
(thin-bedded blue limestone with shale and some chert)

€r — Rome ("Montevallo") formation
(variegated shale with some limestone and sandstone)

25° Strike and dip of stratified rocks
Strike of vertical beds

Faults

H.M. Wilson, Geographer.
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TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
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Geology by Charles Butts,
assisted by E.F. Burchard,
C.W. Washburne, E.M. Dawson,
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ECONOMIC GEOLOGY

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ALABAMA
BIRMINGHAM QUADRANGLE

87°00′ R.4 W. E R.3 W. 50′ D (Bessemer) R.2 W. 40′ R.1 W. R.1 E. 86°30′ C

H.M. Wilson, Geographer.
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LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent

Qal — Alluvium *(flood plain deposits of present streams)*

Pleistocene

Qtg — Terrace gravels *(gravel and sand of probable Pleistocene age on terraces or hills 100 to 300 feet above present streams)*

CARBONIFEROUS

Pennsylvanian

Cpv, Cbr, Cby, Cr, Ccb, Clc, Ccn, Cpi, Cs — Pottsville formation *(sandstone, shale, and coal beds, and Shades, Cs, Boyles, Cby, Pine, Cpi, Chestnut, Ccn, Bremen, Cbr, Lick Creek, Clc, Camp Branch, Ccb, and Razburg, Cr, sandstone members)*

Cpw — Parkwood formation *(gray shale and sandstone)*

Mississippian

Cp — Pennington shale *(gray, green, red, and black shale, some sandstone, conglomerate, and chert)*

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Cb, Ch — Bangor limestone *(thick-bedded gray crystalline limestone with Hartselle sandstone member, Ch, and a little shale and chert)*

Cfp — Fort Payne chert *(chert and limestone)*

DEVONIAN

Dc — Chattanooga shale and Frog Mountain sandstone *(black shale and sandstone below, too thin to separate on map)*

SILURIAN

Sc — Clinton ("Rockwood") formation *(shale and sandstone with beds of iron ore)*

ORDOVICIAN

Oc, Oa — Chickamauga ("Pelham") limestone *(thick to thin-bedded, dove and blue fossiliferous limestone; Attalla conglomerate member, Oa, chiefly chert pebbles, locally at base)*

CAMBRIAN

€Ok, Ckt — Knox dolomite *(heavy bedded cherty dolomite with chert-free Ketona dolomite member, Ckt, at base)*

€c — Conasauga ("Coosa") limestone *(thin-bedded blue limestone with shale and some chert)*

€r — Rome ("Montevallo") formation *(variegated shale with some limestone and sandstone)*

ECONOMIC AND STRUCTURE DATA

Iron ore *(Clinton formation contains workable beds of hematite)*

Coal outcrops *(dashed lines indicate uncertainty as to position or thickness of beds)*

WARRIOR COAL FIELD

cb, *Cobb coal*
pt, *Pratt coal*
np, *Nickel Plate coal*
nc, *Newcastle coal*
ml, *Mary Lee coal*
bc, *Blue Creek coal*
jg, *Jagger coal*
js, *Jefferson coal*
bkc, *Black Creek coal*

CAHABA COAL FIELD

mh, *Mammoth coal*
wd, *Wadsworth coal*
hk, *Harkness coal*
gd, *Gould coal*

PLATEAU COAL FIELD

rs, *Rosa coal*

Structure contours on the top of the Mary Lee coal *(contour interval 100 feet, datum plane, sea level)*

Structure contours on the top of the Black Creek coal *(contour interval 100 feet, datum plane, sea level)*

Coal mines, unless otherwise specified
Iron ore mines
Coal prospects and county banks
Iron ore prospects
Bore holes

Mine names, represented on the map by numbers, are printed on the back of this sheet.

Strike and dip of stratified rocks
Strike of vertical beds

Faults

LIST OF MINES.

Location indicated on the map by numbers.

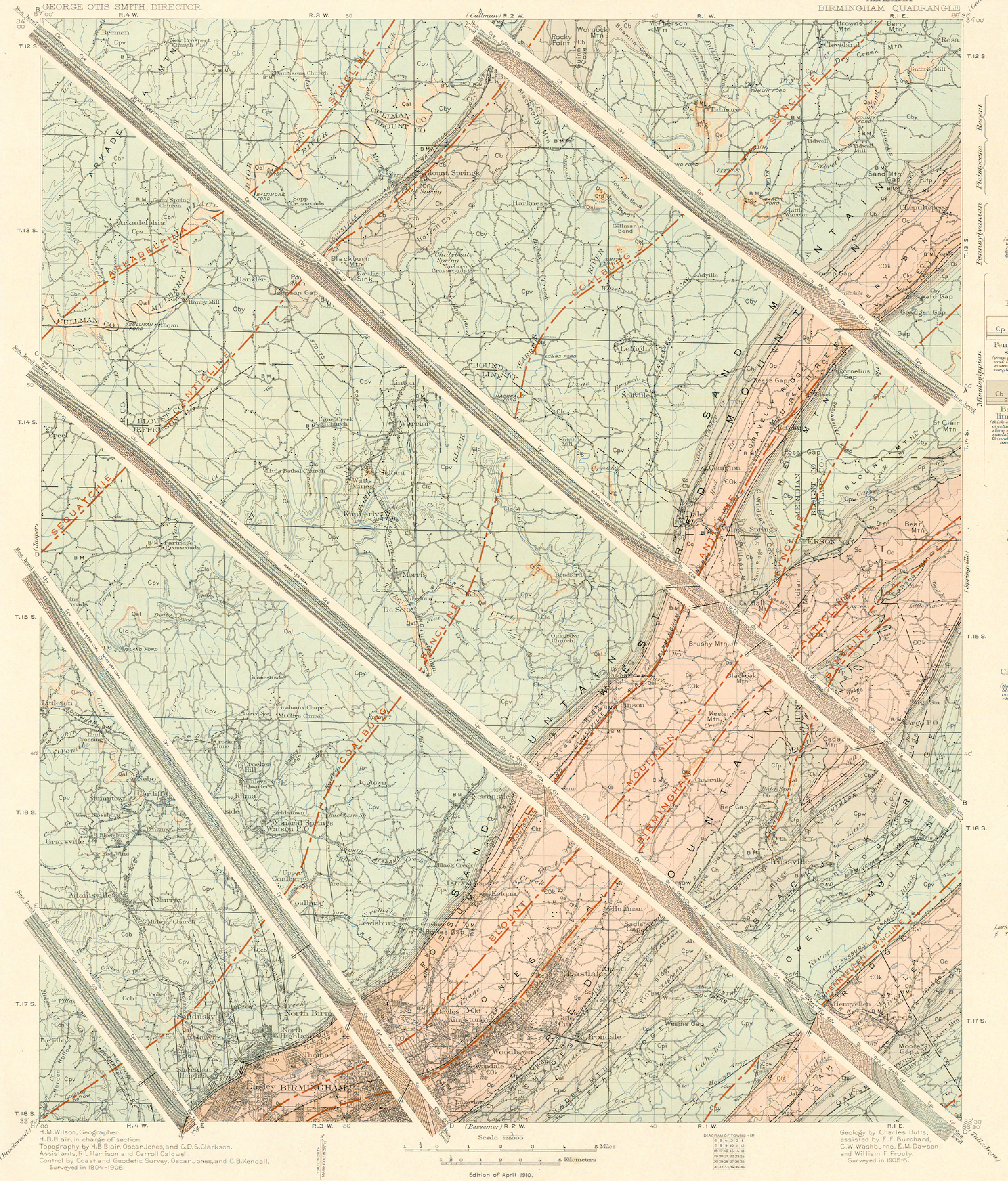
COAL MINES.

1. Red Star.
2. Fairchild.
3. Lehigh No. 1.
4. Lehigh No. 2.
5. Mabel.
6. Hogland
7. Wolf Den Hollow.
8. Watt.
9. Seloca.
10. Kimberly No. 1.
11. Kimberly No. 2.
12. Bradford No. 1.
13. Dixiana.
14. Banner.
15. Nebo.
16. Jet.
17. Brazil.
18. Cardiff.
19. Pratt No. 16.
20. West Blossburg.
21. Blossburg No. 1.
22. West Pratt B.
23. West Pratt A.
24. East Blossburg.
25. West Pratt E.
26. Murray No. 4.
27. Mulga.
28. Durant.
29. Rilma.
30. Kosmo
31 Newfound
32 Goode.
33. Orono
34. Dunn.
35. Clift.
36. Coalburg D.
37. Arcadia.
38. Warner.
39 Eldorado.
40. Coalburg E.
41. Thompson.
42. Pratt No. 7.
43. Pratt No. 2 and No 10.
44. Sandusky.
45. Pratt No. 1.
46. Pratt No 3.
47. Pratt No. 4.
48. Pratt No. 5.
49. Sayreton.
50. Graves.
51. Mary Lee.
52. Newcastle No. 4.
53. Newcastle No. 3.
54. Newcastle No. 2.
55. Henryellen No. 4.
56. Henryellen No. 6.
57. Ratliffe.

IRON MINES.

58. Compton.
59. Alfretta.
60. Bald Eagle.
61. Ruffner
62. Irondale.
63. Hammond.
64. Helen Bess.

STRUCTURE SECTIONS



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

Recent

Qal — Alluvium
(Flood plain deposits of present streams)

Pleistocene

Qtg — Terrace gravels
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Pennsylvanian

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UNCONFORMITY

Mississippian

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Cfp — Fort Payne chert
(chert and limestone)

UNCONFORMITY

DEVONIAN

Dc — Combined with Fort Payne chert on sections
Chattanooga shale and Frog Mountain sandstone
(black shale and sandstone below, too thin to separate on map)

UNCONFORMITY

SILURIAN

Sc — Clinton (Rockwood) formation
(shale and sandstone with beds of iron ore)

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€r — Rome (Montevallo) formation
(variegated shale with some limestone and sandstone)

Faults

Strike and dip of stratified rocks
Strike of vertical beds

Axes of anticlines and synclines

H. M. Wilson, Geographer.
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TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

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ILLUSTRATIONS

PLATE I.—SHALE WITH THIN LAYERS OF CHERT IN THE CONASAUGA LIMESTONE, EXPOSED ON TWENTY-FOURTH STREET, BESSEMER.
Looking south.

PLATE II.—KETONA DOLOMITE MEMBER OF THE KNOX DOLOMITE IN QUARRY AT NORTH BIRMINGHAM.
Quarried for flux. Looking south.

PLATE III.—CHARACTERISTIC HILLY TOPOGRAPHY OF THE KNOX DOLOMITE AREAS.
Crest of Red Mountain, composed of the Clinton formation, in the distance. Looking east from highway about 1 mile south of Pinson.

PLATE IV.—CONASAUGA LIMESTONE NEAR THE LOUISVILLE AND NASHVILLE RAILROAD 1 MILE SOUTH OF BOYLES GAP.
Looking northeast

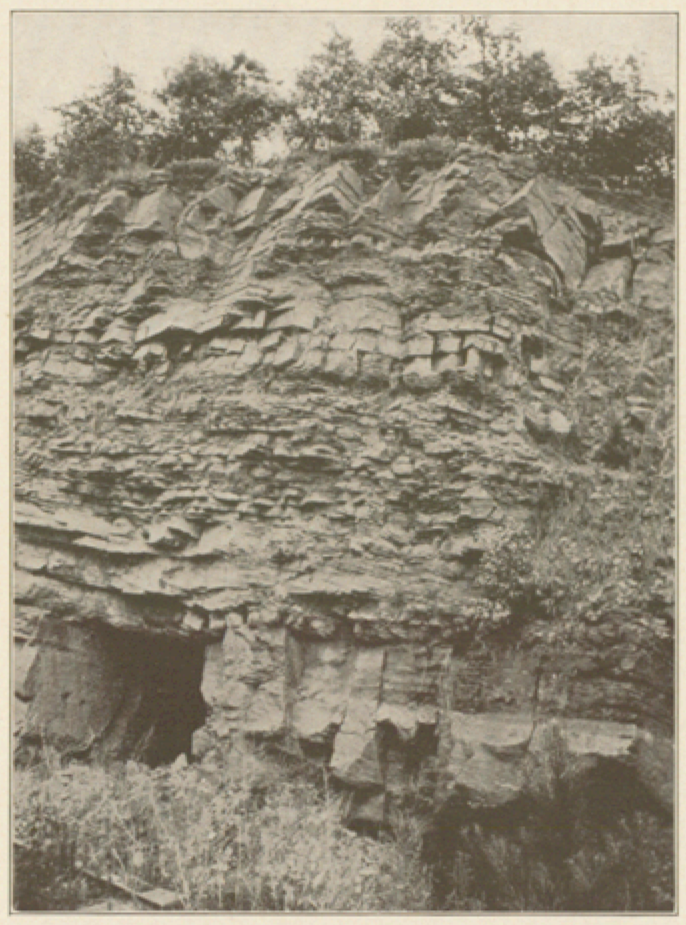

PLATE V.—FERRUGINOUS SANDSTONE AND SHALE OF THE CLINTON FORMATION OVERLYING THE BIG SEAM OF IRON ORE AT SPAULDING.
Looking east.

PLATE VI.—RUFFNER No. 1 MINE, 1 MILE NORTH OF IRONDALE.
Big seam of iron ore above and Irondale seam 20 feet below. Looking north.

PLATE VII.—VIEW IN LOUISVILLE AND NASHVILLE RAILROAD CUT IN LONE PINE GAP RED MOUNTAIN, AT BIRMINGHAM.
Looking east. Fort Payne chert (at right), Chattanooga shale (dark streak near middle), and probably Frog Mountain sandstone below, resting unconformably upon Clinton shale (at the extreme left).

PLATE VIII.—FOSSIL CLINTON IRON ORE FROM VICINITY OF BIRMINGHAM.

PLATE IX.—EVENLY BEDDED FORT PAYNE CHERT IN LOUISVILLE AND NASHVILLE RAILROAD CUT AT DALE GAP, NEAR VILLAGE SPRINGS.
Looking north.

PLATE X.—DIKELIKE OUTCROP OF VERTICAL HARTSELLE SANDSTONE MEMBER 1 1-2 MILES EAST OF NEWCASTLE.
Looking north. This feature extends north to Pinson and is called Rocky Row.

PLATE XI.—OOLITIC CLINTON IRON ORE FROM BIRMINGHAM.

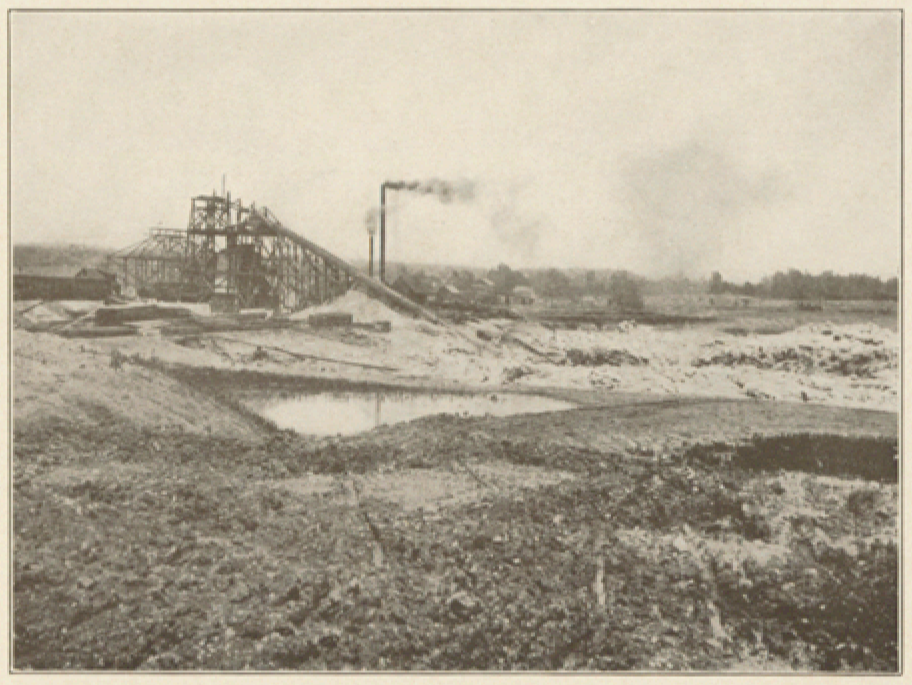

PLATE XII.—DOLOMITE QUARRY FOR FLUX, THOMAS.
Looking north.

and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is in many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Ꞓ	Brick-red.
	Algonkian		A	Brownish red.
	Archean		Æ	Gray-brown.

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

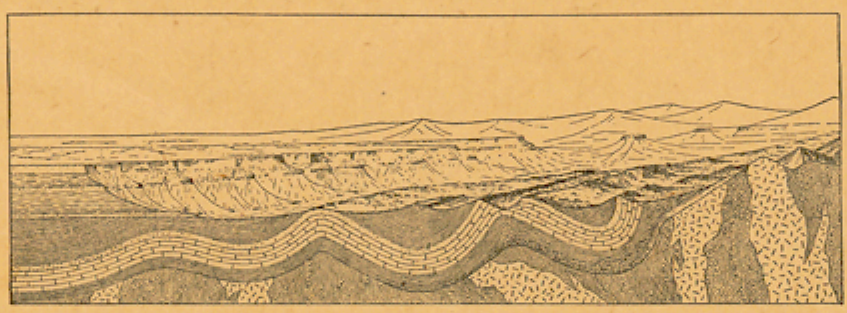

FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

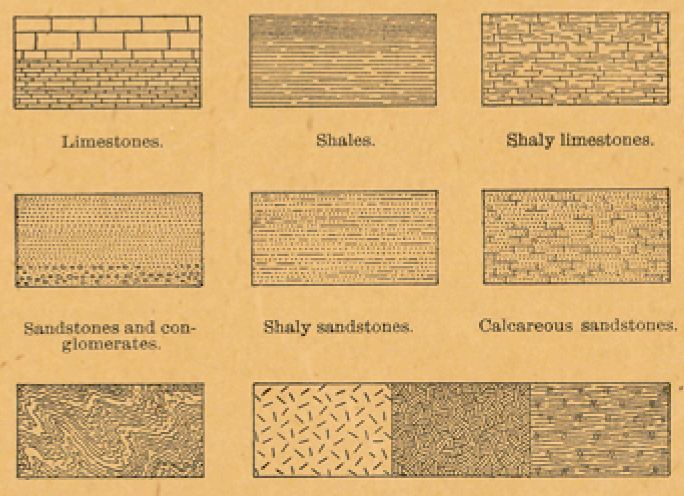

FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

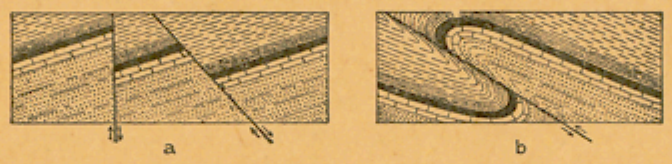

FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,

Director.

May, 1909.

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