DEPARTMENT OF THE INTERIOR

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UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS

OF THE

UNITED STATES

EUREKA SPRINGS-HARRISON FOLIO

ARKANSAS-MISSOURI

BY

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WASHINGTON, D. C.

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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.

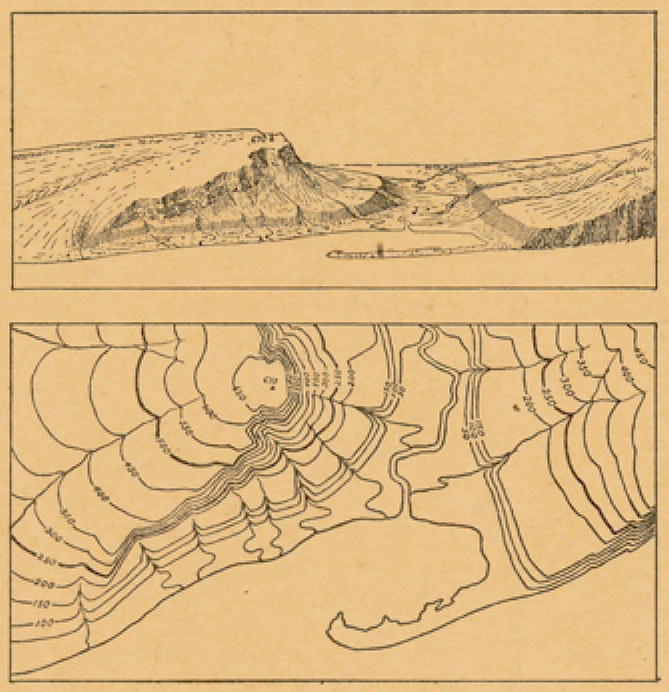

FIGURE 1.—Ideal view and corresponding contour map.

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 EUREKA SPRINGS AND HARRISON QUADRANGLES.

By A. H. Purdue and Hugh D. Miser.[1]

INTRODUCTION.

GENERAL RELATIONS OF THE QUADRANGLES.

The Eureka Springs and Harrison quadrangles lie between parallels 36° and 36° 30′ and meridians 93° and 94° and include an area of about 1,925 square miles. They are in northwestern Arkansas (see fig. 1) and comprise the whole of

FIGURE 1.—Index map of northwestern Arkansas and parts of adjacent States.

The area included in the Eureka Springs and Harrison quadrangles is shown by the darker ruling (202). Published folios that describe other areas, indicated by lighter ruling, are as follows: 119, Fayetteville; 122, Tahlequah; 132, Muskogee; 148, Joplin district; 154, Winslow; 159, Independence.

Carroll County and parts of Benton, Boone, Madison, Newton, and Washington counties. A strip less than a quarter of a mile wide along the north side of the two quadrangles lies in Barry, Stone, and Taney counties, in the State of Missouri.

In their geographic and geologic relations the quadrangles form a part of the Ozark region, which, as the term is ordinarily used, includes the highland area in southern Missouri, northwestern Arkansas, northeastern Oklahoma, the southern end of Illinois, and the southeast corner of Kansas. To a great extent all parts of the region have had a common geologic history, which is recorded in the character, relations, and attitude of the rocks and in the physiographic features of the surface.

GEOGRAPHY AND GEOLOGY OF THE OZARK REGION.

GENERAL FEATURES AND RELATIONS.

The Ozark region is a broad, dissected plateau of moderate relief but noticeably higher than the surrounding provinces. The higher elevations attain considerable prominence in the eastern and the southern parts of the region and are widely known as the St. Francis and the Boston mountains, respectively, though many lower elevations in other parts of the province are locally known as mountains. The general region is known as the Ozark Mountains, but this name has not been applied to any particular group of mountains.

The Ozark region lies between the Mississippi embayment of the Gulf Coastal Plain on the southeast, the Glaciated Plains of the upper Mississippi basin on the north, the Prairie Plains on the west, and the Arkansas Valley on the south, beyond which are the Ouachita Mountains. On the north and northeast it is in general bounded by the alluvial valleys of the Missouri and the Mississippi, but its eastern extremity extends across southern Illinois as a belt of high ground known as Karbers Ridge or the Shawneetown Hills. On the southeast the region falls off by the slope—throughout much of its length a fairly distinct escarpment—that separates the plateau from the lowland of the Mississippi embayment, and on the south it is bounded by the wide, open valley of Arkansas River. The southern part of its western boundary, in Oklahoma and Kansas, is formed by the valleys of Neosho (Grand) and Spring rivers, but the northern part is rather indefinite, the plateau gradually merging into the Prairie Plains. For convenience, this northern part of the western boundary may be represented as a nearly straight line drawn from a point near the southeast corner of Kansas to the sharp bend in Missouri River north of Marshall, Mo.

Topographically the Ozark differs from the adjoining regions in its greater altitude and relief. The Boston Mountains, which form the highest as well as the roughest part of the province, are slightly surpassed in both ruggedness and height by the Ouachita Mountains, but the broad dissected plateau surface of the Ozark region contrasts sharply with the long, narrow, sharp-crested, westward-trending ridges of the Ouachita Mountains and is also very different from the Arkansas Valley, whose nearly westward-trending ridges resemble but are generally lower than those in the Ouachita Mountains.

The Ozark region differs sharply from the Mississippi embayment not only in the character and age of its rocks but in its history and its physiographic development. The rocks of the Ozark region consist chiefly of dolomites, limestones, cherts, sandstones, and shales, ranging in age from Cambrian to Pennsylvanian, and of pre-Cambrian crystalline rocks. The rock beds, though lying nearly flat, have been arched into a broad, low dome. On the other hand, the exposed rocks of the Mississippi embayment, which also are practically horizontal, consist mainly of sand, gravel, and clay and range in age from Cretaceous to Quaternary. The geologic distinction of the Ozark region from the Glaciated Plains and from the Prairie Plains is not so marked; some formations are common to all three provinces, and to a large extent their geologic history has been the same. The rocks common to their adjoining parts are practically horizontal and are mainly shales and sandstones of Carboniferous age. For the most part, however, the Ozark region is distinct, both in rocks and in history, from the Arkansas Valley and the Ouachita Mountains. The rocks of the Arkansas Valley consist of 24,000 feet or more of sandstones and shales of Carboniferous age, which as a rule have not only been rather gently compressed into numerous nearly westward-trending anticlines and synclines but which throughout the greater part of the valley have been bent downward into a westward-trending synclinorium. Although the rocks of the Ouachita Mountains, like those in the Arkansas Valley, are enormously thick, they consist chiefly of cherts, shales, sandstones, and novaculites, which range in age from possible Cambrian to Pennsylvanian. Their structure is that of a westward-trending anticlinorium, the numerous individual folds of which are closely compressed.

RELIEF.

The Ozark region consists of two parts, the northern and larger of which is the Ozark Plateau and the southern and higher the Boston Mountains, whose upper surface is likewise that of a plateau. (See fig. 2.)

The Boston Mountains have an average width north and south of about 35 miles, and they extend east and west a distance of approximately 200 miles, from the valley of Neosho (Grand) River in Oklahoma eastward to the Mississippi embayment near Batesville, Ark. The mountain tops form a greatly dissected table-land, which rises 2,200 feet above sea level and 1,700 feet or more above the flood plain of Arkansas River, though a few remnants along the north side stand 2,300 to 2,400 feet above sea level. The mountains are rather rugged and have steep slopes and sharp projecting spurs separated by narrow ravines, 500 to 1,400 feet deep. The slopes are broken at many places by vertical or nearly vertical cliffs, which are due to the alternation of hard and soft beds of rock. Some of the cliffs are more than 100 feet high.

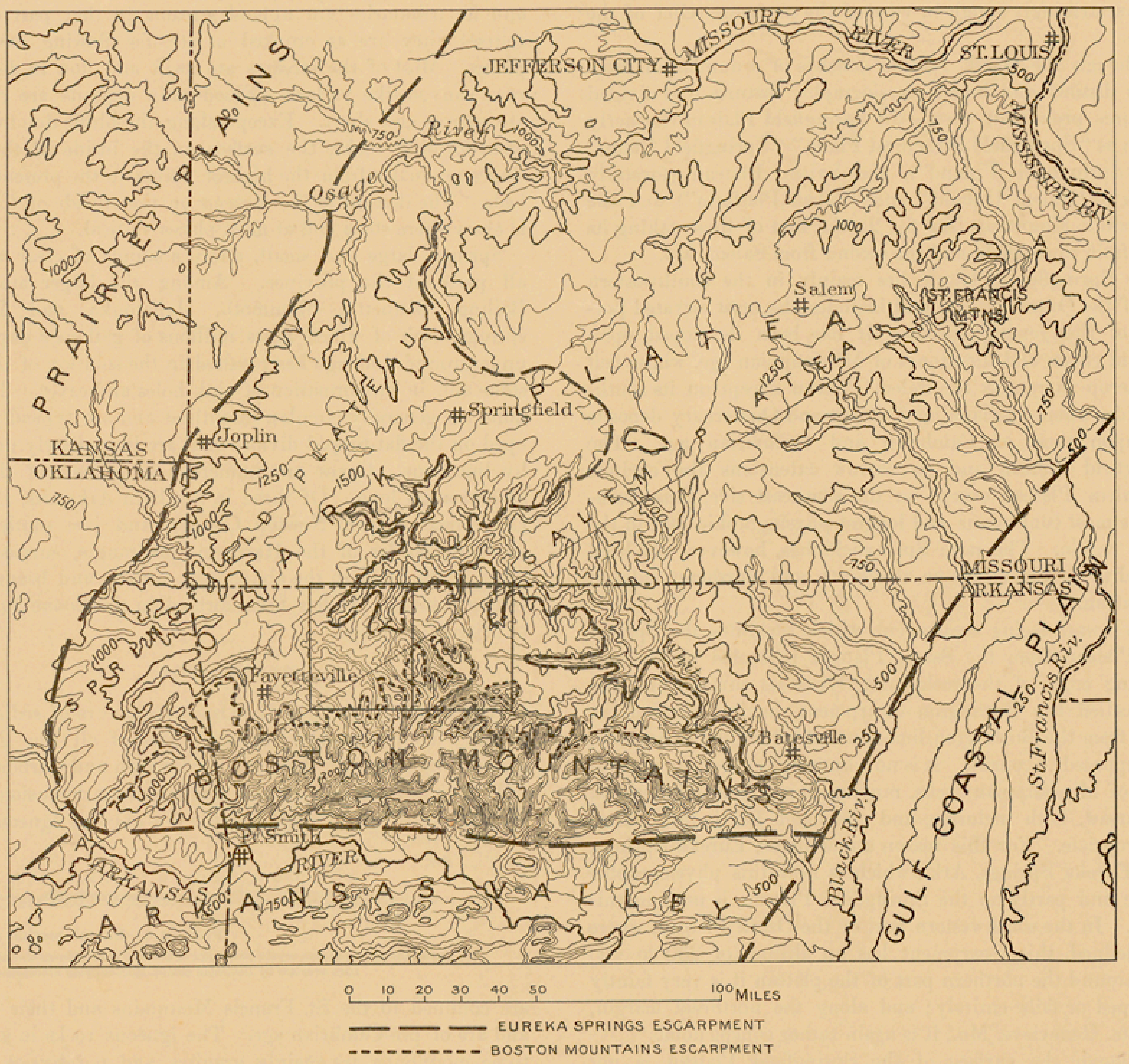

FIGURE 2.—Sketch map of the Ozark region, showing its physiographic divisions and its relations to the adjacent Prairie Plains, Arkansas Valley, and Gulf Coastal Plain regions.

The Ozark region comprises the Boston Mountains, the Ozark Plateau, and the St. Francis Mountains. The Ozark Plateau is divided by the Eureka Springs escarpment into the Springfield Plateau and the Salem Plateau.

The Boston Mountains are separated from the Ozark Plateau by a steep descent, generally ranging in height from 500 to

[1] The lists of fossils and the correlations of the Ordovician and Devonian formations have been contributed by E. O. Ulrich; those of the Carboniferous, except the Winslow formation, by G. H. Girty.

700 feet, to which the name Boston Mountains escarpment has been applied. This escarpment is highest in its middle portion and gradually falls off eastward and westward to the borders of the area. If viewed at a distance from the Ozark Plateau, on the north, this escarpment presents a bold, even, wall-like front and a level crest, but in fact it is very irregular, the plateau being dissected by numerous and deep ravines. (See Pls. I and II.) Moreover, long, narrow spurs project from the mountain area, and numerous knobs and peaks that are isolated from the main upland mass conceal the escarpment and make the boundary between the mountains and the plateau transitional rather than abrupt, in spite of the difference in altitude and of the local steepness of the escarpment. Many of the spurs and outlying peaks are in the southern parts of the Eureka Springs and Harrison quadrangles and are described more fully in the chapter on "Topography." Most of the southern slope of the mountains is less precipitous and passes off gradually into the Arkansas Valley, though at many places it is marked by abrupt descents and is broken by steep-sided canyon-like ravines.

The Ozark Plateau occupies all the Ozark region in Missouri, Illinois, and Kansas, most of that in Oklahoma, and a strip about 40 miles wide in northern Arkansas. It is roughly a broad, rolling area, most of which lies 800 to 1,700 feet above sea level and 500 feet or more above the surrounding country. Except for one or two peaks of the St. Francis Mountains its altitude is greatest east of Springfield, Mo., near the center of the plateau, where a considerable tract lies 1,600 to 1,700 feet above sea level. The surface of the plateau slopes gently both to the northwest and the southeast, the divide standing 1,300 feet or more above sea level and extending in a sweeping curve from the St. Francis Mountains westward and southwestward past Salem and Springfield, Mo., to Fayetteville, Ark. On the northwest the surface descends to Missouri River and its tributaries, along which the altitude is about 900 feet above sea level, and on the southeast it descends to White River and its tributaries, which fall from 1,000 feet above sea level near their headwaters to 250 feet above sea level at the eastern margin of the plateau. Taken as a whole these slopes are uniform, but they are interrupted by certain escarpments, which, though not pronounced, are significant topographic features. The surface along the divide is not greatly dissected and its plateau character is fairly evident, but about most of its margin the plateau is deeply and intricately dissected and appears strikingly rough in view of the moderate relief of the region.

Although the Ozark Plateau consists of a number of more or less distinct and broad physiographic features it is divided into three prominent parts—the Springfield Plateau (formerly known as "Springfield Structural Plain," "Springfield Plain," and "Springfield Upland"), the Salem Plateau (formerly known as "Salem Upland" and "Salem Platform"), and the St. Francis Mountains (see fig. 2), the first of these taking its name from Springfield and the second from Salem, Mo.

The Springfield Plateau lies mainly in the southwestern part of the Ozark Plateau and includes the most elevated portions of the general surface. It has been developed upon resistant cherts and limestones of Mississippian age, whose belt of outcrop surrounds the Salem Plateau except on its southeast side, where overlapping Tertiary and Quaternary deposits rest upon those of Cambrian and Ordovician age. The Springfield Plateau and its narrow extensions also encircle the Salem Plateau except on the southeast side, thus forming the most continuous and longest physiographic belt in the Ozark region. The term Springfield has, however, not been applied to the extensions on the north and northeast sides of the plateau.

The inward-facing escarpment, which separates the Springfield Plateau from the Salem Plateau, is formed by the outcropping edges of the rocks underlying its surface, and has been called the Burlington escarpment, having received the name from the Burlington limestone, of which the escarpment was supposed to consist. It is now known, however, to be composed of Mississippian rocks, ranging in age from Kinderhook to Warsaw, both inclusive, and the name Burlington is thus inappropriate. For this reason a new name, Eureka Springs, from Eureka Springs, Ark., which is near this physiographic feature and partly on the Springfield Plateau, is used in this report. In the southwestern part of the Ozark Plateau, where well defined, this escarpment has an altitude of 250 to 400 feet; around the northern part of the plateau it is very faintly developed or fails entirely; and along the northeast margin, near Ste. Genevieve, Mo., it is again rather conspicuous.

Although the surface of the Springfield Plateau is not uniform in altitude or direction of slope, it is on the whole highest along its eastern margin and descends, with the dip of the rocks, gently westward to the valleys of Neosho (Grand) and Spring rivers and southward to the base of the Boston Mountains escarpment. It is trenched at many places by troughlike valleys, which on the inner border become canyon-like and which give the Eureka Springs escarpment a tortuous and ragged outline. In northwestern Arkansas and the adjoining part of Missouri White River and its tributaries have cut a wide basin in the Springfield Plateau. Much of this basin is included in the Eureka Springs and Harrison quadrangles. Many remnants of the Springfield Plateau occupy the tops of elevations that stand out upon the Salem Plateau at greater or less distances from the Eureka Springs escarpment.

The Salem Plateau occupies southeastern Missouri and a large part of north-central Arkansas. Its surface is not level but dips gently away from the main divide of the Ozark region and is deeply cut by stream erosion except in its central part, where the valleys are shallow and troughlike, but the tops of the higher ridges and hills along its low dissected escarpments stand at the same general level. This dissected upland surface has been developed on the truncated edges of a number of formations.

The St. Francis Mountains occupy a small area in southeastern Missouri near the east end of the Ozark Plateau. They are composed of resistant crystalline rocks and reach an altitude at the highest point, Taum Sauk Mountain, of 1,750 feet above sea level, or 500 to 800 feet above the surrounding valleys and several hundred feet above the general level of the adjoining portions of the plateau.

DRAINAGE.

The Ozark region lies wholly in the basin of the Mississippi, to which it is drained chiefly through tributaries of Missouri and Arkansas rivers. From one side of the main divide that extends from the St. Francis Mountains past Salem and Springfield, Mo., to Fayetteville, Ark., the streams flow northwestward to join northeastward-flowing tributaries of the Missouri and the Mississippi or southwestward-flowing tributaries of the Arkansas, and from the other side they flow southeastward to White River. White River, the largest stream in the region, and its tributaries drain nearly all the plateau southeast of the main divide, most of the southeastern margin of the plateau, and the northern slope of the Boston Mountains. The southern slope of the Boston Mountains is drained directly by small streams to Arkansas River; and the northeast end and east side of the Ozark Plateau is drained to the Mississippi, either directly by short streams or southward through St. Francis River.

The streams of the Ozark Plateau in southern Missouri and northern Arkansas are very crooked. Though White River and its tributaries are upland streams in that part of their courses, they are as crooked as streams flowing over flood plains. Most of the streams are swift and flow in deep, narrow, canyon-like valleys. Flood-plain deposits are rare and are narrow and short. Except along the bluffs due to escarpment-forming rocks, the surface on the inside of the bends slopes gradually from the highest points to the present stream beds. The descent to the streams on the outside of the bends is everywhere steep and at most places vertical.

Springs, large and small, afford a supply of clear water in all parts of the province. Among the larger are Greer, Boiling, Bennett's, Mammoth, Hahatonka, and Meramec springs, each of which flows millions of gallons a day. This underground drainage has resulted in the solution of the limestone and in the formation of sink holes and caves. The sink holes are generally circular in outline and are typically developed on the flat-topped divides that are immediately underlain by limestone. Caves are numerous and some of them are several miles long. Of those in northern Arkansas, Diamond Cave, near Jasper, Newton County, and just south of the southern border of the Harrison quadrangle, surpasses any other in the State in the abundance, variety, and beauty of its calcite crystals. It has been formed in the Boone limestone, of Mississippian age.

STRATIGRAPHY.

Almost all the rocks of the Ozark region are of sedimentary origin. They comprise representatives of all the Paleozoic systems, but most of them are Ordovician and Carboniferous.

With the exception of two small igneous intrusions, probably of post-Carboniferous age, the few exposed igneous rocks are confined to the St. Francis Mountains and their vicinity and are of pre-Cambrian age. The igneous rocks in and near these mountains are mainly granites and porphyries, which, however, are cut by dikes composed of several varieties of basic rocks. The exposed masses protrude upward through the nearly flat-lying Cambrian and Ordovician strata over an area 70 miles square, and many of them rise into peaks that form the St. Francis Mountains. Such rocks doubtless underlie the whole region, as they outcrop in the Arbuckle and Wichita mountains of southern Oklahoma and have been reached in deep borings at Zeandale, Kans., and at St. Louis, Carthage, Raytown (near Kansas City), Sullivan (in Franklin County), and near Rolla, Mo. One of the two younger intrusions is a granitic dike near the mouth of Spavinaw Creek, in northeastern Oklahoma; the other is a dike, or possibly a plug-like intrusion, of graphic granite or pegmatite, on the southern border of Camden County, Mo.

The Cambrian and Ordovician rocks outcrop almost wholly within the Salem Plateau. The oldest formations are exposed on the flanks of the St. Francis Mountains and in general dip away from these mountains, their outer margins therefore being buried by later rocks. Those that form the floor of this plateau consist of a great mass of dolomites and limestones and of smaller amounts of interbedded sandstones, which belong in part to the Upper Cambrian series and in part to the Lower Ordovician series. The youngest of these are the Cotter dolomite and the Powell limestone, which correspond in age to the Beekmantown limestone of the northern Appalachian region. Along the northeastern border of the Ozark Plateau and at some places on its southern and southwestern margins there are saccharoidal sandstones, limestones, and shales, which belong to the Upper, Middle, and partly to the Lower Ordovician series. The oldest of these in the northeastern part of the region is the St. Peter sandstone, of post-Beekmantown age, but the oldest in northern Arkansas and parts of southeastern Missouri is the Everton limestone, which underlies the St. Peter.

The Silurian system is represented chiefly by limestones, which outcrop in small areas on the northeastern and also on the southern and southwestern flanks of the Ozark Plateau.

The Devonian rocks outcrop in small areas along Mississippi and Missouri rivers but are apparently absent in many other parts of the region. They appear, however, in numerous small areas in northern Arkansas, southwestern Missouri, and northeastern Oklahoma.

The Mississippian deposits outcrop only in a narrow belt, except on the southwest, where they form the surface rock over an area approximately 80 miles wide from northwest to southeast and twice as long from northeast to southwest. This area comprises the larger portion of the Springfield Plateau. Limestones and cherts, chiefly of the age of the Osage group, are the principal rocks exposed in this and other parts of the Springfield Plateau; younger shales, limestones, and sandstones, of the age of the Chester group, outcrop in the lower slope of the Boston Mountains escarpment and in some adjoining parts of the Springfield Plateau.

The Pennsylvanian series is represented by shales and sandstones and by thin limestones and conglomerates. These rocks outcrop mainly in the Boston Mountains, where they overlie those of Mississippian age, and also as important outliers in the northern, western, central, and southern parts of the Ozark Plateau, where in places they rest upon beds of Ordovician age.

Ordovician, Devonian, Mississippian, and Pennsylvanian rocks outcrop in the Eureka Springs and Harrison quadrangles, as described under the heading "Stratigraphy." (See pp. 4–16.)

STRUCTURE.

The structure of the strata in the Ozark region is that of a low irregular dome. The St. Francis Mountains, though eccentrically located in the region, form its crystalline nucleus, from which the strata in general dip outward toward the margin of the region, most steeply where the distance from the nucleus is shortest and most gently where it is longest. The older formations therefore outcrop about the base of these mountains, and successively younger beds outcrop in roughly concentric bands that surround the central area. With the exception of small outliers in the western, central, and northern parts of the Ozark Plateau the youngest formations of the region occupy the summits of the Boston Mountains and dip southward from these mountains to the Arkansas Valley. The section extending from the St. Francis Mountains southwestward across the Boston Mountains (see fig. 3) shows on a small scale the general structure of the region and the successive strata dipping away from the center of uplift.

Locally the general structure just described is somewhat complicated by warping and folding, which have produced subordinate domes as well as other minor folds. This flexing of the rocks has been accompanied by some faulting, especially close to the St. Francis Mountains and in the southern part of the region, in which the Eureka Springs and Harrison quadrangles are situated, but most of these irregularities are too small to be shown on a section drawn on the scale used in figure 3.

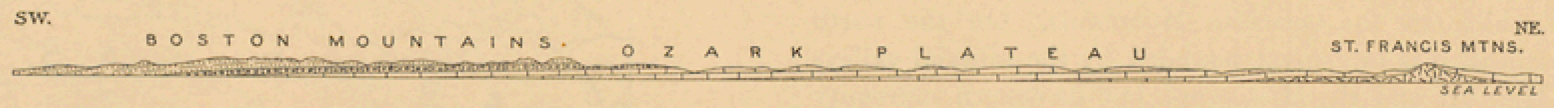

FIGURE 3.—Sketch section across the Ozark region along the line A–A in figure 2.

Shows the pre-Cambrian crystalline rocks of the St. Francis Mountains at the right, overlain by Cambrian and Ordovician limestones of the Ozark Plateau, and these formations in turn overlain by Devonian shales, Mississippian limestones and shales, and Pennsylvanian sandstones and shales in the Boston Mountains at the left.

OUTLINE OF GEOLOGIC HISTORY.

In pre-Cambrian time probably the entire area of the Ozark region was long affected by igneous activity followed by extensive denudation, which was brought to a close by a submergence during Upper Cambrian time of this region as well as of other broad areas in the interior of the continent. The area thus remained a more or less continuous seat of sedimentation throughout the rest of the Paleozoic era, when the stratified rocks of the region were deposited. Constantly recurring slow warpings of the earth's crust produced changes in the outline and depth of the sea, in the position and height of the land where erosion was going on and from which the clastic sediments were derived, and in the position of the shore lines, where marine erosion was taking place and where shore deposits were being formed.

From time to time, as a result of such movements, areas of recently deposited sediments were elevated into land, were attacked by erosion, and were wholly or partly removed. When, as a result of later submergence, deposition was resumed over such areas, the new sediments were in some places laid down upon much older beds, those of intermediate age having been removed. In other places, owing to continued subsidence, the sea encroached upon the land for long distances, and the strata laid down were spread over areas much larger than those covered by strata of but little greater age and so were in places laid down upon considerably older formations. Again, the crustal movements were several times accompanied by slight local warping, which resulted in unequal removal of the rocks by erosion, so that in some places the later deposited beds are not parallel to those beneath.

The net result of such modifications of the deposition as were continually going on somewhere in the region is that in no place were all the strata of Paleozoic age laid down uninterruptedly. Both minor and major unconformities and gaps in the succession of the strata are found in all exposed sections, and they are well shown in that part of the region occupied by the Eureka Springs and Harrison quadrangles.

Near the close of the Paleozoic era the Ozark region was permanently added to the land and has not since been submerged, except perhaps in a narrow strip along its southeastern margin. The uplift was accompanied by some minor warping and fracturing of the strata, especially in the southwestern and northeastern parts of the region, but nowhere was there extensive folding or thrust faulting like that which took place at this time in the Arkansas Valley and the Ouachita Mountains.

Although several times interrupted by periods of subsidence, during which the sea twice approached or perhaps encroached upon the southeastern border of the region, the general movement during the Mesozoic and Cenozoic eras has been that of elevation, and the region now stands at a considerable altitude and is far inland. Throughout these eras the surface has been subjected to denudation and has undergone one or more cycles of active erosion. During each of these cycles the entire region or parts of it were reduced to a nearly featureless plain, whose surface was largely destroyed in the succeeding cycle or cycles. One or more of the uplifts that affected the region were accompanied by slight warpings of the surface of the Ozark Plateau, which at present is not level but slopes in all directions from an area east of Springfield, Mo.

The succession of events in the production of the physiographic features of the Ozark region is not well understood, for the records have been largely destroyed, nor is all the obtainable evidence concerning them at hand. A fuller discussion of the physiographic history is therefore reserved for the section on the geologic history of the quadrangles. It seems probable, however, that the region was uplifted near the close of the Tertiary period, and that the innumerable ravines that now dissect the surface were begun and largely cut during the era of renewed erosion thus brought about.

The great ice sheets that invaded the northern part of the United States during the Pleistocene epoch extended only to the northern and northeastern border of the Ozark region and produced no discoverable effect upon its topography or history.

TOPOGRAPHY.

RELIEF.

The Eureka Springs and Harrison quadrangles, whose surface in most places is rough but without great relief, are situated in the southwestern part of the Ozark region. They are mainly within the Ozark Plateau, but their southern part is within the north border of the Boston Mountains, which present the most broken topography in the quadrangles. That part of the Ozark Plateau which is included in the quadrangles consists of two subdivisions, the Springfield Plateau and, to a small extent, the Salem Plateau.

BOSTON MOUNTAINS.

The Boston Mountains occupy the southeastern part of the Eureka Springs quadrangle and the southwestern part of the Harrison quadrangle. This part of the mountains forms essentially a dissected plateau (see Pls. I and II), consisting of spurs extending northward. The bulk of the mountainous area lies south of the quadrangles and is bounded by a sinuous northward-facing precipitous slope known as the Boston Mountains escarpment. These spurs have a dendritic arrangement, which is due to their dissection by numerous streams and ravines, and as they are capped by nearly horizontal, very resistant beds they are remarkably uniform in height. Their summits are at many places relatively flat table-lands, conspicuous among which are Gaither Mountain and the summit on which Compton stands. The summits in the quadrangles generally range in height from 1,900 to 2,250 feet above sea level, being lowest in the Eureka Springs quadrangle and highest in the Harrison, but some of them in the southwestern part of the Harrison exceed 2,300 feet, and two points, one 4 miles west of Compton and another 2 miles north by west of Ponca, stand 2,400 feet above sea level. So far as determined, these are the highest points in the Ozarks. The highest elevations in the area are locally known as mountains. Not all of them have names, but among those named are Diera, Big Sandy, and Phillips mountains in the Eureka Springs quadrangle, and Saffer, Dodson, Bee Bluff, Gaither, Mutton Point, and Sherman mountains in the Harrison quadrangle. Most of these mountains, as well as those in other parts of the Boston Mountains in the quadrangles, rise from 300 to 700 feet above the general surface of the adjoining parts of the Springfield Plateau, their height above this plateau being least in the Eureka Springs quadrangle and greatest in the Harrison. The numerous valleys that completely dissect the mountains have steep slopes and have been cut 500 to 1,400 feet below the upland surface. The slopes are interrupted by escarpments produced by the alternation of hard and soft beds of rock, forming at many places a bench and bluff type of topography. The escarpments, many of them 100 feet high, are, like the rock beds, nearly horizontal. They form a rather persistent feature of the slopes. One such escarpment, which is in most places inaccessible, occurs near the summits of many of the mountains. Isolated buttelike peaks rise above the Springfield Plateau, and though they are separated from the Boston Mountains, of which they were formerly a part, their slopes are steep and they are nearly as high as those mountains.

Because of the large number of spurs along the northern border of the Boston Mountains and the equally large number of more or less completely separated outliers on the Springfield Plateau these two physiographic divisions at some places gradually merge into each other. The line of separation between the two, however, is fairly well marked in the Harrison quadrangle, where the mountains rise boldly 700 feet above the plateau. In the Eureka Springs quadrangle it is not so marked, for the mountains stand only about half as high above this plateau as they do in the Harrison quadrangle.

OZARK PLATEAU.

SPRINGFIELD PLATEAU.

The Springfield Plateau occupies the parts of the quadrangles that are not covered by the Boston Mountains and the Salem Plateau. The Salem Plateau occupies rather small areas in the northeastern parts of both quadrangles and is separated from the Springfield Plateau by the sinuous Eureka Springs escarpment.

The Springfield is essentially a dissected structural plain whose surface at most places conforms with that of the underlying Boone limestone, the cherty beds of which have preserved it and made it prominent. Much of its surface is rough though its relief is not great. Most of the Springfield Plateau in Missouri, on the north, and in the Fayetteville quadrangle, on the west, is comparatively level, but in the greater part of the Eureka Springs and Harrison quadrangles its surface has been deeply dissected by streams, which have a dendritic arrangement, the interstream areas being narrow spurs. Only in small areas, such as those about Hindsville, Clifty, Oak Grove, Green Forest, Gaither, and Bellefonte are there extensive remnants of what appears to have been a former nearly level plain.

In general this upland surface in the Eureka Springs quadrangle rises from about 1,350 to 1,700 feet above sea level, the highest part being on and near Pension Mountain and in the northwestern part of the quadrangle and the lowest in its southwestern part, near Hindsville and Spring Valley.

In the Harrison quadrangle the surface is in most parts 1,250 to 1,350 feet above sea level, but it gradually rises toward the north, reaching a height of 1,500 feet near Burlington.

A conspicuous difference in the elevation of the Springfield Plateau is well shown around the basin-like portion of the Salem Plateau in the northeast corner of the Eureka Springs quadrangle. Here the Springfield Plateau rises from 1,500 to more than 1,700 feet above sea level, but at the east base of the northward-trending range of hills that skirts the border of the Harrison quadrangle west and southwest of Green Forest this surface abruptly declines to about 1,350 feet above sea level. Moreover, the part of the Springfield Plateau that lies on and near Pension Mountain, at the south side of the Salem Plateau, and that has an elevation of more than 1,700 feet above sea level, is only about 300 feet lower than the remnant of the Boston Mountain plateau that is preserved in Bradshaw Mountain, one of the northernmost outliers of the Boston Mountains.

Among the highest elevations of the Springfield Plateau are Sugarloaf, Trigger, Boat, Pension, and Brush mountains, in the Eureka Springs quadrangle, and Crystal Mountain and Potato Hill, in the Harrison quadrangle.

Several hills which have been separated by erosion from the Boston Mountains stand out in bold relief on the Springfield Plateau in many parts of the Eureka Springs quadrangle and in the western, central, and southeastern parts of the Harrison quadrangle. These hills are composed of remnants of the formations that constitute the Boston Mountains, some consisting of part and others of all of the formations in those mountains. They range in height from 1,500 to 2,200 feet above sea level. Among those in the Eureka Springs quadrangle are Chinkapin, Walker, Swain, Sandstone, Grindstone, Posy, Pond, and Blansett mountains; among those in the Harrison quadrangle are Pilot Knob, Kennedy, Sulphur, Boat, Blacklick, Bradshaw, Fodderstack, and other mountains. Those in the Eureka Springs quadrangle do not stand so high above sea level and above the Springfield Plateau as those in the Harrison quadrangle. Just as remnants of the Boston Mountains stand out upon the Springfield Plateau, so do outliers of this plateau rise above the upland surface of the Salem Plateau.

The work of water, by corrasion and solution, has reached nearly all parts of the Springfield Plateau, completely dissecting it. These processes have produced two classes of valleys—one formed mainly by corrasion and the other formed mainly by solution.

The valleys of the first class include the largest in the region and those minor valleys that contain perennial streams. The larger valleys are sunk into the Springfield Plateau from 300 to 500 feet. The streams occupying them are very crooked, and the slopes to them are gentle on the inside of the curves and steep or even precipitous on the outside.

The valleys of the second class include those that contain no streams except during rainy periods and then only small ones in their lower parts. These are ravines that open out into the perennial streams over all the area covered by the Boone limestone and are confined to it. Tributary ravines enter the main ravines at high angles and in many places at right angles. The courses of these ravines are remarkably straight. They head suddenly, the heads closely resembling half a sink hole cut by a vertical plane. Many are double headed. Those of opposite slopes interlock, so that the divides form very crooked lines. The result is that most of the Springfield Plateau, whose surface is underlain by the Boone limestone, is completely ramified by them. Such is the sameness of topography produced where these ravines occur that any typical area is precisely like any other, and one has to be a good woodsman to keep his bearings among them. These ravines have undergone a small amount of erosion near their mouths, but they owe their origin mainly to the solution of the Boone limestone. A part of the solution takes place at the surface of the bedrock and beneath the chert mantle and a part is the work of ground water along underground drainage lines. The insoluble chert of the limestone is left as a residue upon the surface. (See Pl. IX.)

SALEM PLATEAU.

That part of the Salem Plateau which is included in the northeast corner of the Eureka Springs quadrangle is limited on the south by Pension Mountain, on the west by the bluffs of Kings River, and on the east by a narrow range of hills skirting the eastern border of the quadrangle. This area, like the Springfield Plateau and the Boston Mountain plateau, is a dissected tract which stands about 1,250 feet above sea level. Its surface is lower and more subdued than that of the area which surrounds it. It is bounded by the Eureka Springs escarpment, on the inner border of the Springfield Plateau, the adjoining parts of which in most places rise from 250 to 450 feet above the Salem Plateau. The adjacent part of the Springfield Plateau near and north of Green Forest, in the Harrison quadrangle, rises only about 100 feet above it. The stream valleys are wide and open, and most of the hills are low and well rounded, but in the eastern part of the area there are several isolated steep hills that rise from 250 to 300 feet above the general level These include Brushy Mountain in the northeast corner of the quadrangle, a cluster of knobs northeast of Berryville, Woods Knob and Snow Knob southeast of Berryville, and Round Mountain in the southwest corner of the Salem Plateau. The low altitude and subdued surface features of this area are due to excessive denudation, largely from solution of the limestone and dolomite composing it.

The part of the Salem Plateau in the northeast corner of the Harrison quadrangle is smaller, has a rougher but somewhat lower general surface, and is more poorly defined than the part in the Eureka Springs quadrangle. Its lowest elevation, and in fact the lowest point in the quadrangle, is between 550 and 600 feet above sea level, where White River leaves the northeast corner of the Harrison quadrangle.

DRAINAGE.

White River, which receives the drainage of the quadrangles, rises in the Boston Mountains in the Winslow quadrangle, southwest of the area under study, and crosses the northwestern part of the Eureka Springs quadrangle, following a general northeastward course and leaving the quadrangle near the middle of its north side. About 2 miles of its course farther east is in the northeast corner of the Harrison quadrangle.

In the Eureka Springs quadrangle the principal tributaries of White River are Kings River, which enters the southeast corner, takes a northward course through the eastern part of the area, and enters White River in Missouri, and War Eagle Creek, which runs northwestward across the south half of the quadrangle and enters White River just beyond the western margin. Each of these streams receives numerous small tributaries, among which are Little Clifty, Big Clifty, and Leatherwood creeks, which enter White River in the northwestern part of the quadrangle; Brush and Richland creeks, in the southwestern part, which enter White River in the Fayetteville quadrangle; Dry Fork, Piney, Rockhouse, Keels, and Osage creeks, which enter Kings River; and Holman and Stearns creeks and Stanley Branch, which enter War Eagle Creek.

In the Harrison quadrangle the largest tributaries of White River are Long, Bear, and Crooked creeks, and Buffalo Fork of White River. Long Creek rises in the central part of the quadrangle, flows northward, and joins White River in Missouri. Bear Creek also rises near the central part but flows northeastward into White River, in the northeast corner of the quadrangle. Crooked Creek rises south of Harrison in two forks, flows northeastward and then eastward, and enters White River southeast of Cotter, Ark. Buffalo Fork of White River heads in the Boston Mountains in the western part of Newton County, enters the southwestern part of the quadrangle, leaves it near the southeast corner after making a sweeping curve near the southern border, and joins White River a few miles below Buffalo City in Marion County. Among the principal tributaries of these streams are Terrapin Creek, Lick Branch, and Dry, Yocum, and Cricket creeks, which enter Long Creek; Cheatham Creek and Barren Fork, which enter Bear Creek; Hussar Creek, which enters Crooked Creek in the Yellville quadrangle; and Wells Creek, Mill Creek, and Little Buffalo Fork, which enter Buffalo Fork of White River. The two streams last named are, next to White River, the largest in the quadrangle, but they drain only about one-eighth of it. Much of the western part of the quadrangle is drained by Osage and Piney creeks and by Dry Fork, which join Kings River in the Eureka Springs quadrangle.

Most of the streams mentioned are perennial, and as they are supplied by springs their waters at low stage are clear. They are subject to sudden rises after heavy rains, which convert them from clear streams that can be easily forded to dangerous muddy torrents, but these floods subside within a few hours after the rains cease. A large amount of mineral matter is at all times carried in solution and suspension by the streams. By the loss of this matter the surface of the region is being continuously though slowly lowered.

The streams in the quadrangle are very crooked. The distance in a straight line from the point where White River enters the Eureka Springs quadrangle on the west side to the point where it leaves it on the north side is 17 miles, but the distance by the curves of the river is 43 miles. Big and Little Buffalo forks of White River, in the southern part of the Harrison quadrangle, and the smaller streams of both quadrangles are equally crooked, though the curves of the smaller streams have shorter swings than those of the larger ones. The surface on the inside of the curves, except along bluffs produced by escarpment-forming rocks, slopes gradually from the highest points to the present stream beds. On many such slopes along White River waterworn gravel extends to a height of more than 200 feet above the present stream. On the outside of the bends the descent to the streams is everywhere steep and in many places vertical. These bluffs are prominent features of the topography, many being 200 feet high. The highest bluff, which is on Buffalo Fork of White River, 3 miles in a straight line northeast of Ponca, rises 500 feet above that stream. As the valleys are narrow, only small marginal areas are covered at high water, and the flood plains or alluvial deposits are mere narrow stretches along the streams.

The average fall of White River is about 2½ feet, of War Eagle Creek 4 feet, of Kings River 6 feet, and of Buffalo Fork of White River 10 feet to the mile within the two quadrangles. All these streams have short, comparatively quiet reaches separated by shorter riffles, and waterfalls are common along the upper courses of the small streams.

CULTURE.

The quadrangles are not densely populated, though all parts of them are inhabited, no large portion being without houses. The rural residents, most of whom are engaged in agriculture, live chiefly on the more level upland, where the area of tillable land is greatest, though many houses are built on streams that have alluvial flats, which contain the most fertile land in the quadrangles. The two largest towns, from which the quadrangles are named, are Harrison, the county seat of Boone County, and Eureka Springs, one of the two county seats of Carroll County. Eureka Springs is a prominent health and pleasure resort, which, particularly during the summer, is frequented by many visitors, who enjoy the pleasant climate and drink the clear sparkling water of the cold springs in and near the city. Among the smaller villages and towns are Berryville, the other county seat of Carroll County; Huntsville, the county seat of Madison County; Jasper, the county seat of Newton County; and Green Forest, Bellefonte, Hindsville, Alpena Pass, and Omaha.

The Missouri & North Arkansas (formerly the St. Louis & North Arkansas) Railroad traverses the northern half of the Eureka Springs quadrangle and the central part of the Harrison quadrangle, passing through the principal towns in those parts of the areas. The St. Louis & San Francisco Railroad passes through the northwest corner of the Eureka Springs quadrangle and the White River branch of the St. Louis, Iron Mountain & Southern Railway through the northeast corner of the Harrison quadrangle. All parts of the quadrangles are reached by public roads, most of them in poor condition. A few of the main roads, however, are kept in good repair.

Agriculture is the chief occupation in the quadrangles, which are adapted to general farming, fruit growing, and grazing. More or less lumbering is done. There is a large lumber mill at Eureka Springs and many small mills at other places.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

GENERAL FEATURES.

The rocks of the Eureka Springs and Harrison quadrangles are all of sedimentary origin and consist of dolomite, magnesian limestone, limestone, shale, sandstone, and chert, with some conglomerate. They are unmetamorphosed, having suffered little change other than consolidation since their deposition. They range in age from Ordovician to Carboniferous, but the Silurian system is apparently not represented. The rocks in these areas are graphically represented in the columnar section, given at the end of the text. They belong to seventeen different formations which aggregate in maximum thickness approximately 3,200 feet. Of these formations only five, the Cotter dolomite of the Ordovician system, the Boone limestone and the Fayetteville shale of the Mississippian series, and the Hale and the Winslow formations of the Pennsylvanian series, are everywhere persistent; the other twelve are cut off by unconformities over larger or smaller areas.

The names and sequence of the formations and their stratigraphic positions as determined by the Geological Survey of Arkansas and later revised by G. I. Adams, E. O. Ulrich, G. H. Girty, David White, J. A. Taff, and the authors are shown in the correlation table on page 21.

ORDOVICIAN SYSTEM.

Ordovician strata are exposed in two rather wide areas, one in the northeast corner of each quadrangle. Elsewhere they outcrop as a rule in narrow bands along the larger streams and their tributaries. Except the Cotter dolomite (the oldest) and the overlying Powell limestone, which is generally present, the eight formations representing this system are wanting over large parts of the areas, but they commonly appear southward in ascending order of age, wedged in beneath younger rocks, in some places of Devonian and in others of Mississippian age.

LOWER ORDOVICIAN SERIES.

COTTER DOLOMITE.

Definition.—The Cotter dolomite, as the name implies, consists largely of dolomite, but it also contains some shale, chert, and sandstone. The formation is named by E. O. Ulrich from Cotter, Baxter County, Ark., where it is well exposed. In the reports of the Geological Survey of Arkansas it is known simply as "magnesian" limestone, and in Missouri it has been included in the "Second Magnesian limestone." The name Yellville was applied in 1904 and again in 1905 by G. I. Adams and E. O. Ulrich[1] to strata that have subsequently been separated into what are herein known as the Cotter dolomite and the Powell limestone, the limestone overlying the dolomite. In 1911 Ulrich[2] called the Cotter the Jefferson City dolomite, but in 1912 he determined that the beds he called Jefferson City in the Eureka Springs and Harrison quadrangles are younger than this formation at the type locality. This name, therefore, is not applicable to these areas, and for this reason the name Cotter is applied.

Distribution.—In the Eureka Springs quadrangle the Cotter dolomite is the surface rock along White River and its tributaries, and the largest exposure is in the northeastern part of the quadrangle. The largest exposure in the Harrison quadrangle, as in the Eureka Springs quadrangle, is in the northeast corner, though small exposures occur along Osage, Long, and Bear creeks, and south of Compton on two small tributaries of Buffalo Fork of White River.

[1] Adams, G. I., Zinc and lead deposits of northern Arkansas: U. S. Geol. Survey Prof. Paper 24, pp. 1–89, 1904. Ulrich, E. O., Determination and correlation of formations [of northern Arkansas]: Idem, pp. 90-113. Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (No. 119), 1905.

[2] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, No. 3, pp. 281–680, 1911. [Index]: Geol. Soc. America Bull., vol. 24, pp. 625–668, 1913.

The outcrops are marked by bluffs and more or less steep slopes along the larger streams, where good exposures are abundant; but away from them, particularly in the northeast corner of the Eureka Springs quadrangle, the relief is less rugged, the hill slopes are gentle, and rock exposures are less numerous. In many places the outcrop produces glades almost barren of soil but forested here and there by red cedar. (See Pl. IV.)

Thickness.—The thickness of the formation is not known, because at no place in the areas has erosion cut through it to the underlying formation, the Jefferson City limestone, which is exposed in Missouri and farther east in Arkansas. The part exposed in the Eureka Springs quadrangle is about 250 feet thick along Kings River; in the Harrison quadrangle it is about 500 feet thick along White River in the northeast corner.

A deep well a mile south of Green Forest, a complete log of which could not be obtained, had reached a depth of 2,100 feet when visited by the junior author. The drillings from that depth consisted of a gray sandy limestone. If the probable thickness of strata overlying the Cotter dolomite be subtracted it appears that the drill, in reaching that depth, passed through approximately 1,500 feet of strata that represent the Cotter and possibly lower formations not exposed in the quadrangles.

Character.—The formation consists mainly of two kinds of dolomite—a fine-grained argillaceous, earthy-textured, relatively soft, white to buff or gray variety, known as "cotton rock," and a more massive medium-grained gray variety that weathers hackly on the surface and becomes dark on exposure. These two sorts occur in beds ranging from a few inches to 4 feet in thickness and are interbedded with each other and with thinner layers of sandstone, shale, and some chert. The lime and magnesia constituting the greater part of the dolomite occur in almost the exact proportion in which they are found in true dolomite, as is shown by analyses of the rock at and near Eureka Springs, published by the Geological Survey of Arkansas.[3]

Partial analyses of Cotter dolomite.

[R. N. Brackett, analyst.]

	A	B	C
Silica and silicates	8.65	([a])	14.71
Iron and alumina	4.72	([a])	([a])
Magnesia	18.68	19.05	17.03
Lime	26.83	27.74	26.57

[a] Present but not determined.

A, Leatherwood switch (south side); B, Leatherwood switch (north side); C, depot at Eureka Springs.

Several beds contain chert in the form of angular fragments, therein resembling breccia, and others contain a good deal of dense gray to dark chert in lenticular and irregularly shaped masses. The nodules near the top of the formation are in most places beautifully banded with concentric light and dark layers. Irregularly hemispherical masses of chert, with a more or less perfect concentric structure of fine markings abound in two or three beds and are known as *Cryptozoon minnesotense*. In one bed near the top of the formation many of these masses are 12 to 18 inches or more in diameter. Some of the chert is oolitic, and a good deal of the porous chert, in which the fossils are commonly found, is residual and is apparently produced by the surficial segregation of the silica when certain beds of dolomite are exposed to weathering.

Sandstone and shale form but a small part of the formation. The sandstone occurs in the dolomite as streaks, most of which are not more than half an inch thick, and as layers, few of which exceed 2 feet in thickness. It is saccharoidal, and the surfaces of both the streaks and the heavier layers are generally finely ripple marked. The lower surface of many of these sandstone layers shows the casts of well-developed sun cracks that were formed in the underlying layers of calcareous mud before the sand was deposited. The shale consists of a few thin green beds, which weather to fine scales.

Fossils and correlation.—Organic remains are not generally distributed through the Cotter dolomite, but in certain beds fossils are locally very abundant. The masses of chert known as *Cryptozoon minnesotense* are common and are everywhere striking. Though they occur in Missouri and farther east in Arkansas, as well as in the underlying Jefferson City limestone, the upper range of the silicified, reef-building, coral-like plants, which these chert masses are supposed to represent, is the base of the succeeding Powell limestone. They are therefore of unfailing value in these quadrangles in determining that the rock containing them belongs to the Cotter dolomite. The other fossils consist chiefly of gastropods, the remainder being cephalopods. The following list comprises the species so far collected in northern Arkansas, nearly all of which are characteristic of the formation:

[3] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, p. 117, 1893.

*Cryptozoon minnesotense Winchell.	*Lophonema basistriatum Ulrich.
Tryblidium angustum Ulrich.	*Lophonema peccatonica (Sardeson).
Sinuites? cf. S. rossi Collie.	*Hormotoma cf. H. artemesia (Billings).
Maclurea? aff. M. affinis Billings.	*Hormotoma sp., small, very slender.
Ceratopea keithi var. Ulrich.	*Liospira subplana (Shumard).
*Eccyliopterus planidorsalis Ulrich.	Plethospira n. sp.
Eccyliopterus planibasilis Ulrich.	*Cameroceras consuetum (Sardeson).
*Orospira bigranosa Ulrich.	Cameroceras sp.
*Lophonema angulare Ulrich.	Tarphyceras cf. T. seelyi (Whitfield).
Lophonema striatellum Ulrich.	Pycnoceras complanatus (Shumard).

Some or all species of Lophonema are found in the Powell limestone.

The general aspect of this fauna leaves no doubt of its Lower Ordovician age. Compared with New York fossil faunas it agrees best with those marking the middle and upper divisions of the Beekmantown limestone in the Champlain Valley. Half of the species listed above—those distinguished by a prefixed asterisk—are identical with characteristic fossils of the Shakopee dolomite in the upper Mississippi Valley. The Cotter dolomite may therefore be said to correspond to a part of the Shakopee.

Stratigraphic relations.—The base of the formation is not exposed in the quadrangles, but in Missouri and farther east in Arkansas, where erosion has cut through it, the Jefferson City limestone underlies it. The upper surface of the formation is one of erosion and is rather uneven. The beds are slightly folded or warped, so that they are not everywhere parallel with those of the succeeding formation, the Powell limestone.

POWELL LIMESTONE.

Definition.—The Powell limestone consists of magnesian limestone, some shale, and in most places a bed of conglomerate at the base. The formation was named by E. O. Ulrich from Powell station, on the White River branch of the St. Louis, Iron Mountain & Southern Railway, where it is well exposed. In the reports of the Geological Survey of Arkansas this formation and the underlying Cotter dolomite are known simply as "magnesian" limestone. In Missouri it has been included in what is described as the "Second Magnesian limestone." The term Yellville, as has been stated under the heading "Cotter dolomite," was applied in 1904 and again in 1905 by G. I. Adams and E. O. Ulrich[1] to strata that have since been divided into what are herein called Cotter dolomite below and Powell limestone above; and Ulrich,[2] in 1911, restricted the name Yellville to the upper of the two.

Distribution.—The Powell limestone outcrops in narrow sinuous bands along the larger streams and their tributaries in the northern parts of the quadrangles, and near Willcockson and south of Compton in the southern part of the Harrison quadrangle. It is wanting over a small area northwest of Green Forest, another area northeast of Omaha, and a third on Boat Mountain northeast of Eureka Springs.

The formation weathers rather easily, so that it almost everywhere forms the slopes of escarpments that are capped by more resistant strata. Compared with the Cotter dolomite, the Powell limestone produces the more rounded slopes. Along most of its outcrop this formation is exposed as ledges that protrude through only a very thin covering of surficial material. In fact the outcrop at many such places produces barren glades, though it is dotted here and there with clumps of red cedar.

Thickness.—The formation ranges in thickness from a few feet to 200 feet, occurring in maximum thickness near the mouth of Leatherwood Creek, in the Eureka Springs quadrangle. The following measurements show its thickness in different parts of the area: In the Eureka Springs quadrangle, at Eureka Springs, 20 feet; near Beaver, 120 to 200 feet; southwest of Beaver and Eureka Springs, 25 to 50 feet; near Oak Hill, 60 feet; near Winona Springs, 30 to 60 feet; on Trigger Mountain, 50 to 130 feet; at Rockhouse, 110 feet; on and near Brushy Mountain, 30 feet; on Ant Mountain, 140 feet; and southeast of Berryville, 25 to 80 feet. In the Harrison quadrangle its thickness on Cricket Creek is 40 to 60 feet; near Burlington, 90 to 110 feet; north of Self, 10 to 90 feet; east and south of Self, 90 to 100 feet; near Myrtle, 95 to 130 feet; and in Hemmed-in Hollow, 2 miles south of Compton, 170 feet.

Character.—The Powell limestone, as already stated, consists of magnesian limestone, a small amount of shale, and at most places a bed of conglomerate at the base. The conglomerate is a dark argillaceous magnesian limestone, containing pebbles of chert and limestone derived from the Cotter dolomite. At a few places it includes a layer that seems to be a part of an old residual mantle recemented in place and containing lenses of chert and silicified masses of *Cryptozoon minnesotense*. As a result of weathering of the old land surface some of these lenses broke into pieces in the residual mantle and their fragments became separated. Their distribution in the conglomerate is like that of similar fragments in many exposures of the residual cover of cherty beds to-day. With the exception of one or more beds of calcareous green shale, the formation consists of finely crystalline gray or greenish-gray magnesian limestone, containing more or less argillaceous matter. Most of the limestone effervesces rather freely in cold dilute hydrochloric acid, showing that the proportion of magnesium carbonate is not so great as in the underlying Cotter dolomite, which is more nearly a true dolomite. The light-colored, most porous beds are locally known as "cotton rock." The exposed layers do not as rule present hackly surfaces but are somewhat rounded, and at many places they break with a conchoidal fracture into small angular pieces. More or less concentrically banded, dense white chert in the form of small nodules is sparingly distributed through the limestone. This formation resembles certain beds, known as "cotton rock," in the Cotter dolomite, but the small amount of chert throughout the formation and the absence, except in the basal conglomerate, of the cherty masses of *Cryptozoon minnesotense* are generally sufficient to distinguish this limestone from the Cotter.

A bed containing much drusy quartz and outcropping as a single massive dark ledge with a rough surface occurs in the lower half of the formation in the eastern and southern portions of the Harrison quadrangle. This bed, which is several feet thick, contains abundant fossils in the adjoining Yellville quadrangle, on the east, but none have been found in it in the Harrison quadrangle.

In the upper part of the Powell limestone there are numerous veins and irregular masses composed of white, well-rounded quartz sand grains and containing at many places blocks of limestone and at a few places blocks of laminated sandstone. The veins may be appropriately called dikes. They range in thickness from that of a knife blade to 6 inches, and some of the larger ones extend downward 20 feet from the top of the limestone. The largest of the irregular masses are 75 feet in diameter and 40 feet in height. Many of these large masses are conspicuous, especially in the northern halves of the quadrangles, where they have been laid bare by the erosion of the inclosing limestone. (See Pl. III.) The sandstone of most of these masses consists of homogeneous sand, but in a few of them it is finely laminated. The sides of many masses are vertical; those of others converge downward. Horizontal joints and more or less vertical slickensides are found at many places. All these masses were formed by the filling of cavities by sand from above. Some of the cavities were doubtless sink holes formed while this formation was at the surface and filled by sand; others were cavities formed by ground water, which dissolved the limestone, making openings which were filled by the downward settling of the partly indurated sands of the Kings River sandstone member of the Everton limestone and in some places possibly of the St. Peter sandstone. The way in which these masses were formed is illustrated in figure 9 (p. 7), which is a sketch of a sandstone mass in the Powell limestone, connected above with a sandstone "pipe" in the Kings River member.

At the base of the formation in the western part of the Eureka Springs quadrangle there are a few sandstone lenses several feet thick and more than a hundred feet across. They are practically horizontal and are thought to be sand reefs formed while the shallow Powell sea was advancing over the eroded surface of the Cotter dolomite.

Fossils and correlation.—Though fossils are rare in most parts of the Powell limestone, fairly good collections were made in the adjoining Yellville quadrangle, most of the specimens having been found near Yellville. Here, as usual, they are confined almost entirely to the bed which lies from 50 to 70 feet below the top of the formation and which is so conspicuously marked by drusy quartz. About 20 species in the collections made at Yellville have been determined as follows:

Deltatreta cf. D. electra (Billings).	Cameroceras n. sp., large.
Syntrophia? (n. subgen. of) cf. S. palmata and S. campbelli Walcott.	Protocycloceras lamarki (Billings).
Scenella sp.	Cyrtoceras? confertissimum Whitfield.
Maclurea? cf. M. sordida and M. matutina Hall.	Tarphyceras cf. T. seelyi (Whitfield).
Maclurea aff. M. crenulata Billings.	Tarphyceras cf. T. clarkei Ruedemann.
Lophospira cf. L. carinifera (Shumard)	Deltoceras? (probably new genus) large, abruptly expanding, closely septate; siphuncle large.
Lophonema? yellvillensis Ulrich.	Asaphus sp.
Liospira canadensis (Billings).	Bolbocephalus cf. B. seelyi Whitfield.
Hormotoma exactus (Sardeson).	Bathyurus cf. B. conicus and B. nero Billings.
Cameroceras cf. C. montrealensis (Billings).	Clelandia (Harrisia) cf. C. parabola Cleland.

This fauna, like that of the Cotter dolomite, is unquestionably Lower Ordovician. A few of the species are found farther north, in the Shakopee dolomite, but the Powell formation probably corresponds only to the upper part of the Shakopee. Other species of the list are either the same as or closely allied to upper Beekmantown fossils in New York and adjacent parts of Vermont and Canada.

Stratigraphic relations.—The Powell limestone rests unconformably upon the rather uneven eroded surface of the Cotter dolomite and is unconformably overlain at different places by the Everton limestone of the Ordovician system and the Chattanooga shale of the Devonian system.

EVERTON LIMESTONE.

Definition.—The Everton limestone was named by E. O. Ulrich from Everton, Ark., where it is well developed. It consists of three subdivisions, whose diverse character from place to place is graphically represented in figure 4, namely, (1) at the base a sandy magnesian limestone, called the Sneeds limestone lentil, from Sneeds Creek, southwest of Compton, in the Harrison quadrangle, where it is typically developed; (2) a massive saccharoidal sandstone, called the Kings River sandstone member, from Kings River, in the Eureka Springs quadrangle, where it is best developed; and (3) a fine-grained nonmagnesian limestone interbedded with sandstone, which forms the bulk of the formation in the Harrison quadrangle and a small part of it in the Eureka Springs quadrangle.

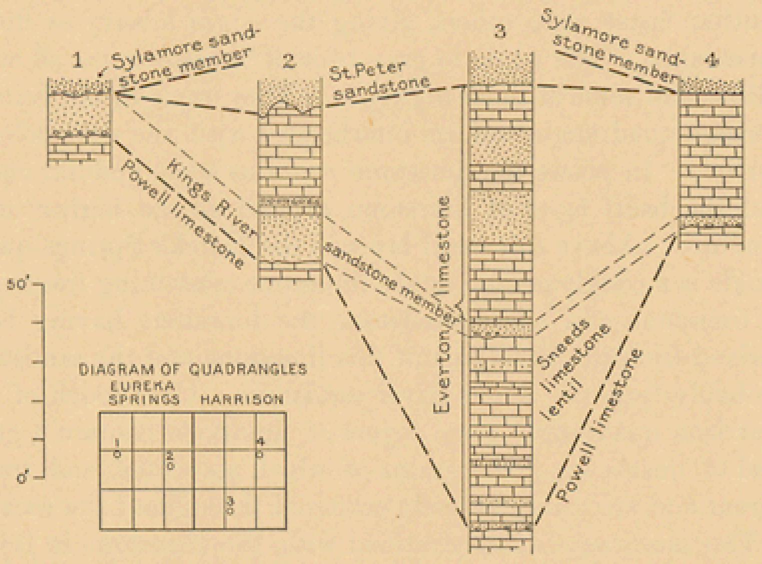

FIGURE 4.—Sections of the Everton limestone in the Eureka Springs and Harrison quadrangles, showing the variability of the formation, the unconformity within it, and the overlap of the Sylamore sandstone member of the Chattanooga shale.

1, Little Clifty Creek; 2, Kings River, 1 mile above the mouth of Piney Creek; 3, Hemmed-in Hollow, 2 miles south of Compton; 4, Wolf Creek, east of Francis.

All these parts are well exposed on Sneeds Creek and in Hemmed-in Hollow, about 2 miles south of Compton, but elsewhere in the quadrangles one, two, or all of these divisions may be wanting. The formation ranges in thickness from a feather edge to 115 feet but is absent over much of the area.

Distribution.—The most northern outcrops of the Everton limestone in the quadrangles lie along or a little south of parallel 36° 20′. In the Eureka Springs quadrangle this limestone is exposed on Little Clifty Creek and its tributaries; on the upper parts of Big Clifty Creek, Keels Creek, and in Williams Hollow; along Kings River and its tributaries most of the way from a point a mile south of Winona Springs to the mouth of Pine Creek; and along Piney Creek. In the Harrison quadrangle it is exposed along Osage Creek near the western border, on the heads of the streams from Francis eastward, on Hussar and Crooked creeks on the eastern border, and along the two Buffalo forks of White River and their tributaries on the southern border. The outcrop is usually a sinuous narrow band that occurs on steep slopes adjacent to the streams, but in many places where the formation is overlain by the St. Peter sandstone the outcrop is in bluffs capped by that sandstone or by higher formations. (See Pl. V.) The Kings River sandstone, which is thickest in the Eureka Springs quadrangle, produces a practically continuous bluff, which is a conspicuous feature of the steep slopes in that area.

Character and subdivisions.—The Everton limestone consists, as already stated, of a fine-grained limestone and of two lower subdivisions, the Kings River sandstone member above and the Sneeds limestone lentil below.

That portion of the Everton which overlies the Kings River sandstone outcrops in the east-central part of the Eureka Springs quadrangle, along Piney Creek and Kings River, at the head of Rockhouse Creek, and in the heads of hollows between this creek and Kings River. It outcrops in the Harrison quadrangle along Osage Creek near the western border, on the heads of the streams from Francis eastward, on Hussar and Crooked creeks on the eastern border, on Harp and Mill creeks south of Willcockson, on Buffalo Fork of White River south of Compton, on Wells Creek and the two Buffalo forks north and northeast of Jasper, and near Yardelle. Its most northern outcrops are a little south of parallel 36° 20′, and it probably underlies the younger rocks of the quadrangles south of that parallel and east of Kings River.

The thickness of the upper limestone portion of the Everton ranges from a feather edge to 100 feet in these quadrangles, but in the adjoining Yellville quadrangle the maximum is considerably more. Its thickness is irregular within short distances, though taken as a whole it is fairly uniform. In general it decreases northward and westward. The maximum thickness is found on Crooked Creek near the eastern border of the Harrison quadrangle, where it is in places 100 feet, but at other places in the same locality it is only 40 feet. Along Osage Creek, in the western part of the Harrison quadrangle, its thickness ranges from 3 to 53 feet. Along Kings River and its tributaries in the Eureka Springs quadrangle its thickness is generally 15 feet. On Buffalo Fork of White River and near Willcockson it is from 30 to 75 feet.

[1] U. S. Geol. Survey Geol. Atlas, Fayetteville folio (No. 119), 1905.

[2] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, No. 3, pp. 281-680, 1911. [Index]: Geol. Soc. America Bull., vol. 24, pp. 625-668, 1913.

The part of the Everton that overlies the Kings River sandstone consists of alternate beds of limestone and sandstone, the calcareous portion comprising 50 to 75 per cent or more of this part. It is even bedded and the layers range from thin bedded to massive. The prevailing color is somewhat lighter than dove color, but some beds are white or light gray. The dove-colored portion has a conchoidal fracture and is compact, brittle, and, with the exception of abundant small segregations of white calcite crystals, noncrystalline. Many of the layers are made up of hemispherical masses from 6 to 8 inches in diameter, convex upward. The structure of these masses is that of concentric shells, whose layers or laminae turn out at the base and join those of the surrounding masses. Where such layers are exposed, as in the beds of creeks, the surface is distinctly botryoidal. In the bluffs some of the laminae weather faster than others, giving the edges a wavy or fluted appearance. The white to gray beds of limestone are all crystalline, and some of them highly so. They occur in the Eureka Springs quadrangle and are interbedded with the dove-colored portion. In places the limestone contains some nodular chert, and the basal layer of limestone, as well as the higher ones, is oolitic. Above this basal layer in the Eureka Springs quadrangle is a conglomeratic sandy limestone containing fragments of limestone and white sandstone, the limestone having been derived from the basal part of this limestone and the sandstone probably from the Kings River sandstone. Over much of the Harrison quadrangle some layers of limestone contain a great deal of quartz sand, the grains of which are round and transparent and are rather sparsely scattered throughout the rock.

The sandstone is interstratified with the limestone in layers from a foot to several feet thick. It is friable and is generally in every way like the Kings River sandstone, or the overlying St. Peter sandstone. The amount of sandstone in the formation varies from place to place, though it seems to increase southward in the Harrison quadrangle. In the exposure in the bluff north of the confluence of the two Buffalo forks of White River, where the following section was measured, the sandstone constitutes half the exposed thickness of the formation:

Section in bluff north of confluence of Little Buffalo Fork and Buffalo Fork of White River.

	Ft.	in.
Jasper limestone, basal sandstone:		
Massive friable saccharoidal sandstone	14	0
Joachim limestone:		
Hard sandy dark magnesian limestone	18	0
Friable saccharoidal sandstone	2	0
Rather massive sandy dark magnesian limestone	75	0
St. Peter sandstone:		
Massive saccharoidal sandstone	25	0
Unconformity, shown by irregular eroded surface.		
Everton limestone:		
Compact dove-colored limestone	20	0
Friable massive saccharoidal sandstone	10	0
Compact dove-colored limestone	1	0
Saccharoidal sandstone		8
Compact dove-colored laminated limestone; laminae wavy	2	0
Saccharoidal sandstone	1	0
Laminated compact dove-colored limestone; laminae wavy	1	6
Saccharoidal sandstone	5	6
Compact dove-colored limestone		6
Sandy limestone		6
Compact dove-colored limestone		6
Sandstone grading by lamination into limestone layer above	1	6
Laminated compact dove-colored limestone; laminae wavy		6
Saccharoidal sandstone	3	6
Compact dove-colored limestone containing 1 foot of sandstone in upper part	2	6
Saccharoidal sandstone	1	0
Compact dove-colored limestone		10
Massive laminated saccharoidal sandstone to base of exposure at water's edge of Little Buffalo Fork	10	0
Thickness of exposed beds of Everton	63	0

The Sneeds limestone lentil is exposed south of Compton and near Willcockson. In those places it consists of sandy, hard, compact dark-drab magnesian limestone in thick layers that everywhere stand out as hackly ledges on the surface, in marked contrast with the underlying Powell limestone. The lowest layer contains a good many pebbles from the Powell limestone. The greatest thickness is in Hemmed-in Hollow, a little less than 2 miles south of Compton, and at one or two near-by localities, in all of which it is 50 feet. At one place on Sneeds Creek, the limestone is 35 feet thick, but at another place on this stream, as well as everywhere farther north in this quadrangle and the Eureka Springs quadrangle, it is wanting.

The Kings River sandstone occurs at every place in the Eureka Springs quadrangle where this horizon of the formation is exposed. In fact, it is the only part of the formation found along Little Clifty Creek and its tributaries, on Big Clifty and Keels creeks, in Williams Hollow, and at many places on Kings River and Rockhouse and Piney creeks.

In the Eureka Springs quadrangle its thickness ranges from 2 to 40 feet but in most places is about 25 feet. In the Harrison quadrangle its thickest outcrops are on Buffalo Fork of White River south of Compton and on Osage Creek, where it is in places 4 to 12 feet thick; at other places along these streams, however, as well as in many other parts of the quadrangle, it is only 1 foot or 2 feet thick and is scarcely distinguishable from the overlying limestone. It is a white, friable, finely and evenly laminated sandstone composed of clear, well-rounded quartz grains of medium size and with smooth surfaces. It generally occurs in a single massive layer, and everywhere on weathered surfaces it shows rather close laminations parallel with the bedding. Between these laminations there is a fine cross-bedding, but at a few places in the Harrison quadrangle it is coarse. The edges of the sandstone become fluted on weathering, so that in some parts of the area the lamination and cross-bedding are conspicuous. At its base the sandstone contains pebbles of chert, quartzite, and limestone, which were obviously derived from the underlying rocks. Cylindrical columns of sandstone, whose sides converge downward, are exposed here and there in transverse sections in the bluffs of this sandstone. As already explained, they were produced by the downward settling of sand into solution cavities in the Powell limestone beneath, at some time before the sand had become thoroughly indurated. These columns are herein called "pipes" and are more fully described in connection with the St. Peter sandstone, which shows similar phenomena. The outcrops of this sandstone in the Eureka Springs quadrangle produce a sinuous vertical escarpment whose height generally depends on the thickness of the sandstone. Where the Sylamore sandstone—to be described later—is the overlying rock, it caps the escarpment and is so closely joined to the Kings River sandstone that it is not easy to distinguish the one from the other.

Sections.—The best observed section of the Everton limestone, where the Sneeds limestone, the Kings River sandstone, and the overlying limestone are present, is given below.

Section of Everton limestone in Hemmed-in Hollow south of Compton.

	Feet.
St. Peter sandstone:	
Massive laminated saccharoidal sandstone, forming bluff.	
Everton limestone:	
Compact dove-colored limestone	10
Friable saccharoidal sandstone	10
Compact dove-colored limestone	6
Friable saccharoidal sandstone	15
Compact dove-colored limestone	20
Kings River sandstone member (white friable sandstone, containing fragments of quartzite)	4
Sneeds limestone lentil (rather massive hard sandy compact dark magnesian limestone; basal layer contains fragments from the underlying Powell limestone)	50
Powell limestone:	
Massive and thin-bedded gray compact magnesian limestone	170
Cotter dolomite:	
Gray cherty dolomite to base of hill	40

The following section is exposed on Kings River a mile south of the mouth of Piney Creek, in the Eureka Springs quadrangle, where the Kings River sandstone is well displayed.

Section of Everton limestone on south side of point in NW. ¼ sec. 3, T. 18 N., R. 25 W.

	Ft.	in.
St. Peter sandstone:		
Friable laminated saccharoidal sandstone, forming top of bluff.		
Unconformity, shown by irregular surface, some depressions 10 feet deep.		
Everton limestone:		
White to light-gray and dove-colored limestone, in parts compact, in others crystalline; certain layers sandy	25±	
Thin layer of chert nodules.		
Compact limestone		10
Conglomerate, consisting of fragments of limestone and sandstone in a sandy calcareous matrix	1	6
Bluish-gray, in part oolitic limestone	1	0
Kings River sandstone member (massive laminated saccharoidal sandstone)	12±	
Powell limestone:		
Compact gray magnesian limestone.		

At many places in the Eureka Springs quadrangle the Kings River sandstone is the only representative of the formation, as on Little Clifty Creek, where the following section was measured:

Section of Everton limestone on Little Clifty Creek.

	Feet.
Chattanooga shale:	
Black fissile shale, exposed on bench.	
Sylamore sandstone member:	
Angular chert fragments in fine-grained quartzite	1
Massive unlaminated coarse-grained white sandstone, with layer at base 6 to 8 inches thick, containing rounded fragments of sandstone and chert. This bed caps a low bluff	4
Everton limestone:	
Kings River sandstone member (laminated white sandstone in single ledge producing low bluff; fragments of chert in the basal part)	10
Powell limestone:	
Fine-grained gray magnesian limestone.	

The following section was measured in the Harrison quadrangle on the west side of Wolf Creek half a mile above the mouth. At this place the Kings River sandstone is very thin.

Section of Everton limestone on the west side of Wolf Creek half a mile above its mouth.

	Feet.
Sylamore sandstone member (?) of Chattanooga shale:	
Friable saccharoidal sandstone.	
Everton limestone:	
Gray to dove-colored limestone, oolitic in most beds and containing a good deal of calcite in thin seams	12
Thin-bedded compact dove-colored limestone containing small crystals of calcite	1¼–2
Gray to dove-colored limestone containing a good deal of calcite in thin seams	18
Kings River sandstone member (white compact quartzitic sandstone, with a layer of weathered, apparently brecciated material below)	2 –3
Powell limestone:	
Dark-gray compact, very thinly laminated limestone.	

Fossils and correlation.—Organic remains in the Sneeds limestone have been observed only in the matrix of the conglomeratic basal layer at two localities in the Yellville quadrangle, which adjoins the Harrison on the east. The following species have been determined as far as the imperfect specimens permit:

Plates of cystidean with numerous rhombs.
Lophospira cf. L. gregaria (Billings) and perangulata (Hall).
Lophospira? sp., low spired, with sharp peripheral keel, the general aspect resembling L. abnormis, a Trenton species.
Turritoma n. sp., shell about 11 millimeters high, last whorl about 6 millimeters wide.
Hormotoma aff. H. gracilis.
Aparchites sp. undet.
Bathyurus? sp., free cheeks only.

Most outcrops of that part of the formation overlying the Kings River member are fossiliferous. The best-known localities for fossils are in the eastern part of the Harrison and in the adjoining western half of the Yellville quadrangle. Organic remains, however, are not generally distributed through the beds. As a rule the fossils, particularly the Ostracoda, are confined to certain layers in which they are often extremely abundant. The *Raphistomina* of the following list is also commonly found in great numbers. The pelecypods are more local in distribution, but where they occur at all their separated valves are likely to be numerous. In all, twelve species, which with one or two exceptions are undescribed, have been determined, as follows:

Monotrypa n. sp.
Ctenodonta novica (Sardeson).
Two or three undetermined Pelecypoda.
Raphistomina n. sp., same also in the Jasper limestone.
Lophospira sp., low spired, same also in the Sneeds limestone.
Lophospira sp., larger than the preceding and resembling L. conradana Ulrich.
Fusispira? sp., small, height less than 10 millimeters, ventricose.
Isochilina sp. 1, surface punctate.
Isochilina sp. 2, surface smooth.
Leperditia? sp.
Primitia cf. P. logani Jones.

The Ostracoda are all small, not exceeding 5 millimeters in length.

No fauna closely resembling this is known from elsewhere. One of the pelecypods is identified with a species collected from the St. Peter sandstone, one of the gastropods is found also in the underlying Sneeds limestone, and another can not be distinguished from a species found in the Jasper limestone. The general aspect of the fauna indicates that it might be of pre-Chazy age, though it is distinctly younger than the Beekmantown fauna. These relations are in accord with the known fact that the St. Peter sandstone underlies the Stones River (of early Chazy age) in Kentucky. According to the evidence in hand the fossils herein listed from the Everton limestone, the Joachim limestone, and perhaps the Jasper limestone, seem to give an imperfect conception of the first post-Beekmantown fauna in America.

Stratigraphic relations.—In some places the basal part of the formation contains fragments of chert, quartzite, and limestone derived from the older formations beneath; at other places there is a distinct unconformity. For these reasons the formation is thought to lie unconformably upon the Powell everywhere in the Eureka Springs and Harrison quadrangles, but the surface of unconformity is very even and can be detected only where the exposures are most favorable.

The Sneeds limestone lentil, whose exposures are confined to small areas along Buffalo Fork of White River and its tributaries, is unconformably succeeded by the Kings River sandstone member, as exhibited by the presence of a conglomerate at the base of the sandstone. Along this stream and at places farther north in the quadrangles, where the Sneeds limestone is wanting, it is overlapped by the Kings River member, and at other places both the Sneeds and the Kings River are overlapped by the upper limestone member of the formation. A conglomerate known to be of local distribution in the Eureka Springs quadrangle occurs near the base of the upper limestone member, but in the Harrison quadrangle neither a conglomerate nor any other physical feature suggesting a stratigraphic break at this horizon was observed.

Near the mouth of Piney Creek, in the Eureka Springs quadrangle, the Kings River member is overlain by the St. Peter sandstone, the upper part of the Everton being absent. At other places in that quadrangle all the younger strata of Ordovician age are lacking, so that in one place on the East Fork of Little Clifty Creek the Kings River member is overlain by the Clifty limestone, of Middle Devonian age, and at other places in that quadrangle by the Sylamore sandstone member of Upper Devonian age.

At the top of the Everton limestone there is a marked unconformity in the Eureka Springs quadrangle and along Osage Creek and the head of Bear Creek in the Harrison quadrangle. This unconformity is a conspicuous feature of the stratigraphy in the bluffs along the streams in the areas mentioned. The upper surface of the limestone as shown in the bluffs appears to contain numerous pockets, some of them 8 and 10 feet deep, filled with sand from the overlying St. Peter sandstone. Some of these depressions are doubtless old stream channels, but most of them are attributable to solution by ground water while the limestone was the surface rock of a land area. Others again are interpreted as caverns filled by St. Peter sand. Figure 5 gives an idea of the character of this unconformity. Along Buffalo Fork of White River the

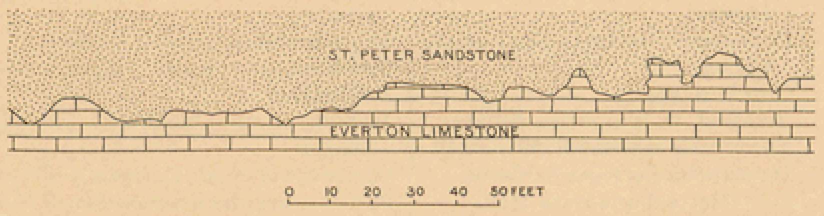

FIGURE 5.—Unconformity between the Everton limestone and St. Peter sandstone exposed in bluff 3½ miles southwest of Green Forest, in sec. 19, T. 19 N., R. 23 W.

The irregular unconformable surface was produced by the solution of the limestone when it was exposed at the surface and by the removal of the residual clay before the sand of the St. Peter formation was deposited.

upper surface of the Everton is more even, so that in many places the unconformity is not distinct.

The Everton limestone is overlain by the St. Peter sandstone except about its northern border in the Harrison quadrangle, where the overlying beds are the Sylamore sandstone, as shown in figure 6. The mass of sandstone shown in the figure

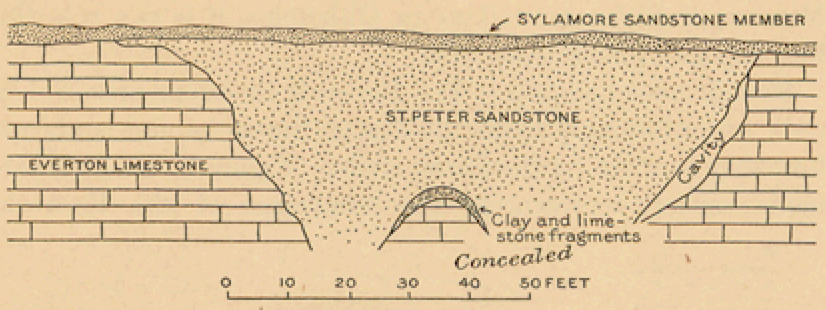

FIGURE 6.—Relations of the Sylamore sandstone member of the Chattanooga shale to the Everton limestone and St. Peter sandstone in a bluff on Bear Creek, 1 mile northeast of Francis, in sec. 13, T. 19 N., R. 21 W.

This sand of the St. Peter formation was deposited in a hole or channel formed by solution in the Everton limestone, where it was protected from the erosion which removed the rest of the St. Peter sandstone before the sand of the Sylamore member was deposited.

is either cave, channel, or sink-hole filling, the upper part of which was removed by erosion. A later submergence of the area brought about the deposition of the Sylamore.

ST. PETER SANDSTONE.

Definition.—The St. Peter sandstone is widely distributed in the upper Mississippi Valley and extends as far south as northern Arkansas. It receives its name from the fact that it occurs along the lower course of St. Peter (now known as Minnesota) River, in Minnesota, where it is well developed. In different parts of the Ozark region it has been known as the "Key" sandstone (in the Yellville district in Arkansas), "Burgen" sandstone (in northeastern Oklahoma), "Saccharoidal" sandstone, "First" sandstone, "Crystal City" sandstone, "Pacific" sandstone, and "Cap-au-Gres" sandstone. Most of these names have been applied to the formation in Missouri. It consists of a massive bed of white quartz sand firmly cemented, where not weathered, by a small amount of calcium carbonate.

Distribution.—In the Eureka Springs quadrangle the St. Peter sandstone outcrops along Kings River and its tributaries south of Rockhouse post office and at one locality on War Eagle Creek northeast of Hindsville; in the Harrison quadrangle it outcrops on Osage Creek near the western border, on Crooked and Hussar creeks in the eastern part, and on Buffalo Fork of White River and its tributaries in the southern part.

In those parts of the quadrangles that lie north of the areas where the St. Peter sandstone is mapped numerous large isolated masses of saccharoidal sandstone stand up conspicuously on the hill slopes. Some of these are cave deposits; others are sink hole deposits and have been described under the Powell limestone; but still others rest on top of the Powell and Everton limestones, and they are interpreted as remnants of the St. Peter sandstone, left after the long interval of erosion that followed the close of Ordovician sedimentation in the Ozark region.

The St. Peter sandstone along much of its outcrop produces an escarpment which in many places is a precipitous bluff. The much-weathered vertical face of this bluff is fluted here and there, and the upper edge is in most places more or less rounded. These bluffs form a conspicuous feature of the slopes, especially along Buffalo Fork of White River north and northwest of Jasper, where the formation ranges in thickness from 75 to 150 feet. (See Pls. I, V, VI.)

Thickness.—The maximum observed thickness of the formation, 150 feet, is at a point on Buffalo Fork of White River south of Compton. From that point the sandstone becomes thinner northward and disappears about the middle of the quadrangles. It also becomes thinner eastward, and near Yardelle it is only 15 feet thick. Along Kings River its thickness ranges from 10 to 70 feet. On Osage Creek its thickness is generally about 30 feet, but it reaches 100 feet at the most southern outcrop along that stream. On Crooked and Hussar creeks it is 10 to 20 feet thick.

Character.—The formation is saccharoidal and is composed of well-rounded medium-sized transparent quartz grains cemented by a small amount of calcium carbonate. Well-developed ripple marks appear in places. The sandstone becomes friable on weathering and shows fine lamination and cross-bedding, and in many places presents fluted surfaces.

A foot of sandy bluish-gray limestone in the St. Peter sandstone, 40 feet from its top, is exposed on Little Buffalo Fork, 3½ miles northeast of Jasper. It is possible, however, that this sandy limestone is the upper part of the Everton and that the underlying 30 feet of massive friable white sandstone that is calcareous in thin layers is the Kings River sandstone member, but as a similar calcareous sand near the base of the St. Peter has been seen at a few other places in this part of the Harrison quadrangle these beds are referred to the St. Peter.

A peculiar feature of both the St. Peter and the Kings River sandstones is the rather common occurrence in them of pipes, as shown in figures 7, 8, and 9. These pipes are exposed in

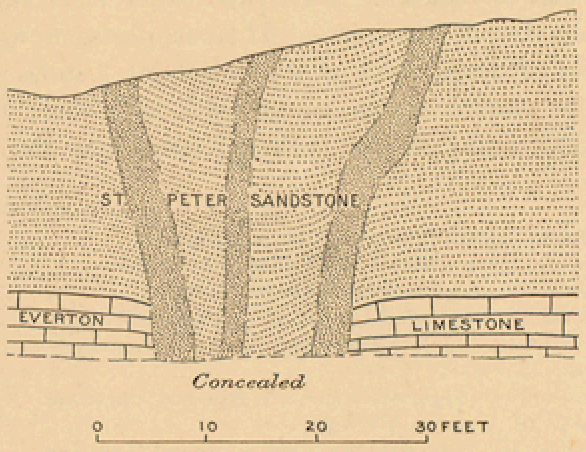

FIGURE 7.—Pipe in St. Peter sandstone exposed in a bluff 1 mile southwest of Willcockson, in sec. 30, T. 17 N., R. 20 W.

The pipe, which extends downward into the Everton limestone, is believed to have been formed by the solution of the Everton limestone beneath it before the St. Peter sandstone was thoroughly consolidated. The sand slumped into the solution cavity and acquired a structure which resembles an inverted cone. The denser layers are zones of greatest movement in which the original bedding is entirely destroyed.

longitudinal section along bluffs and in transverse section over more or less level areas where either sandstone is the surface rock and is barren of soil. Many of the pipes in such level

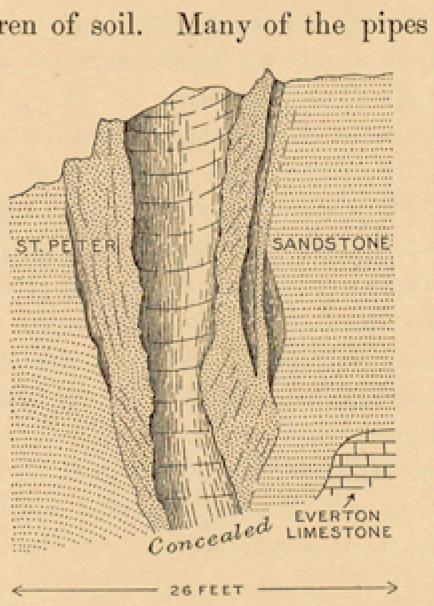

FIGURE 8.—Pipe in St. Peter sandstone exposed in a bluff 3½ miles southwest of Green Forest, in sec. 19, T. 19 N., R. 23 W.

The central filling of the pipe has recently weathered out, leaving a cylindrical hole.

areas form low domes from 2½ inches to 150 feet in diameter and have a somewhat concentric structure. Blocks of sandstone lie in the sandy matrix in many of the larger domes with their laminae edgewise. The domes are attributed to the differ-

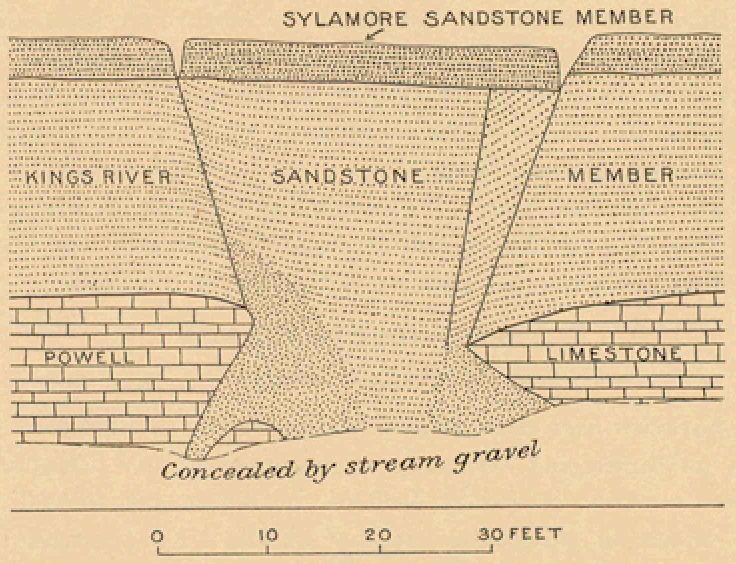

FIGURE 9.—Pipe in the Kings River sandstone member of the Everton limestone exposed in a bluff on Big Clifty Creek just south of the mouth of Scaldhog Hollow, in sec. 13, T. 19 N., R. 27 W.

The pipe is connected with a sandstone mass that fills a solution cavity in the underlying Powell limestone. The solution of the limestone and slumping of the sandstone into the solution cavity occurred before the deposition of the Sylamore sandstone member of the Chattanooga shale, which covers the Kings River sandstone member nearly horizontally and is only slightly disturbed by later settling along the old lines of movement.

ential weathering of the rock of the pipes and of that surrounding them. One such pipe in the St. Peter sandstone on Kings River extends downward through 28 feet of the upper limestone of the Everton into the Kings River sandstone, and how much farther is unknown, as its base is concealed. The pipes are thought to have had their origin in the settling of the Kings River and St. Peter sands, while they were loose or only partly indurated, into caverns or enlarged sand-filled openings in the underlying limestone. That this settling of these sands into such caverns or openings did not take place until after their deposition is shown by the high angles assumed by the sides of the pipes and by shearing planes and slickensides. Had the settling taken place at the time of the deposition of the sand, funnel-shaped depressions with slopes equal to the angle of repose of the sand instead of high angles, as shown in the figures, would have been formed above the openings into the caverns. The shearing planes are strikingly similar to the planes of movement observed in layers of differently colored loose sand placed in a box and allowed to run through a hole in the bottom. The angular fragments in the sand matrix are thought to have been formed by the breaking up of partly indurated thin layers as pressure came upon them in the movement of the sand, which perhaps at times had its stimulus from earthquakes. The method of origin of these pipes here suggested is confirmed by a pipe exposed in a bluff of the Kings River sandstone which passes into a sand-filled cavern in the Powell limestone beneath, as illustrated by figure 9. The pipe has settled a foot on the north side but none on the south since the deposition of the sand that subsequently became the Sylamore sandstone member of the Chattanooga shale, indicating that the greater part of the downward movement of the pipe took place prior to the invasion of the Sylamore sea during late Devonian time. Most of the downward movement in many if not in all the other sandstone pipes of the quadrangles probably took place prior to this time, though this is the only locality where the relation of the sandstone pipes to overlying formations was observed.

Fossils and correlation.—As might be expected from the character of the deposits, fossils are extremely rare in the St. Peter sandstone, and it has furnished none in Arkansas. *Psiloconcha senecta*, one of a number of fossils described from the St. Peter sandstone in Minnesota by F. W. Sardeson, was procured from the lower part of the overlying Joachim limestone near Guion, Ark., on White River, about 65 miles east of the Harrison quadrangle. Another of these species described by Sardeson has already been listed among the fossils of the Everton limestone. Still other species have been observed in a sandstone in a similar position in the section in southeastern Missouri. So far, then, as we may rely on this rather meager paleontologic evidence, the sandstone here referred to the St. Peter is of the same age as the typical St. Peter sandstone in the upper Mississippi Valley. The propriety of the correlation indicated by the fossils seems, however, assured by the fact that the St. Peter sandstone has been traced by means of numerous deep-well records from Iowa into Missouri and thence by continuous outcrop to southeastern Missouri. From Missouri to the Harrison quadrangle in Arkansas only one considerable break in the continuity of outcrops of the sandstone occurs, namely, between Cape Girardeau, Mo., and Lawrence County, Ark., a distance of about 100 miles. Though remnants of the sandstone occur in this interval, it is as a rule absent, being covered by the much younger Tertiary and Quaternary deposits, which overlap it and rest on older rocks of Lower Ordovician age.

Stratigraphic relations.—The St. Peter sandstone rests unconformably upon the upper part of the Everton limestone, except at two places. One of these is near the mouth of Piney Creek, in the Eureka Springs quadrangle, where it rests upon the Kings River sandstone; the other is a small area on Osage Creek, at the western border of the Harrison quadrangle, where it rests upon the Powell limestone. In those parts of the quadrangles that lie north of the areas where the formation is mapped the large isolated masses of saccharoidal sandstone that are interpreted as erosion remnants of the St. Peter rest at some places on top of the Powell limestone and at others on the Everton limestone. At its top the St. Peter is apparently conformable with the Joachim limestone. At some places the later Ordovician formations are lacking, and there the Sylamore sandstone member of Devonian age or the St. Joe limestone member of Carboniferous age rests upon the St. Peter. In lithologic character and topographic expression the St. Peter resembles very closely the Kings River, from which it is at most places separated by a greater or less thickness of Everton limestone. This resemblance is so close that where only one of these sandstones is present and the upper limestone division of the Everton is absent, as at places in the Eureka Springs quadrangle, the identity of the sandstone can be determined only by following the outcrop to some locality where the limestone is present.

JOACHIM LIMESTONE.

Definition.—The Joachim limestone consists of magnesian limestone and greater or less amounts of saccharoidal sandstone. Besides being widely exposed on the southern border of the Ozark region in Arkansas, the formation is found along the eastern border of this region in Missouri, where it was named by Arthur Winslow. In the Missouri section it is also known as the "First Magnesian" limestone and the "Folley" limestone. In Arkansas east of the quadrangles herein treated the

Joachim limestone represents the lower part of the Izard limestone. The thickness of the formation is 90 feet near Ponca and 95 feet in the southeastern part of the Harrison quadrangle. Its thickness diminishes abruptly northward and at Willcockson and farther north it is absent.

Distribution.—The Joachim limestone outcrops along Buffalo Fork of White River and its tributaries in the Harrison quadrangle, but it does not outcrop in the Eureka Springs quadrangle. It is exposed in narrow bands, generally occurring on steep slopes just above the escarpment usually produced by the underlying St. Peter sandstone.

Character.—The formation consists mainly of compact drab-colored, finely crystalline magnesian limestone, the greater part of which contains a large percentage of quartz sand. The limestone is rather heavy bedded and on the surface stands out as hackly ledges. Layers of hard calcareous sandstone several feet thick are intercalated with the limestone. These layers become friable on weathering and are then not unlike the weathered exposures of the underlying St. Peter sandstone.

Good sections of the formation, one of which is given on page 6, are exposed at many places in the Harrison quadrangle.

Fossils and correlation.—*Psiloconcha senecta* (Sardeson), a few specimens of which were procured by E. O. Ulrich from the lower part of the formation near Guion, Ark., on White River, about 65 miles east of the Harrison quadrangle, is the only species thus far found in the Joachim limestone in northern Arkansas. This is one of a number of fossils described by F. W. Sardeson from the St. Peter sandstone in Minnesota. So far as we may rely on this rather meager paleontologic evidence the Joachim limestone does not differ greatly in age from the St. Peter in the upper Mississippi Valley. This relationship is further indicated by the lack of visible evidence of an unconformity between the St. Peter and the Joachim.

As indicated in the correlation table on page 21 the Joachim limestone is equivalent to the lower part of the Izard limestone. The typical exposures of that formation in the southern part of Izard County show that its lower and more or less magnesian and sandy part grades downward without evidence of interrupted sedimentation into typical St. Peter sandstone. Moreover, the lower magnesian part is separated from the upper, fine-grained, nearly pure limestone part by a stratigraphic break. This break evidently is partly represented in Arkansas by the Jasper limestone, which is of either Chazy or older age. The break seems also to represent the time required to lay down several thousand feet of deposits of Chazy age in the Appalachian Valley, as is indicated by the fact that the fossils of the upper division of the Izard in the typical outcrops consist almost entirely of well-known early Black River species.

Stratigraphic relations.—The formation rests conformably upon the St. Peter sandstone and is overlain by the Jasper limestone. The contact with the Jasper limestone is somewhat irregular and may represent an unconformity. At most places the later formations of Ordovician age are lacking, so that the Sylamore sandstone member, of Devonian age, or the St. Joe limestone member, of Carboniferous age, rests upon the Joachim limestone.

JASPER LIMESTONE.

Definition.—The Jasper limestone receives its name from Jasper, in the southern part of the Harrison quadrangle, where it is well exposed. This formation was described in the reports of the Geological Survey of Arkansas as the Izard limestone, though, according to E. O. Ulrich, the Izard at the type locality consists of the Joachim limestone and the Plattin limestone, which are separated by a stratigraphic break that is partly represented in Arkansas by the Jasper limestone. The formation consists in part of interbedded limestone and sandstone but chiefly of limestone, and it ranges in thickness from a few inches to 50 feet, the thickest exposure being at Jasper.

Distribution.—The Jasper limestone occurs in the Harrison quadrangle along Little Buffalo Fork and its tributaries from Jasper to its confluence with Buffalo Fork of White River and thence southeastward along Buffalo Fork and its tributaries to the border of the quadrangle. Elsewhere along Buffalo Fork this limestone occurs only in patches. It is not exposed in the Eureka Springs quadrangle. The outcrops are in most places on steep slopes just below the low escarpment produced by the overlying St. Joe limestone.

Character.—The formation consists of limestone interbedded with a subordinate though considerable amount of sandstone. The limestone is even bedded and occurs in layers ranging in thickness from a few inches to 4 feet. It is grayish blue, noncrystalline, and has a conchoidal fracture and a homogeneous texture, except that it contains numerous minute cavities filled with colorless calcite crystals. In places it has yielded a few fossils. The sandstone layers, some of which are 5 feet thick, occur throughout the formation but are most abundant and thickest near its base. In fact, the basal bed of the formation is sandstone ranging in thickness from 8 to 20 feet. This sandstone is white and friable, is made up of rounded translucent quartz grains, and lacks the fine lamination and cross-bedding that are so prominent in the St. Peter and the Kings River sandstones.

The following section of the Jasper limestone is exposed on the bluff a quarter of a mile east of Jasper:

Section of Jasper limestone one-fourth mile east of Jasper.

	Feet.
St. Joe limestone member of the Boone limestone:	
Pink to red or gray even-bedded, coarsely crystalline limestone, the thickest layers measuring 20 inches. The lowest layer contains black pebbles that are probably phosphatic	50
Sylamore sandstone member (?) of the Chattanooga shale:	
Rusty to white pitted sandstone containing phosphatic pebbles embedded in top of the uppermost layer	4
Jasper limestone:	
Compact, finely crystalline bluish-gray limestone, in which are numerous minute cavities filled with colorless calcite. The layers range in thickness from a few inches to 4 feet	30
Friable white sandstone in layers 2 feet or less thick and a few thin layers of bluish-gray noncrystalline limestone like that above; separated from the Joachim limestone below by a rather indistinct irregularity	20
Joachim limestone:	
Sandstone and dark, more or less sandy limestone to water's edge of Little Buffalo Fork.	

Fossils and correlation.—As a rule fossils occur rather sparingly in the Jasper limestone. At some places, however, as in the vicinity of Jasper and at a point about 4 miles southwest of Yardelle, certain layers are crowded with shells of various kinds. The fauna so far collected comprises the following species:

Girvanella sp., subglobular, an inch in diameter.
Scolithus sp., tubes about 1 millimeter in diameter.
Psiloconcha sp., short, subquadrate in outline.
Psiloconcha (Whiteavesia ?) sp., small and relatively short.
Whiteavesia ? sp., small, longer than the preceding shell.
Helicotoma sp. undet.
Raphistomina sp., apparently same in Everton limestone.
Plectoceras aff. P. jason (Billings).
Leperditia n. sp., valves rather large, compressed convex.
Leperditia (Isochilina ?) n. sp., small, surface punctate.
Leperditella sp. undet.

As stated above, the Jasper limestone has heretofore been called the Izard limestone. Prior to the discovery and study of the foregoing fossils it was supposed to correspond to the upper or Plattin division of the Izard. But the fossils show that it does not, for none of them is found in either the upper or the lower of the two formations into which it has been found desirable to divide the Izard limestone of the sections in Izard and Independence counties on which the geologists of the Geological Survey of Arkansas based this composite formation. In the typical outcrops the Izard consists of a lower, more or less magnesian limestone that corresponds to the Joachim limestone and an upper finer-grained pure dove-colored limestone that corresponds to the Plattin limestone of Missouri. The Jasper limestone evidently belongs in the hiatus between these two divisions of the typical Izard. It overlies the Joachim and, judged by its fossils, it is almost certainly older than the Plattin.

The apparent stratigraphic position of the Jasper limestone suggests that it is of Chazy age, but the fossils offer no satisfactory warrant for this correlation. On the other hand, they seem to show beyond question that the formation is older than the Plattin. Perhaps, as suggested by the presence of *Raphistomina*, which is found in great numbers in the Everton limestone, the Jasper represents a final stage of the series of deposits consisting of the Joachim limestone, the St. Peter sandstone, and the Everton limestone, which, according to E. O. Ulrich, represent a time interval between the Beekmantown and the Chazy of the New York section.

Stratigraphic relations.—The Jasper limestone rests upon the Joachim limestone, though an unconformity between the two is suggested by their somewhat irregular contact. The next formation in order above the Jasper limestone is the Fernvale limestone, which is exposed at only one locality in the quadrangles and there the contact between the two is concealed. At most places the succeeding Ordovician formations are lacking and the Sylamore sandstone member or the St. Joe limestone member rests upon the Jasper limestone.

UPPER ORDOVICIAN SERIES.

FERNVALE LIMESTONE.

Character and distribution.—The Fernvale limestone consists of light-gray, coarsely crystalline, highly fossiliferous limestone that is evenly bedded in layers not exceeding a few inches in thickness. In the quadrangles described it is exposed at only one locality, a mile northeast of Jasper, where it outcrops for about 100 yards at the water's edge on the north side of Little Buffalo Fork. This exposure shows only 5 feet of the top of the formation. The entire thickness, however, probably does not greatly exceed that amount.

The Fernvale limestone was named by C. W. Hayes and E. O. Ulrich from Fernvale, Williamson County, Tenn., where it is well exposed. This limestone has been known in Arkansas as the Polk Bayou limestone, but according to Ulrich the Polk Bayou at the type locality consists of two formations, the Kimmswick limestone below and the Fernvale limestone above, separated by an unconformity representing the time interval of the Lorraine and the Trenton.

Fossils and correlation.—The fossils from the Fernvale near Jasper belong to many species, and most of them are in a good state of preservation. In fact the Fernvale contains more fossils and a larger fauna than any other pre-Mississippian formation in northwestern Arkansas. In a few hours' search specimens representing no less than 46 species were collected.

The following selection gives a fair idea of the fauna:

Barrel-shaped columnals of an undescribed crinoid.	Strophomena planodorsata Winchell and Schuchert.
Crepipora hemispherica Ulrich.	Plectambonites praecosis Sardeson.
Anaphragma mirabile Ulrich and Bassler.	Parastrophia divergens Hall and Clarke.
Phaenopora wilmingtonensis Ulrich.	Rhynchotrema capax (Conrad).
Crania n. sp.	Trochoceras? baeri Meek and Worthen.
Orthis cf. O. laurentina Billings.	Isotelus n. sp. related to I. jacobus Clarke.
Plectorthis whitfieldi (Winchell).	Onchometopus cf. O. susae (Calvin).
Dalmanella porrecta Sardeson.	Sphaerocoryphe maquoketensis Slocum.
Dinorthis subquadrata Hall.	Cyphaspis sp.
Dinorthis proavita Winchell and Schuchert.	Proetus sp.
Herbertella insculpta Conrad.	Arges n. sp.
Rafinesquina n. sp.	Pterygometopus larrabee Slocum.
Strophomena cf. S. cardinalis (Whitfield).	

All these species have been found at one or more localities in Oklahoma, Missouri, Tennessee, Illinois, Iowa, and Minnesota, in beds regarded as representing the Fernvale formation of middle Tennessee. In Tennessee the Fernvale is the second formation of the Richmond group, the Arnheim shale of that group lying under it, but in areas immediately adjacent to Mississippi River, as well as in Oklahoma, it is as a rule the first deposit of Richmond time.

Stratigraphic relations.—The Fernvale limestone presumably rests unconformably upon the Jasper limestone and is unconformably overlain by the Cason shale. Figure 10 is a diagrammatic section representing the occurrence of the Fernvale

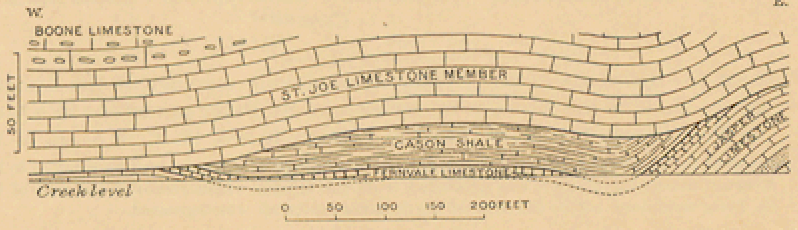

FIGURE 10.—Diagrammatic section showing the probable stratigraphic relations of the Cason shale and Fernvale limestone to the St. Joe limestone member of the Boone limestone and to the Jasper limestone, on Little Buffalo Fork, 1 mile northeast of Jasper. The beds in this locality are only partly exposed.

Both edges of the upturned Fernvale limestone and Cason shale are shown as completely overlapped by the St. Joe member.

limestone and the Cason shale at the locality named. As may be seen from the figure, they occupy a pre-Carboniferous syncline, from which they were not removed during the long period of erosion that probably lasted from the time of the deposition of the Cason shale, at the close of the Ordovician, to the deposition of the St. Joe limestone, at the beginning of the Carboniferous.

CASON SHALE.

Definition and character.—The Cason shale was named by H. S. Williams from the Cason tract in the manganese ore district near Batesville, Ark., where it is typically developed.[1] The term is applied to a calcareous shale with a basal conglomerate, the whole formation aggregating a little more than 21 feet in thickness at the single exposure in the quadrangles. This exposure is in a low bluff at the water's edge of Little Buffalo Fork, a mile northeast of Jasper, in the Harrison quadrangle, where the Fernvale limestone, just described, is also exposed. A stratigraphic break separates it from the overlying St. Joe limestone and from the underlying Fernvale limestone, which, with the Cason, represents Richmond time in the area. The relation of this shale to these two formations is diagrammatically represented by figure 10.

The following section is well exposed at this locality:

Section of Cason shale on Little Buffalo Fork, 1 mile northeast of Jasper.

	Ft.	in.
Boone limestone:		
St. Joe limestone member (thin-bedded pinkish-gray limestone).		
Cason shale:		
Bluish and greenish-yellow platy shale, calcareous in the least-weathered parts	20	0
Argillaceous platy drab limestone, the base of which contains some pebbles	1	0
Greenish platy shale		3
Conglomerate consisting of round sand grains and dark fossiliferous phosphatic pebbles embedded in a ferruginous and manganiferous earth	0–1	
Fernvale limestone:		
Gray fossiliferous, coarsely crystalline limestone to edge of water in Little Buffalo Fork		5

The basal conglomerate is a ferruginous phosphatic earth containing some manganese oxide, a few rounded translucent quartz sand grains, and some dark phosphatic pebbles containing a good many fossils. It ranges from a feather edge to a bed 12 inches thick. The next layer above is composed of 3 inches of greenish shale and is overlain by a layer of platy greenish argillaceous limestone, in which are a few pebbles derived from the earthy bed below. Above these beds

[1] Williams, H. S., On the age of the manganese beds of the Batesville region of Arkansas: Am. Jour. Sci., 3d ser., vol. 48, pp. 326-329, 1894.

is the bulk of the formation, consisting of 20 feet of fissile bluish and greenish-yellow shale, which splits into rough plates of uneven thickness. Before weathering the shale is a greenish-gray argillaceous limestone like the layer of limestone near the base of the formation.

Fossils and correlation.—Organic remains are by no means generally distributed through the Cason shale, but the phosphatic basal conglomerate contains fragmentary fossils in many places, with here and there more complete remains of what seems to have been a rather large fauna. One of the best localities for collecting these fossils is near Jasper. Another is at the phosphate mines near Cushman, in Independence County. On account of their fragmentary condition the specific identification of the fossils is usually difficult. The following list gives a fair conception of the fauna so far as determined:

Calloporella sp.	Dalmanella aff. D. testudinaria (Dalman).
Leptobolus occidentalis Hall.	Camarotoechia aff. C. neglecta (Hall).
Leptobolus sp., more nearly triangular than the preceding.	Cyrtodonta? sp.
Lingulops? sp. subovate, 6 millimeters in length.	Cyclora sp.
Lingula? sp., very short, almost circular.	Coleolus iowensis? James.
Schizotreta cf. S. pelopea (Billings).	Orthoceras sp., an inch in diameter.
Strophomena sp.	Orthoceras cf. O. socialis Hall.
	Calymene mammillata Hall.
	Pterygometopus? sp.

Of these fossils *Leptobolus occidentalis*, a small shell that is one of the most characteristic fossils of the lower part of the typical Maquoketa shale in Iowa, is perhaps the most significant as a means of stratigraphic correlation. Other species of the list tend to confirm this suggested correlation. As now used, however, the term Maquoketa is too comprehensive to justify its adoption in Arkansas in place of Cason. The Cason shale is the second formation of Richmond age in Arkansas, just as the Maquoketa shale is in the Mississippi Valley proper.

DEVONIAN SYSTEM.

The strata assigned to the Devonian system consist of shale, sandstone, and limestone, which are comprised in two formations, the Clifty limestone, of Middle Devonian age, and the Chattanooga shale, with the Sylamore sandstone member, of Upper Devonian age.

MIDDLE DEVONIAN SERIES.

CLIFTY LIMESTONE.

Definition and distribution.—The Clifty limestone is named from East Fork of Little Clifty Creek, in the Eureka Springs quadrangle, where, within an area not exceeding half a square mile, all its known exposures are found. The formation is a bed of limestone that is nowhere more than 2½ feet thick.

Character.—The best observed section of the formation is at the head of a large ravine on the north side of the stream, on the west side of the SW. ¼ sec. 17, T. 19 N., R. 27 W., where it occurs in its maximum thickness. The lower 1½ feet is gray compact laminated and cross-bedded limestone containing a few fossils and a large amount of quartz sand, the grains of which are rounded and translucent. The upper 12 inches is compact light bluish-gray limestone, which has a conchoidal fracture and contains a small amount of sand like that in the bed below. The upper bed was observed only for about 100 yards along the slope of the large ravine indicated above, where the following section was measured:

Section of Clifty limestone on East Fork of Little Clifty Creek, in the SW. ¼ sec. 17, T. 19 N., R. 27 W.

	Ft.	in.
Chattanooga shale:		
Black fissile shale	40	0
Sylamore sandstone member; friable coarse-grained white to brown sandstone, pitted on surface	4	0
Clifty limestone:		
Compact, slightly sandy, light bluish-gray limestone, breaking with conchoidal fracture	1	0
Sandy laminated cross-bedded gray limestone in which are a few fossils	1	6
Everton limestone:		
Kings River sandstone member; friable laminated, somewhat cross-bedded saccharoidal sandstone, forming low escarpment on the bench above which the overlying beds are exposed	15	0
Powell limestone:		
Fine-grained gray magnesian limestone.		

Fossils and correlation.—The basal 18 inches of the Clifty limestone at the only locality in northern Arkansas at which rocks of this age have been found contains a small but highly characteristic Middle Devonian faunule. The matrix is hard and the fossils are therefore somewhat difficult to prepare for determination. Altogether some 10 or 12 species are represented. Of these *Spirifer fornacula* Hall, *Spirifer audaculus* Conrad, *Tropidoleptus carinatus* Conrad, and *Homalonotus dekayi* Green are positively identified, and *Spirifer sculptilis* Hall, *Coleolus tenuicinctum* Hall, *Tentaculites scalariformis* Hall, and *Proetus rowi* (Green) are identified with some doubt. The remaining species are brachiopods and gastropods that resemble forms commonly found in association with the fossils named; at least their testimony does not in any way invalidate that of the others. On the evidence afforded by these fossils the Clifty limestone is therefore confidently assigned to the age of the Hamilton shale of the New York section. More exactly correlated it is of the age of the Sellersburg limestone of Indiana.

Stratigraphic relations.—The Clifty limestone rests upon the even surface of the Kings River sandstone member, but the two are separated by a break that represents a period of erosion lasting probably through middle and late Ordovician, Silurian, and early Devonian time. It is overlain by the Sylamore sandstone member, from which it is separated by a stratigraphic break. There is, however, no marked physical evidence of the true stratigraphic relations of these members except that afforded by the overlap of the Sylamore upon the Kings River member.

UPPER DEVONIAN SERIES.

CHATTANOOGA SHALE.

Definition.—The Chattanooga shale was named by C. W. Hayes from Chattanooga, Tenn., where it is well developed, but the name was not used in northern Arkansas until 1905, when it was applied by G. I. Adams and E. O. Ulrich to the late Devonian sandstone and shale in the Fayetteville quadrangle.[1] The formation in the Eureka Springs and Harrison quadrangles, as in the Fayetteville, consists of shale and a basal member known as the Sylamore sandstone, this name having been taken by J. C. Branner from Sylamore Creek in Stone County, Ark. The formation has also been called "Sylamore formation," "Eureka" shale, and "Noel" shale.

Distribution and character.—The Chattanooga shale occurs in the northern half of the Eureka Springs quadrangle and on the northwestern border of the Harrison quadrangle. It is conformable with but not coextensive with the Sylamore sandstone member. In the northwestern part of the Harrison quadrangle and the northern part of the Eureka Springs quadrangle it overlaps the Sylamore, and in the southern and eastern parts of the quadrangles it is not present where the sandstone is exposed. It is best developed along War Eagle Creek at the western border of the Eureka Springs quadrangle, where 50 feet of it is exposed, without, however, disclosing the Sylamore beneath. From War Eagle Creek it thins toward the north and east. Its thickness along the northern part of the Eureka Springs quadrangle is 5 to 8 feet. In the northeastern part of the quadrangle and in the vicinity of Eureka Springs it is 5 to 6 feet thick. It occurs on the north slope of Pension Mountain but is absent farther south, along Rockhouse and Piney creeks and their tributaries. Its outcrop is generally a narrow band on the hill slopes and appears just below the escarpment produced by the St. Joe limestone and above the small bench produced by the Sylamore sandstone or possibly other underlying resistant beds. It is exposed at many places, but along most of its outcrop it is covered with residual material and débris derived from the overlying Boone.

Where the shale is thickest the lower and greater part of it is black carbonaceous, thinly fissile clay shale, which weathers into thin flakes and rattles as one walks over it. It is intersected by numerous straight and clean-cut joints. Its upper part is dark to brown, in places contains sandy streaks that are phosphatic, is less fissile than the lower part, weathers into prismatic blocks irrespective of bedding, and contains pyrite. Where the lower part is absent and the upper part rests upon the Sylamore sandstone the surface of the sandstone is at many places thickly set with crystals of pyrite.

Sylamore sandstone member.—The Sylamore sandstone is widespread over the quadrangles, being exposed along the larger streams and many of the smaller ones in the Harrison quadrangle and in the northern two-thirds of the Eureka Springs quadrangle. At several places in the southern part and in the northwest corner of the Harrison quadrangle it is not found, and in the knobs along the northern border of the Eureka Springs quadrangle it is either wanting or occurs in a single layer an inch or so thick. At most places it caps a low escarpment and produces a narrow bench on which the black shale of the Chattanooga is exposed.

Some of the sandstone mapped as Sylamore in parts of the Eureka Springs and in much of the Harrison quadrangle, where it is not overlain by the shale of the Chattanooga, may possibly be of lower Mississippian age. If it is Mississippian the sandstone in such areas, like the Sylamore in areas where it is overlain by the shale, is composed of sand picked up from sandy beds that immediately underlie it. Such sand would have been spread along the bottom of the Mississippian sea as the shore line advanced over the base-leveled land area. But as sandstone has nowhere been found in the quadrangles immediately above the Chattanooga shale, and as this sandstone is apparently continuous with the Sylamore, it is referred to the Sylamore.

The Sylamore sandstone is generally 2 to 5 feet thick, but at some places within a short distance it changes in thickness from a few inches to several feet. It consists typically of one or more massive beds, but it is locally thin bedded. It is composed of white to yellow and in places of mottled-brown medium to coarse grained friable sandstone. The sand grains are well rounded and translucent, and in places it contains small particles of limonite derived from pyrite. Oval phosphatic pebbles, some as large as walnuts, are here and there cemented to its top surface, and a few such pebbles lie in and between the layers of sandstone. The pebbles are yellow to brown on the outside but on fresh surfaces are black. At some places thin layers of the sandstone contain a small amount of disseminated black phosphatic material. In the Eureka Springs quadrangle the sandstone contains pieces of chert that look like waterworn pebbles, but many of these pieces are so irregular that they can not be so classed. Exposed upper surfaces of the sandstone show numerous small pits, and the under surfaces of overhanging ledges are similarly pitted, from the dropping out of loose material.

The phosphatic pebbles, conglomerate, and limonite are characteristic of this sandstone, but they are not found at some places, and at these places it is difficult to distinguish the rock from the St. Peter and the Kings River sandstones, upon either of which it may rest. Under such conditions it must be identified by less prominent differences, such as those of color, size of grain, and rate of weathering. As a rule, the Sylamore sandstone is not so white as the other two sandstones and weathers with more rounded edges. Other differences are the absence from the Sylamore of the cross-bedding and fine lamination that are characteristic features of the other sandstones.

The sand of this member was derived mainly from the St. Peter and the Kings River sandstones, though some of it was doubtless derived from sandstone in the Joachim and Jasper limestones and in limestone of the Everton, which overlies the Kings River.

Fossils and correlation.—Aside from a small *Lingula*, which may not be specifically distinguishable from *L. spatulata* Hall of the Genesee shale of New York and which is much like *L. melie* Hall of the Sunbury shale of Ohio, and from some forms that have minute denticulated jaws and are known as conodonts, the Chattanooga shale has yielded no invertebrate fossils. Both the *Lingula* and the conodonts are characteristic fossils of the Chattanooga shale in Tennessee. The only other fossil collected from this formation in Arkansas is an imperfect fish bone about 5 inches long, 2 inches wide, and possibly half an inch thick, which may be one of the mandibles of a species of *Dinichthys*. The specimen is embedded in a piece of sandstone from the Sylamore, found at the base of the member in the adjoining Yellville quadrangle, near Duff, Ark. Bones of apparently the same fish occur in a phosphate bed at the base of the Chattanooga shale in Tennessee.

Lithologically the Chattanooga shale agrees very closely with the formation of the same name in Tennessee and adjoining States. As the evidence furnished by the fossils is in entire accord with the correlation thus suggested, the practice of using the same name for the black shale and the sandstone in Arkansas seems fully warranted. There is some legitimate difference of opinion as to whether the formation should be classed as late Devonian or earliest Mississippian, but in this folio it is classed as Devonian.

Stratigraphic relations.—The Chattanooga shale is unconformable with the formations upon the eroded surfaces and truncated edges of which it rests, but the contact is only slightly irregular. In the southern part of the Harrison quadrangle it rests upon the Jasper limestone where that is present; elsewhere it rests upon the Joachim limestone and the St. Peter sandstone. It overlaps northward and westward upon the St. Peter sandstone, the Everton limestone, the Powell limestone, or the Cotter dolomite, its position depending on the amount of local erosion that preceded its deposition.

The absence of the shale of the Chattanooga formation from the southern and eastern parts of the area in which the Sylamore sandstone member outcrops is thought to be due to erosion that resulted from a slight elevation of those parts.

CARBONIFEROUS SYSTEM.

GENERAL FEATURES.

The rocks of the Carboniferous system in the area are divided into two series—the Mississippian below and the Pennsylvanian ("Coal Measures") above. These names are taken from the Mississippi Valley and Pennsylvania, respectively, the regions in which the two series are typically developed. In the Eureka Springs and Harrison quadrangles the Mississippian series includes the Boone limestone, the Batesville sandstone, the Fayetteville shale, and the Pitkin limestone, and the Pennsylvanian series includes the Hale formation, the Bloyd shale, and the Winslow formation. Only the lower part of the Pennsylvanian series is exposed in the quadrangles, but higher rocks, which are coal bearing over considerable areas, are widely distributed in the Arkansas Valley, farther south.

MISSISSIPPIAN SERIES.

BOONE LIMESTONE.

Definition. — The Boone limestone consists of chert and limestone varying in amount horizontally as well as vertically.

[1] Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (No. 119), 1905.

It comprises strata of Kinderhook, Osage, and Warsaw age. At the base of the formation there is a persistent and conspicuous limestone that is mapped and described as the St. Joe member. This member was named by J. C. Branner, from St. Joe, Ark., where it is typically exposed and where it was first studied by the Geological Survey of Arkansas.[1]

The formation is named from Boone County, Ark., most of which is included in the Harrison quadrangle, the name having been first applied to it by J. C. Branner, though it was introduced into geologic literature by F. W. Simonds[2] and R. A. F. Penrose[3] in their reports, that appeared simultaneously in 1891. H. S. Williams[4] has used the name "Carrollton limestone" for the gray limestone exposed in the cliff half a mile west of Carrollton, in the Harrison quadrangle, where 90 feet of more or less cherty limestone at the top of the Boone is exposed. In Missouri these limestones, besides being called Boone, have generally been termed Burlington or Keokuk. The Fern Glen limestone on the eastern flank of the Ozark region is the equivalent of the St. Joe and certain overlying beds exposed on War Eagle Creek in the Eureka Springs quadrangle. An oolitic limestone near the top of the formation in the Joplin district has been described by C. E. Siebenthal as the Short Creek oolite member, and a heavy chert bed about 100 feet below it as the Grand Falls chert member.[5] These two members are probably represented in places in the Eureka Springs and Harrison quadrangles by beds of similar lithology and stratigraphic position, the Short Creek oolite member by an oolitic limestone near the top of the formation and the Grand Falls chert member by some part of the chert beds beneath the oolite.

The thickness of the Boone, not including the St. Joe member, is generally 300 to 350 feet, but near Ponca, in the southern part of the Harrison quadrangle, it is about 400 feet.

Distribution and surface form.—The Boone limestone is the surface rock over a larger area within the quadrangles than is occupied by any other formation. In the Harrison quadrangle it outcrops over a broad, irregular belt that extends northwestward across it a little north of the center. In the area northeast of this belt and along Buffalo Fork of White River and its tributaries in the southeast corner of the quadrangle the exposures consist of outliers or of branching tonguelike areas that occupy the crests of the hills. In the area west of this belt the formation usually outcrops in narrow bands along the streams and at only a few places does it occur as outliers or inliers. It is exposed over considerable areas in the central and northwestern parts of the Eureka Springs quadrangle. Elsewhere in this quadrangle the outcrops are less extensive and lie along the hills in the northern part and in the valleys in the southern part.

The outcrops of the Boone over a large part of the quadrangles are dissected by narrow valleys, most of which are canyon-like; but inland from the larger streams the surface is less broken and is gently rolling, as about Hindsville, Oak Grove, Harrison, Gaither, Elmwood, and Bellefonte. In the northern part of both quadrangles and in the southeast corner of the Harrison, where the streams have cut through the Boone into underlying rocks, its outcropping edges form a steep slope known as the Eureka Springs escarpment. This escarpment is probably most conspicuously developed east of Eureka Springs, where it forms a highland rim that practically surrounds the basin-like area in which Berryville is situated; elsewhere it is, as a rule, equally high but less steep or less rugged in outline than about Berryville. Though the areas of this formation are rather densely forested, except where cleared, rock exposures are abundant in all parts of the quadrangles.

If the valleys that have been cut into the Boone were refilled to the level marked by the crests of the highest hills composed of this formation, the result would be a remarkably even structural plain. Practically the only hills or mountains that would rise above it would be the Boston Mountains and a few hills of circumdenudation made up of formations overlying the Boone.

Character.—The Boone limestone, exclusive of the St. Joe member, which will be described under a separate head, consists of limestone, cherty limestone, and chert, the last two predominating. The relative proportions of chert and limestone differ both horizontally and vertically, but as a rule the limestone is found mainly at the top, at the middle, and at the base of the formation and increases in amount from the northern to the southern parts of the areas. In the E. ½ sec. 13, T. 16 N., R. 22 W., the entire formation consists of limestone containing only a little nodular chert, but this is the only exposure of that kind observed. Where best developed, the limestone is 100 feet or more thick, and that thickness may be reached in any part of the formation. Near Ponca, in the Harrison quadrangle, the limestone in the upper half is 180 feet thick. On the mountain south of Cecil Creek, northwest of Jasper, the limestone in the middle is 100 feet and that at the top is 75 feet thick. Near Willcockson, also in the Harrison quadrangle, the limestone in the lower part ranges in thickness from 90 to 200 feet and contains little or no chert. Farther north and west in the quadrangles a persistent bed of limestone 40 to 60 feet thick occurs near the middle, and here and there considerable limestone occurs at or near the top. The beds consist of gray compact, very pure limestone, ranging from finely to coarsely crystalline and containing only a little chert. Most of the beds are massive and vary in thickness from 1 foot to more than 3 feet. Fossil crinoid stems are numerous; brachiopods and other marine shells less so. North of Jasper, in the Harrison quadrangle, a bed of massive pink limestone occurs 50 feet above the top of the St. Joe member.

An oolitic limestone near the top of the formation was observed at Kingston, in the Eureka Springs quadrangle, and at Burlington and Carrollton, in the Harrison quadrangle. This is probably the equivalent of the Short Creek oolite member, which is widely distributed in southwestern Missouri and northeastern Oklahoma. The bed ranges in thickness from 7 to 15 feet and consists of compact light-gray limestone made up of small round oolitic grains. Where it is exposed in bluffs it shells off parallel to the surface, thus producing a concave face between projecting ledges above and below. The following section at Carrollton, where this oolitic limestone is well exposed, is compiled from notes by P. V. Roundy and R. D. Mesler:

Section of Boone limestone on bluff half a mile west of Carrollton.

	Feet.
Batesville sandstone:	
Brown sandstone.	
Hindsville limestone member (fossiliferous, rather massive gray limestone)	15–20
Boone limestone:	
Even-bedded gray limestone, interbedded with chert which increases toward the top, where it predominates	55
Oolitic light-gray limestone, the upper 6 feet of which shells off parallel to the weathered surface and forms a concave face (Short Creek oolite member ?)	7½
Light-gray to dark-gray hard heavy-bedded limestone to base of bluff	30

The limestones of the Boone above the St. Joe member are nearly pure calcium carbonate. They are very soluble in ground water and contain many underground drainage systems and caves. Sink holes are of common occurrence in areas where the limestones are the surface rock. Prospects in this part of the formation exhibit fissures and enlarged joints filled with red clay and chert boulders. In some places this material is cemented together with stalactite and stalagmite deposits. A fissure containing red clay and like deposits, in which are embedded bones of Pleistocene mammals, is found 4 miles west of Willcockson, in the Harrison quadrangle. It is known as the Conard fissure, and in it were found, in addition to others previously known, two new genera and 20 new species of mammals, which have been described by Barnum Brown.[6] The upper surface of the limestone is likewise covered with a mantle of red clay and residual chert, the clay occurring in greatest quantity over the more level areas, as about Spring Valley, Whitener, Hindsville, Oak Grove, Harrison, Gaither, Elmwood, and Bellefonte.

Chert occurs in all parts of the formation above the St. Joe member but is the principal rock near the middle or lower parts of this division of the Boone. The vertical transition from beds of limestone to beds that are composed wholly or mainly of chert is everywhere gradual, by increase of the one and decrease of the other. In some layers of limestone the chert occurs in nodules that are widely separated; in others the nodules are in part united; in still others the chert is sufficiently abundant to form a sheet or lens in the middle of the layer. At many places it occurs as successive layers. Sections 100 feet thick or more, some of them exposed in the vertical and picturesque bluffs along the largest streams of the area, are composed wholly of chert. The chert where unaffected by weathering is dense, hard, compact, and brittle, has a more or less perfect conchoidal fracture, and is white or light gray, but at some places it is blue, green, or black and has the waxy luster of chalcedony. The compact variety, which breaks with a conchoidal fracture, was extensively used by the Indians for making stone implements, some of which may still be found here and there in the quadrangles, especially in the bottom lands.

Near the top of Pension Mountain and around the whole western part of it there is a heavy ledge of chert, the base of which is about 80 feet above the St. Joe member. It is much jointed and full of irregular cavities (the largest about 14 inches long and 2 inches wide with its greater dimension horizontal), yet it is firm and holds together well enough to produce a bluff 12 feet high. At many places the chert contains calcium carbonate or secondary quartz in small pockets or joints. A noteworthy occurrence of such quartz is on Crystal Mountain, 4 miles southwest of Green Forest, where it is found in numerous short crystals ranging from microscopic size to a diameter of an inch or more. The mountain takes its name from these crystals.

Great quantities of the chert are left as a residue on the surface by the solution of the limestone by ground water. (See Pl. IX.) From the chert itself is removed whatever calcium carbonate it originally contained, together with more or less of its silica, so that much of it is porous and spongy, though a great deal still remains compact. The weathered parts are generally white, gray, brown, or yellow, their color depending mainly on the amount of iron oxide they contain. The chert in places contains many fossils, which occur as perfect siliceous casts from which the calcium carbonate of the original organic remains has been leached and as siliceous bodies in which the original calcium carbonate has been replaced by silica. Changes of temperature cause the chert to break into small fragments, which collect in great quantities and form a good natural macadam along such roads as follow the base of the slopes.

Most of the silica that forms the chert was probably deposited contemporaneously with the calcareous material that forms the limestone, but some of it may have been introduced from outside sources and may have replaced the limestone, though there appears to be no possible source for so much silica. The minimum estimate of the quantity of chert in the two quadrangles before any was removed by erosion—and these quadrangles are only a small part of the area occupied by the formation in the Ozark region—is 52 cubic miles. This estimate and the fact that the great mass of chert is confined to definite parts of the formation seem to indicate the contemporaneous deposition of the silica and the calcium carbonate for at least the most siliceous part of the formation. If most of the silica was deposited with the limestone the silica composing the nodules and sheets in the layers of limestone was apparently concentrated in such forms from the general mass of the limestone through the agency of ground water, the silica replacing much of the calcium carbonate. The bedded cherts were probably for the most part siliceous deposits and thus owe their present nature only in small part to segregation. The silica could have been laid down contemporaneously with the limestone-forming material (1) as fine-grained detrital quartz, (2) as a deposit derived from organic remains, or (3) as a deposit by chemical precipitation in colloidal form. The purity of the limestone leads the authors of this folio to attribute the silica to one or both of the two sources last indicated. Sponge spicules have been recognized in the chert at only a few places in the Ozark region, and the apparent general absence of these spicules and of other siliceous tests is adverse to but does not disprove the assumption of its organic origin, for such remains would have been largely or wholly destroyed by the partial crystallization of the silica and its segregation by ground water. The fact that silica of organic origin is more soluble than that of chemical origin inclines one to consider siliceous organisms the most probable source of the silica.

St. Joe limestone member.—The St. Joe limestone, though comparatively thin, is one of the most persistent and conspicuous beds in the quadrangles. It is at no place absent, and it is exposed in the northern two-thirds of the Eureka Springs quadrangle and in most parts of the Harrison quadrangle, its outcrop generally occurring in the Eureka Springs escarpment, whose upper part contains the overlying cherty beds of the Boone. The member generally stands out on this escarpment as a low bluff produced in part by the undermining of the Chattanooga shale by weathering and in part by the rapid weathering of the lower part of the St. Joe itself, which causes the beds to project in overhanging layers. (See Pl. VII.) Some ledges break down into large slabs and blocks, which lie on the slope below. Beneath the jutting ledges of the shale at many places there are low caves, caused by the breaking down of the limestone along underground water channels, many of which extend upward along joint planes that have been widened by solution.

The thickness of the St. Joe member in the Eureka Springs quadrangle is generally from 20 to 25 feet. In several places it does not exceed 10 feet; in others it reaches 30 feet; in one or two places it reaches 40 to 50 feet. At and near Eureka Springs it is 25 feet thick. The following are some of the exceptions to the usual thickness: At War Eagle, 16 feet; 1 mile east of Jennings Ford on White River, 10 to 12 feet; on the head of West Leatherwood Creek, north of Beaver, and on Brush and Brushy mountains, 15 feet; at Mundell, near Winona Springs, at places southeast of Berryville, and at places on Piney Creek, 30 feet; at the north end of Pension Mountain, 40 feet; and on Piney Creek east of the mouth of Brushy Hollow, 50 feet. In the northern part of the Harrison quadrangle its ordinary thickness is about 30 feet, though in places it is thicker. At Jennings Gap its thickness is 40 feet; at Cisco, 55 feet; at Omaha, 66 feet; at Enon and near the

[1] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, pp. 253–349, 1893.

[2] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, pp. 27–37, 149, 1891.

[3] Penrose, R. A. F., jr., Manganese: its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 129–138, 1891.

[4] Williams, H. S., The Paleozoic faunas of northern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 5, pp. 334–337, 1900.

[5] Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Joplin district folio (No. 148), pp. 2–5, 1907 (reprinted in 1914).

[6] Brown, Barnum, The Conard fissure, a Pleistocene bone deposit in northern Arkansas, with descriptions of two new genera and twenty new species of mammals: Am. Mus. Nat. Hist. Mem., vol. 9, pt. 4, pp. 155–208, 12 pls., February, 1908.

head of McGill Hollow northeast of Omaha, 50 feet; and on Little Walnut Creek southeast of Omaha, 50 feet or more. In the southern part of the quadrangle its thickness ranges from 45 to 60 feet, though it is usually about 50 feet. T. C. Hopkins[1] reports it as 70 feet north of Wells Creek post office and from 40 to 100 feet on Harp, Mill, and Flatrock creeks near Willcockson.

The upper limit of this member is commonly defined by the presence of chert in the superjacent beds but is not marked by any decided variation in the color or the texture of the limestone as it merges into that part of the Boone. In places the succeeding limestone of the Boone is of considerable thickness and is not cherty.

At its northern outcrops this member consists of three well-defined divisions. At most places the upper 10 to 15 feet is massive, even-bedded gray coarse-textured crystalline limestone full of crinoid stems. It is this division that forms the projecting ledge so frequently found in the steep escarpment produced by this member. Below this is about 5 feet of thin-bedded limestone that weathers like shale and is red, gray, or chocolate-colored. The lower division is more massive and resistant than the middle but less so than the upper one, and in places it contains nodules and lenses of gray to chocolate-colored chert some of which are 4 feet long and 6 inches thick.

Near Omaha, where the member measures 66 feet, the mass of the lower and the upper divisions has increased, but the middle division retains the usual thickness. The following section is exposed in the railroad cut beyond the farther end of the first railroad tunnel north of Omaha:

Section of St. Joe limestone member in railroad cut north of first railroad tunnel north of Omaha.

	Ft.	in.
St. Joe limestone member:		
Rather massive gray crystalline limestone, exposed on hill slope	50	0
Red shaly thin-bedded limestone	4	0
Gray, crystalline limestone containing chert beds at base	12	0
Green shale		4
Sylamore sandstone member (?):		
White to rusty sandstone	3	0

Along Buffalo Fork of White River and its tributaries the three divisions mentioned above are less apparent than they are farther north. At most places the limestone is coarsely crystalline, but at others it is compact and very finely crystalline. Most of it is gray, though some is of various shades of red and green. All these colors occur together in some of the layers and produce a mottled effect. Fragments of crinoid stems are very numerous in the limestone. The layers are uniform in thickness and are commonly thin, though some of them are 2 and a few are 4 feet thick, the massive layers occurring locally and near the base. Also near the base there is at some places a layer of dark-bluish to yellow shaly limestone, 3 to 4 feet thick, which is probably the same bed as the similar one in the northern outcrops. Dense chert possessing a conchoidal fracture and a waxy luster and varying in color from place to place through several shades of red, gray, and blue occurs here and there as tabular sheets or nodular masses in the layers of limestone in the upper part of the member. A section of the St. Joe member in the middle of the west part of sec. 29, T. 17 N., R. 20 W., on the Harp Creek side of the hill, is described by T. C. Hopkins[2] as follows:

The St. Joe marble varies in color and texture; the bed is nearly 100 feet thick, the bottom layers, 10 to 15 feet, being shaly, yellow, soft, and crumbling; the next 8 or 10 feet of a purplish-red color, in thin solid slabs from 1 to 3 inches thick, overlying which is the main body, 70 to 80 feet, in strata from 2 to 5 feet thick, varying in color from dark reddish brown to light rose-colored, with some bands of gray. It is nearly all fossiliferous, crinoid stems being the most abundant.

Hopkins states that it was near the half-mile corner on the east side of sec. 30 of the township and range just mentioned that the block was taken for the State offering in the Washington Monument.[3] He describes the marble constituting the ledge from which the block was taken as being about 4 feet thick, of a light-red color variegated with numerous white spots of fossil casts, and of a homogeneous texture. An analysis of a sample from the ledge follows:

Analysis of limestone from the St. Joe member near Willcockson.

[R. N. Brackett, analyst.]

Alumina (Al_2O_3)	0.009
Ferric oxide (Fe_2O_3)	.051
Magnesia (MgO)	.190
Lime (CaO)	55.390
Soda (Na_2O) / Potash (K_2O)	.054
Titanic oxide (TiO_2)	Trace.
Loss on ignition (CO_2, etc.)	43.740
Phosphoric acid (P_2O_5)	.023
Manganese oxide (MnO_2)	.015
Zinc oxide (ZnO) present but not determined.	
Insoluble residue (silica, etc.)	.800
	100.272
Calcium carbonate	98.710

[1] Hopkins, T. C., Marbles and other limestones: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 4, pp. 276–283, 1893.
[2] Idem, p. 278.
[3] Idem, p. 208.

On Davis Creek a quarter of a mile northwest of Yardelle there is an apparent unconformity in what is called the St. Joe, the part above the unconformity consisting of even-bedded pinkish limestone and that below of irregularly bedded limestone in thin plates and massive layers. (See fig. 11.) The lower limestone, 10 feet of which is exposed above the stream,

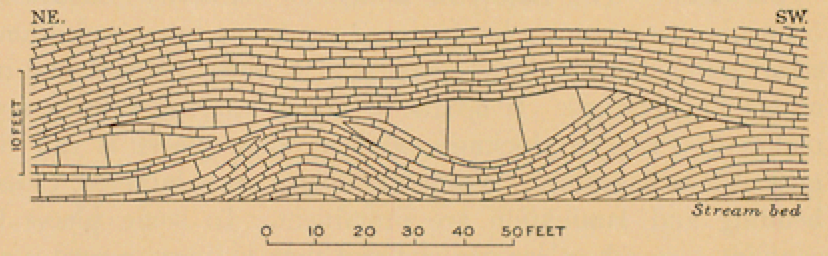

FIGURE 11.—Sketch section showing an apparent unconformity in the St. Joe limestone member of the Boone limestone on Davis Creek, one-fourth mile northwest of Yardelle.

varies in texture from compact and finely crystalline to coarsely crystalline and in color from gray to pink. It contains crinoid stems and brachiopods. That the apparent unconformity between the two beds does not represent a long interval of time is suggested by fossils collected both above and below the stratigraphic break, which, according to G. H. Girty, are markedly similar and indicate Fern Glen age for the limestone. This apparent stratigraphic break is believed to be due to submarine erosion. C. E. Siebenthal, who has studied several similar breaks at and near this horizon in the Wyandotte quadrangle in northeastern Oklahoma and southwestern Missouri, suggests that most of them may have been caused by irregularity of deposition, due to the action of ocean currents, such as occurs in the formation of sand bars.

A somewhat similar though more pronounced unconformity near the base of the Boone exists on War Eagle Creek, at the west side of the Eureka Springs quadrangle. The following section by E. O. Ulrich gives a detailed description of the rocks. A photograph of the exposure is shown on Plate VIII.

Section of the base of the Boone limestone exposed in bluff half a mile northwest of War Eagle post office.

	Feet.
Boone limestone:	
Residual chert of Boone.	
Overlapping, rather massive, medium-grained light-gray limestone, cherty in slope to the west of the bluff but nearly free of chert in the fresh rock of the bluff itself. This bed is Keokuk or Burlington in age, and at its base there is an apparent unconformity	0–45
Very fine grained light bluish, irregularly bedded limestone, interbedded or mixed with calcareous shale. The limestone is largely replaced by flinty chert. Fern Glen fossils, especially Bryozoa, are abundant in both kinds of rock	0–60
Fairly even bedded, very cherty, fine-grained, light dove colored limestone. The chert is flinty and in layers, occurring either as nodules or replacing whole layers of the limestone. The fossils consist chiefly of shells. *Taonurus* zone is in lower part	10–30
St. Joe limestone member, noncherty even-bedded grayish-blue crinoidal limestone of small subcrystalline grain. The upper half has thin shaly partings that contain a few fenestellid Bryozoa	16
Base not exposed.	

Only the lowest bed in this section is identified as St. Joe, because the two overlying beds are lithologically different from the St. Joe elsewhere in the area. This identification places the apparent break not in the St. Joe member, as at Yardelle, but in the beds that overlie that member. The suggestions offered to explain the apparent break at Yardelle and similar phenomena in Oklahoma apply also to this locality. The fossils from the section near War Eagle Creek were obtained in the beds above the St. Joe. They indicate Fern Glen age, which is also the age of the St. Joe itself. The fauna differs somewhat, however, from that of the pink crinoidal limestone of the St. Joe at Yardelle and presents more analogies with certain gray limestone and shaly beds believed to represent the same formation in the Siloam Springs and Wyandotte quadrangles.

Beneath the St. Joe member at a few places lies a thin bed of gray to green clay shale, that breaks into small pieces with conchoidal fracture. It is thickest near War Eagle, where it ranges from 4 to 7 feet, where the lower part is dark gray, and where it includes at its base a thin layer of conglomerate, which is sandy, phosphatic, glauconitic, and ferruginous and contains conodonts. This shale at and near Eureka Springs ranges in thickness from 12 to 18 inches. On Little Clifty Creek, in the Eureka Springs quadrangle, it is 2 feet thick; and north of Omaha, in the Harrison quadrangle, it is reduced to 4 inches.

Fossils and correlation.—The Boone limestone of this area is believed to be equivalent to the Fern Glen, Burlington, Keokuk, and Warsaw limestones of the typical Mississippian section. The lower portion of the Boone, which has been separated from the rest as the St. Joe limestone member, is the equivalent of the Fern Glen limestone, but certain beds, which are known by their fossils to be of Fern Glen age, overlie the typical St. Joe on War Eagle Creek in the Eureka Springs quadrangle. The rest of the Boone is about equally divided between the Burlington and the Keokuk and Warsaw, the part above the oolite now being thought to be equivalent to the Warsaw rather than to the Keokuk, to which it has heretofore been referred. The three divisions of the Boone corresponding to the Fern Glen, the Burlington, and the Keokuk limestones are characterized in a general way by distinctive faunas, but the faunas appear not to change abruptly and they have many species in common.

Some of the more characteristic species of the St. Joe fauna, those which especially show its affinity with the Fern Glen, are listed below:

Cyathaxonia minor.	Brachythyris fernglenensis.
Cystodictya lineata.	Delthyris novamexicana.
Euactinopora sexradiata.	Spiriferina subtexta.
Leptaena analoga.	Cliothyridina prouti.
Chonetes logani.	Hustedia circularis.
Productus sampsoni.	Ptychospira sexplicata.
Camarophoria bisinuata.	Platyceras paralium.
Spirifer grimesi.	

The Boone does not contain typical Burlington and Keokuk faunas. Its faunas lack some of the species that are found in the Burlington and Keokuk of the northern areas and contain some that are not known there. Still other species are common to both areas but appear not to have the same range. However, the Boone does contain some of the diagnostic Burlington and Keokuk species; and, furthermore, the Burlington species occur in the lower half of the Boone and the Keokuk species occur in the upper half. Some of the common and more significant types of fossils found in the lower half of the Boone are listed below:

Cyathaxonia arcuata.	Girtyella booniana.
Cyathaxonia minor.	Camarotoechia aff. C. cooperensis.
Cladochonus americanus.	Pseudosyrinx keokuk.
Orthotetes keokuk.	Spirifer grimesi.
Rhipidomella dubia.	Spiriferella plena.
Schizophoria swallowi.	Brachythyris suborbicularis.
Chonetes illinoisensis.	Delthyris similis.
Chonetes logani.	Cliothyridina incrassata.
Avonia millespinosa.	Cyrtina burlingtonensis?
Productus burlingtonensis.	Platyceras paralium.
Productus levicosta.	

The fossils listed below were found in the upper half of the Boone limestone.

Triplophyllum carinatum.	Reticularia pseudolineata.
Amplexus fragilis.	Camarophoria simulans.
Cladochonus beecheri.	Pseudosyrinx keokuk.
Worthenopora spinosa.	Cranaena? booniana.
Dichotrypa sp.	Spirifer keokuk.
Glyptopora aff. G. plumosa.	Spirifer logani.
Derbya keokuk.	Spirifer rostellatus.
Rhipidomella dubia.	Brachythyris suborbicularis.
Chonetes illinoisensis.	Delthyris similis.
Productus altonensis?	Cyrtina neogenes.
Productus ovatus.	Eumetria marcyi.
Productus semireticulatus.	Myalina keokuk.
Productus wortheni.	Bembexia aff. B. nodimarginata.
Pustula punctata.	Platyceras paralium.
Rhynchopora beecheri.	Brachymetopus elegans.

Some novel features of these faunas are the occurrence of two Fern Glen species of *Cyathaxonia* at horizons equivalent to the Burlington, the occurrence of shells apparently belonging to the genus *Delthyris* practically throughout the Boone at horizons as high as the Keokuk, and the occurrence of *Hustedia circularis* and *Ptychospira sexplicata* in one or both of the Keokuk and Burlington parts of the Boone. The abundance of *Cranaena booniana*, *Girtyella booniana*, *Pseudosyrinx keokuk*, *Cyrtina neogenes*, and *Rhynchopora beecheri* is also characteristic of the fauna.

The upper 100 feet of the Boone, that portion which in the Joplin district comes above the Short Creek oolite member, contains a few species that suggest a higher horizon than the Keokuk and is probably of Warsaw age. A stratum of oolite is known to occur in the Boone at about the horizon of the Short Creek oolite at several localities in the Eureka Springs and Harrison quadrangles and is believed to be a continuation of that member. A collection made from this oolite at Carrollton, in the Harrison quadrangle, contains the following species:

Dichotrypa sp.	Cliothyridina parvirostris?
Stenopora sp.	Myalina keokuk.
Fenestella aff. F. tenax.	Conocardium sp.
Rhipidomella dubia.	Platyceras sp.
Productus wortheni?	

This fauna differs somewhat from the peculiar assemblage of species found in the Short Creek oolite member at its typical localities, but nevertheless the correlation of the two horizons is probable.

Two small collections were obtained from the Boone at the same locality but above the oolitic zone. Their combined fauna is as follows:

Zaphrentis sp.	Rhynchopora beecheri.
Chonetes illinoisensis.	Dielasma aff. D. utah.
Productus semireticulatus.	Brachythyris suborbicularis.
Productus wortheni?	Pseudosyrinx keokuk.
Productus aff. P. mesialis.	Camarophoria aff. C. simulans.
Pustula punctata.	Eumetria marcyi.
Avonia millespinosa.	Phillipsia sp.

This fauna is essentially identical with those at horizons below the oolitic member and is much more Keokuk in its aspect than it is Warsaw. Yet, in spite of the defect in the faunal evidence the upper part of the Boone in the Eureka Springs and Harrison quadrangles is probably of Warsaw age.

Stratigraphic relations.—In the northern and western parts of the Eureka Springs quadrangle the St. Joe member rests upon the Chattanooga shale. In the central-eastern part of this quadrangle and most of the northern part of the Harrison it rests upon the Sylamore sandstone member of that shale. In the southern part of the Harrison quadrangle it rests upon the Sylamore sandstone, the Cason shale, the Fernvale limestone, the Joachim limestone, the Jasper limestone, or the St. Peter sandstone, the particular formation found beneath it depending on the extent of the local erosion that preceded its deposition. Where it rests upon the upper part of the Chattanooga shale it is apparently conformable with the rocks beneath, though the sandy phosphatic conglomerate at the base of the underlying green shale at War Eagle probably indicates at least local erosion following the deposition of the Chattanooga. Elsewhere the St. Joe is unconformable with the underlying rocks. However, the surface of the unconformity, like most others in the Ozark region, is so even that it can be detected only by observing that the overlying formation rests upon rocks of different ages at different localities. Although the Sylamore member is only a few feet thick, the St. Joe is apparently conformable upon it throughout much of the hundreds of miles of its sinuous outcrop.

At its top the Boone limestone is unconformable with the Batesville sandstone. The physical evidences of this unconformity are the slightly uneven surface of the Boone, the lithologic difference between it and the succeeding formation, and the conglomerate in the Hindsville limestone member of the Batesville. This conglomerate is derived from the chert of the Boone and consists of material varying from small pebbles to cobblestones several inches in diameter.

BATESVILLE SANDSTONE.

Definition.—The Batesville sandstone was named from Batesville, Ark., by J. C. Branner. The formation name, however, was first introduced into geologic literature by F. W. Simonds [1] and R. A. F. Penrose [2] in reports that appeared simultaneously in 1891. The Wyman sandstone of Simonds [3] is the Batesville, the Batesville sandstone of this author being the Wedington sandstone member of the Fayetteville shale. Simonds's erroneous identification of these sandstones arose from the mistaken view that the Moorefield shale, which underlies the Batesville sandstone at Batesville, is the same as the Fayetteville shale.

The formation under discussion consists of sandstone and a basal limestone member, the Hindsville, which takes its name from Hindsville, in the Eureka Springs quadrangle, where it is well developed. In all previous reports on northern Arkansas this member has apparently been described as a part of the Boone, but in the quadrangles herein described it has been separated from that formation and is included as a member of the Batesville on paleontologic grounds and because of a marked unconformity, though one of only slightly uneven surface, at its base.

Distribution.—The sandstone of the Batesville and the Hindsville limestone member are coextensive over much of the quadrangles, but in places in the southwest and southeast corners of the Eureka Springs and in the southern part of the Harrison the sandstone overlaps the limestone and rests upon the Boone limestone. Furthermore, in places in the southwest corner of the Eureka Springs quadrangle this limestone member is the only part of the formation present and there are other places where the entire formation is wanting. The formation is exposed in all parts of the area, though generally near the base of the Boston Mountains escarpment and the hills to the north. As a rule the sandstone of the Batesville is exposed in rather narrow belts on the slopes, but about Green Forest, Burlington, Capps, Gaither, Batavia, and Elmwood, all of which are in the Harrison quadrangle, it is the surface rock over areas aggregating several square miles, though the outcrop of the Hindsville limestone is there, as elsewhere, a very narrow band. Where the sandstone is present on slopes, it commonly produces a narrow bench, the existence of which is due not entirely to the resistant character of the sandstone itself but in part to that of the chert in the underlying Boone limestone.

Thickness.—The Batesville sandstone, exclusive of the Hindsville member, reaches in places a thickness of 10C feet, its thickness increasing in a general way from the south toward the north. In the southwestern part of the Eureka Springs quadrangle it is locally absent, and where present its thickness does not usually exceed 2 feet. About Kingston it is 6 feet; in the vicinity of Postoak Gap west of Marble it is 8 to 10 feet; and in the knobs in the northwestern part of the quadrangle it is 15 to 30 feet. In the Harrison quadrangle, from Jasper westward along the two forks of the Buffalo and their tributaries, its usual thickness is from 6 to 8 feet, except on Cove and Cecil creeks, where it is from 20 to 40 feet. At the head of South Fork of Osage Creek, near George, its thickness is from 5 to 10 feet. About Boat, Sulphur, and Gaither mountains and at the towns of Osage and Carrollton its usual thickness is 30 feet. On Terrapin Creek, east of Carrollton, it is 60 feet; about Green Forest it is 75 feet; and in the vicinity of Burlington it is 75 to 100 feet.

Character.—The Batesville sandstone ordinarily consists of brown, rather porous, even-textured sandstone having medium-sized grains, though in some parts it is coarse grained and in others fine grained. It occurs in layers varying from a few inches to 3 feet in thickness, and in most places it can be quarried as flagstone. Where the edges are weathered, cross-bedding and lamination are prominent. In some places it contains so much calcareous material that builders regard it as a compact hard limestone. In different parts of the same quarry may be seen porous brown sandstone from which the calcareous material has been leached and compact gray stone in which it is yet retained. Owing to the interlamination of the sandy and the calcareous layers, some of the beds appear to be as much as 7 feet thick in places, but where leached, the strata are thin bedded. Some of the calcareous sandstone layers grade into limestone. This, together with the ordinary porous charcter of the sandstone division, leads to the inference that the whole of the sandy part was originally calcareous. Near Carrollton, in the Harrison quadrangle, a bed of shale several feet thick occurs near the top of the formation, and in the area of its northernmost occurrence in the Harrison quadrangle a bed of green shale 1 to 2 feet thick occurs near its base. The basal part of the formation consists of the Hindsville limestone member, described below.

Hindsville limestone member.—As previously stated, the Hindsville limestone member and the overlying sandstone are coextensive over much of the quadrangles. In the Eureka Springs quadrangle its belts of outcrop, which are everywhere narrow, occur in the northwest corner and in the central and southern parts. At most places in the southwest corner the limestone, though absent here and there, is the only part of the Batesville represented. At some places in this part it is overlapped by the sandstone. It is absent from the southeast corner. Its greatest areal exposure is near Hindsville, from which it was named. In the Harrison quadrangle, in which it is less widely distributed, it outcrops near Green Forest, Burlington, Carrollton, Batavia, Capps, Gaither, and along Osage Creek and Dry Fork but is wanting in most places along Dry and Sweden creeks, Buffalo Fork of White River and its tributaries, and about Elmwood and Watkins.

The thickness of the Hindsville member in the Eureka Springs quadrangle ranges from 18 inches in the vicinity of Goshen to 30 feet in the bases of the highest points a few miles south and southwest of Eureka Springs, and from 30 to 50 feet in the vicinity of Garfield. Elsewhere in the areas the common thickness is from 10 to 20 feet.

The Hindsville member consists mainly of limestone interbedded with some sandstone. The limestone is dark gray on fresh surfaces, but on weathering it becomes lighter. Along the outcrop it is exposed as well-rounded masses or ledges protruding through a thin covering of surficial material. In most places it occurs in rather heavy layers and is coarsely crystalline, compact, and of homogeneous texture. It is strongly charged with bitumen and gives off a fetid odor when struck with a hammer. In places it contains fossils in abundance and in others it is oolitic to pisolitic. At one locality west of Garfield, in the Eureka Springs quadrangle, a bed of oolitic chert a few inches thick was found in oolitic limestone near the middle of the member, the limestone obviously having been replaced by the silica that makes up the chert. Parts of the limestone are cross-bedded, as is shown by the presence of sandy streaks brought out by weathering. A bed of conglomerate a few feet thick commonly occurs at the base of the member, as near Osage, Postoak Gap, Huntsville, Hindsville, Whitener, Spring Valley, Goshen, and in places about Garfield. This conglomerate has a dark-gray limestone matrix containing waterworn and angular fragments of chert and limestone, the largest 4 inches in diameter. At some places these fragments constitute the greater part of the bed, but at others they are sparsely scattered through the basal layers of limestone. The fragments of chert and limestone were derived from the Boone limestone, but whether they came from that part of it immediately beneath the Hindsville or were washed into it from an adjacent exposed area of the Boone is problematic. The significance of this conglomerate is that it marks an unconformity between the Boone limestone and that above. The sandstone forms thin layers and platy beds, some of them 3 to 4 feet thick. It is soft, yellow to brown, porous, and fine grained and before weathering is calcareous, thus resembling the sandstone of the Batesville. This lithologic resemblance is, in fact, one of the reasons for regarding the Hindsville as a member of the Batesville sandstone.

Fossils and correlation.—The fauna of the Hindsville limestone differs greatly from that of the Boone limestone. It is especially rich in pelecypods and gastropods, most of them small, in which respect, as well as in the resemblance or identity of many of the species, it resembles the fauna of the Spergen limestone of Indiana. It even more closely resembles the less well known fauna of the typical Ste. Genevieve limestone, and the presence of such types as *Diaphragmus elegans*, *Spiriferina transversa*, and a few others indicates that it is of Chester rather than of Meramec age. All the upper Mississippian faunas of northern Arkansas present so many differences from the typical upper Mississippian faunas that an exact correlation is not yet possible. There is even some difficulty in correlating the Hindsville member paleontologically with other formations in near-by sections. Its position between the sandstone typical of the Batesville and the Boone limestone is the same as that of the Moorefield shale of the Batesville quadrangle, but its fauna has little in common either with the fauna of the shaly portion of the Moorefield or with that of the "Spring Creek limestone," which is found also in the upper part of the so-called Boone near Batesville. In the Wyandotte quadrangle of Oklahoma the lithologic sequence is similar to that of the Eureka Springs and Harrison quadrangles, a calcareous bed corresponding to the Hindsville being found between the typical sandstone of the Batesville and the Boone limestone. The paleontologic correspondence is less close, for the calcareous bed of the Wyandotte quadrangle lacks the variety of small pelecypods and gastropods of the typical Hindsville. This part of the "Hindsville" in the Wyandotte quadrangle may be a distinct formation below the Hindsville.

The fauna of the Hindsville limestone is extensive and varied and many of the species are undescribed. Its general character is shown by the following list, which includes the common and more interesting forms:

Agassizocrinus conicus.
Fistulipora excellens.
Fenestella several sp.
Septopora cestriensis?
Archimedes intermedius.
Stenopora several sp.
Batostomella parvula.
Glyptopora aff. G. michelinia.
Streblotrypa nicklesi.
Rhipidomella dubia.
Productus ovatus.
Productus adairensis?
Productus arkansanus.
Productus punctatus.
Diaphragmus elegans.
Camarotoechia purduei var. agrestis.
Girtyella turgida var. elongata.
Spirifer batesvillae.
Reticularia setigera.
Spiriferina transversa.
Composita subquadrata.
Cliothyridina sublamellosa.
Cliothyridina elegans.
Eumetria verneuiliana.
Aviculipecten talboti.
Leptodesma n. sp.
Myalina welleriana.
Myalina monroensis.
Nucula illinoisensis.
Cypricardinia indianensis.
Parallelodon micronema.
Cypricardella aff. C. oblonga.
Cypricardella subalata.
Levidentalium venustum.
Bellerophon sublevis.
Bucanopsis textilis.
Euphemus n. sp.
Pleurotomaria sev. sp.
Euomphalus similis var. planus.
Naticopsis several sp.
Zygopleura several sp.
Cyclonema sp.
Griffithides mucronatus
Paraparchites nicklesi.

The sandstone of the Batesville is less fossiliferous than the Hindsville limestone member below it, and its fossils are in general not so well preserved. Its fauna is therefore less varied and some of the species can not be so certainly identified. The fauna of the sandstone of the Batesville is of Chester age, and, in so far as it is known, is related in a broad way to the Hindsville fauna. A thin limestone found at one locality and supposed to belong at the top of the Batesville even contains numerous diminutive gastropods and pelecypods of which many are identical with species of the Hindsville fauna. Some of the more important species found in the sandstone of the Batesville formation are as follows:

Batostomella sp.
Fenestella sp.
Archimedes confertus?
Glyptopora michelinia.
Orthotetes subglobosus?
Diaphragmus elegans.
Girtyella turgida var. elongata.
Dielasma gracile.
Spirifer batesvillae.
Composita subquadrata.
Cliothyridina sublamellosa.
Eumetria marcyi.
Myalina monroensis.
Myalina illinoisensis?
Leptodesma carboniferum.
Leptodesma spergenense?
Aviculipecten multilineatus.
Deltopecten batesvillensis?
Nucula illinoisensis.
Bellerophon sublevis.
Pleurotomaria aff. P. meekana.
Holopea proutana?
Naticopsis n. sp.
Aclisina sp.
Cyclonema n. sp.

Stratigraphic relations.—In the eastern part of the Paleozoic area in Arkansas the Batesville sandstone rests upon the Moorefield shale, which there lies between it and the Boone limestone; but this shale is absent from the western part of the State, including the Eureka Springs and Harrison quadrangles, over which areas the Batesville sandstone rests unconformably upon the Boone limestone. From the field evidence sedimentation passed without interruption from the Batesville sandstone to the Fayetteville shale. The areas in which the Fayetteville shale rests upon the Boone limestone are thought to be those in which the sand forming the Batesville sandstone was never deposited.

FAYETTEVILLE SHALE.

Definition.—The Fayetteville shale was named by F. W. Simonds [4] from Fayetteville, Ark., near which it is well displayed. The formation consists of a lower and an upper shale separated by the Wedington sandstone member, which receives its name from Wedington Mountain, in Washington County, Ark. The Wedington is tne same as the Batesville

[1] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, pp. 49–53, 1891.
[2] Penrose, R. A. F., jr., Manganese: its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 1, pp. 139–140, 1891.
[3] Simonds, F. W., op. cit., pp. 38–41.
[4] Simonds, F. W., op. cit., pp. 42–48.

sandstone of Simonds in his report on Washington County.[1] Simonds also used the name Marshall shale, from Marshall, Ark., for the upper shale of the Fayetteville, though the "Marshall" shale at the type locality is the same as the Fayetteville.

Distribution.—The Fayetteville shale is nowhere absent in the Eureka Springs and Harrison quadrangles. In the Eureka Springs quadrangle it outcrops on Posy, Pond, Poor, Blansett, Sugar, and other mountains in the northwest corner; on Grindstone, Pond, Sandstone, and Swain mountains in the central part; and on the slopes of the mountains and along the streams in the southern part. In the Harrison quadrangle it is the surface rock over a large part of the southwest two-thirds of that area, where it is commonly exposed in rather steep slopes. The areas where this is the surface rock nearly all remain in forest. Because of the steep slopes and the poor soil only small tracts have been cleared and put under cultivation. The shale is exposed at the surface at few places, being concealed almost everywhere by residual and other surface material in which there are large and small boulders derived from the Pitkin limestone, Hale formation, and Winslow formation, all of which outcrop higher on the slopes.

Thickness.—In the Eureka Springs and Harrison quadrangles the thickness of the formation ranges from 10 to 400 feet. The minimum thickness observed is in some of the knobs in the northwestern part of the Eureka Springs quadrangle, although in most of those knobs, as well as in those south of Eureka Springs, the formation is from 20 to 30 feet thick. The area of greatest thickness is a northwestward-trending belt a few miles wide, extending from the vicinity of Green Forest to that of Yardelle, in the Harrison quadrangle. The common thickness in this belt is 350 feet. From this belt the formation becomes thinner westward and southwestward, so that in the Harrison quadrangle along the two Buffalo forks west of Jasper and along Possumtrot Creek, South Fork of Osage Creek, Dry Creek, and Sweden Creek, its ordinary thickness is from 150 to 200 feet. In the Eureka Springs quadrangle, along Kings River from the vicinity of Kingston northward and westward to Brush Creek and near Hindsville and Spring Valley, its thickness is from 25 to 50 feet. In the southwest corner of the Eureka Springs quadrangle it is 250 feet thick.

At three localities in the southwestern part of the Harrison quadrangle its thickness changes so greatly in a short distance as to deserve special mention. One of these is 4 miles southeast of Carrollton on what is called the Carrollton dome, where the formations below the Fayetteville are abruptly domed to the height of 325 feet. The thickness of the Fayetteville shale at the top of the dome is only 40 feet; a mile and a half east of this it is 350 to 400 feet, and at the same distance to the north and west it is 250 to 300 feet. (See section E–E, structure-section sheet.) A second locality is a small area 2 to 3 miles north of Osage post office, where the Fayetteville shale is 25 to 30 feet thick. A mile to the east it is 300 feet thick and 2 miles to the southeast, south, and southwest it is 150 feet thick. The third locality is on the Sneeds Creek dome, along Sneeds Creek and the head of South Fork of Osage Creek, southeast of George. There the Fayetteville shale is only 40 feet thick; but away from the dome its thickness increases in all directions until it is 100 to 350 feet within a distance of 3 miles. (See sections F–F and G–G, structure-section sheet.)

Character.—The Fayetteville shale consists chiefly of shale but includes a thin sandstone member, the Wedington, in the upper part and a very small amount of limestone.

The lower shale, which is that part below the Wedington sandstone, forms the bulk of the formation. It is black carbonaceous fissile clay shale that weathers to highly plastic clay of a yellow or red color. Globular concretions of black siderite known as clay ironstone are common in it, and on weathering these scale off in concentric shells of yellow limonite. Many of these concretions are cut into a great number of segments by a network of joints, now filled with calcite, which form what are known as septaria. Near the base there are septarian layers of limestone, whose segments are cemented together with white calcite that is blackened in many places by some organic matter. These layers are dark, and when freshly broken their surfaces give off a fetid odor—in some specimens that of petroleum. Locally there occurs at the base a layer of fossiliferous limestone, which as a rule is only a foot or two thick and commonly is bluish drab to bluish gray; but in the northwest corner of sec. 15, T. 20 N., R. 28 W., it is dark gray, coarse textured, somewhat oolitic, and contains numerous brachiopods and calcite crystals. Near Batavia this bed is several feet thick.

The upper shale of the Fayetteville—that is to say, the part lying above the Wedington sandstone member—is neither so dark nor so fissile as the lower shale of the formation. In the Eureka Springs quadrangle it contains in places thin layers of fossiliferous limestone. A maximum thickness of 70 feet for this part is reached in the southwest corner of that quadrangle, from which area it thins eastward and northward. It occurs on Holman Creek southwest of Huntsville, but no farther north along that stream; it is absent north of the confluence of War Eagle and Wharton creeks, but south of that point it occurs on both streams and is 50 feet thick. In the Harrison quadrangle its common thickness is from 10 to 20 feet. It is present over a small area on one of the branches of Sweden Creek; on the heads of Osage, Cecil, and Cove creeks; on the end of the point 2 miles northwest of Jasper; and on the slopes of Pinnacle Mountain and of other prominences in its immediate vicinity to the south.

Wedington sandstone member.—The Wedington sandstone is exposed on the slopes of the mountains in the southern part of the quadrangles. Along most of its outcrops it produces a narrow bench, below which is a low steep escarpment. In most places it is coextensive with the upper shale member, but in some areas it is of wider extent than that part of the formation. In the southwest part of the Eureka Springs quadrangle it is in many places present at the proper horizon. It occurs along the upper part of Holman Creek southwest of Huntsville, and along War Eagle and Wharton creeks above their confluence, but is absent north of those areas. In the Harrison quadrangle there are exposures along Dry and Sweden creeks in the southwestern part; on the end of the point south of Ponca; at the heads of Osage, Cecil, and Cove creeks; on the point 2 miles northwest of Jasper; and on Boat and Sulphur mountains and others in their vicinity.

In the Eureka Springs quadrangle its usual thickness is from 4 to 10 feet. Along Dry Creek, in the Harrison quadrangle, its thickness is only 2 feet, and in Gaither Mountain it is 45 feet. Elsewhere in the Harrison quadrangle it is from 6 to 10 feet thick.

The sandstone is ordinarily thin bedded, but in a few places the beds are more than 3 feet thick. The rock is dense, hard, light gray to brown, fine grained, and thinly laminated, and at many places shows cross-bedding. Ripple marks are not uncommon. In the Harrison quadrangle this member is fossiliferous. Along most of its outcrop it is free from calcareous material, and where it is undermined by the weathering of the shale it is sapped off in blocks having straight sharp edges and smooth faces. So resistant is most of the stone to weathering that the blocks commonly collect in large numbers on the slopes and retain their sharp outlines, but in places in the Harrison quadrangle the rock is calcareous and weathers with rounded edges. On Gaither Mountain it is argillaceous. At a few places it is overlain by the Pitkin limestone, and at such places it occurs at the base of the escarpment of that formation.

Fossils and correlation.—The Fayetteville shale contains at its base in many localities a limestone lens which is highly fossiliferous. Its fauna is of Chester age and is closely related to the faunas of the sandstone of the Batesville and of the Hindsville limestone member of the Batesville, except that it is richer in bryozoans, brachiopods, and crustaceans, and poorer in pelecypods and especially in gastropods. Such of these types as occur in the Fayetteville shale are not notably small but are of normal size. The list below shows some of the more characteristic species in the limestone at the base of the Fayetteville shale as it occurs in the Eureka Springs and Harrison quadrangles.

Michelinia meekana.
Fistulipora excellens.
Stenopora longicamerata.
Rhombopora persimilis var. miseri.
Streblotrypa nicklesi var. robusta.
Orthotetes subglobosus.
Chonetes sericeus.
Productus inflatus.
Productus adairensis.
Productus arkansanus.
Productus ovatus.
Diaphragmus elegans.
Camarophoria explanata.
Camarotoechia purduei var. laxa.
Dielasma gracile.
Girtyella turgida var. elongata.
Spirifer fayettevillae.
Brachythyris ozarkensis.
Reticularia setigera.
Spiriferina transversa.
Composita subquadrata.
Cliothyridina sublamellosa.
Cliothyridina elegans.
Eumetria marcyi.
Aviculipecten inspeciosus.
Myalina sanctiludovici.
Sanguinolites simulans.
Straparollus similis var. planus.
Euconospira disjuncta.
Griffithides mucronatus.
Paraparchites nicklesi.
Primitia fayettevillensis.

The black fissile shaly portion of the Fayetteville is also in places highly fossiliferous. The fossils consist almost wholly of one or two species of pelecypods, whose tenuous shells are for the most part crushed and fragmentary. Those specimens that can be identified appear to belong to *Caneyella nasuta*.

A collection made in the Wedington sandstone member contains the following species:

Archimedes proutanus.
Archimedes compactus.
Archimedes swallowianus.
Archimedes terebriformis.
Archimedes aff. A. owenanus.
Batostomella? sp.
Orthotetes subglobosus var. batesvillensis.
Orthotetes subglobosus var. protensus?
Productus ovatus.
Spiriferina spinosa?
Composita subquadrata?
Sphenotus aff. S. constrictus.
Sphenotus n. sp.
Nucula rectangula.
Yoldia sp.
Deltopecten batesvillensis.
Deltopecten n. sp.
Myalina elongata.
Prothyris? sp.
Leptodesma spergenense var. robustum.
Leptodesma carboniferum.
Schizodus depressus var. abruptus.
Cypricardella sp.
Schizostoma n. sp.
Euphemus aff. E. carbonarius.
Euphemus n. sp.
Naticopsis sp.
Levidentalium venustum?
Pseudocycloceras aff. P. ballianum.
Pseudocycloceras sp.
Orthoceras sp.
Ostracoda undet.

A siliceous limestone in the shale overlying the Wedington sandstone has yielded the following fossils:

Fenestella several sp.
Archimedes swallowianus.
Batostomella sp.
Crania sp.
Orthotetes sp.
Chonetes sericeus?
Productus ovatus.
Diaphragmus elegans.
Camarophoria explanata.
Camarotoechia purduei var. laxa.
Spirifer pellensis.
Spiriferina transversa.
Ambocoelia planiconvexa var. fayettevillensis.
Cliothyridina sublamellosa.
Eumetria verneuiliana.
Edmondia? sp.
Sphenotus branneri?
Nucula rectangula?
Leda vaseyana.
Yoldia sp.
Caneyella? sp.
Deltopecten batesvillensis.
Deltopecten aff. D. coxanus.
Leptodesma aff. L. spergenense.
Cypricardinia fayettevillensis.
Euphemus n. sp.
Worthenia n. sp.
Phanerotrema n. sp.
Orthoceras 2 sp.
Goniatites richardsonianum?
Griffithides mucronatus.
Primitia sp.

Stratigraphic relations.—The Fayetteville shale rests upon the Batesville sandstone where that is present; elsewhere it rests upon the Boone limestone. In the Eureka Springs and Harrison quadrangles it overlies the sandstone of the Batesville except in the southwest corner of the Eureka Springs quadrangle, where it rests in some places upon the Hindsville limestone member and in others upon the Boone limestone. It is overlain by the Pitkin limestone, of Mississippian age, where that is present, and elsewhere by the Hale formation, of Pennsylvanian age.

PITKIN LIMESTONE.

Definition.—The Pitkin limestone consists wholly of limestone. The name is taken from the post office of Pitkin, in Washington County, south of Fayetteville, where it is well exposed. In the reports of the Geological Survey of Arkansas it is known as the "*Archimedes*" limestone, because of the presence of *Archimedes*, an easily recognized bryozoan, the screwlike stems of which are common on the weathered surface of the rock.

Distribution.—The Pitkin limestone, like many other formations in these quadrangles, is absent over a large part of the area under discussion. In the Eureka Springs quadrangle it outcrops in the vicinities of Wesley, Drakes Creek, and Huntsville; along the upper parts of Holman, War Eagle, and Wharton creeks; and along Kings River and its tributaries from the vicinity of Round Mountain southward. In the Harrison quadrangle it is exposed in the vicinity of Dry Fork post office; on the slopes above Sweden Creek; on the heads of Osage, Cecil, and Cove creeks; on the southeast projection of Gaither Mountain; from the vicinity of Low Gap post office eastward to Jasper; and in the region of Sulphur and Boat mountains.

The limestone is so much undermined by the weathering of the Fayetteville shale, on which it rests, that it breaks off in huge blocks, which fall upon the slopes below, where they disintegrate through weathering. As a result of being undermined, this formation generally outcrops as a steep escarpment, whose height is usually the thickness of the formation. The prominence and persistence of this escarpment are generally sufficient to distinguish the formation from the other limestones of the area. The only mountain in the quadrangles whose summit is capped by this limestone is Fodderstack Mountain, south of Harrison.

Thickness.—The ordinary thickness of the Pitkin limestone in the southeastern part of the Harrison quadrangle and south and southwest of Huntsville, in the Eureka Springs quadrangle, is 50 feet; but in Pilot, Sulphur, Pinnacle, Boat, and neighboring mountains it is from 50 to 100 feet, the maximum thickness being in the south end of Boat Mountain. In the southwestern part of the Harrison quadrangle and the adjoining part of the Eureka Springs quadrangle the thickness of this limestone is less than elsewhere and ranges from a few inches to 20 feet.

Character.—The beds of this limestone are almost everywhere massive and are several feet thick. The rock is compact bluish-gray limestone, which in many places is porous and ferruginous and which shows rather indistinct cross-bedding on exposed surfaces. On weathering it usually becomes coarse grained and breaks up into angular blocks and thin plates that lack the rounded edges so characteristic of purer limestones.

Fossils and correlation.—Fossils, especially bryozoans, corals, crinoids, and brachiopods, are abundant in most exposures of the Pitkin limestone. The easily recognizable fossil bryozoan of the genus *Archimedes*, though by no means confined to the Pitkin, is so generally abundant in it that this limestone can thereby be readily distinguished from the other limestones in the area.

The Pitkin fauna denotes Chester age for this limestone. It is fairly distinctive, but many of its species occur also in the underlying beds, as appears in the following list:

Archimedes invaginatus?
Archimedes swallowianus.
Glyptopora michelinia.
Chonetes sericeus.
Productus ovatus.
Productus arkansanus.
Diaphragmus elegans.
Tetracamera n. sp.
Camarophoria explanata.
Dielasma formosum?
Spirifer pellensis?
Reticularia setigera.
Composita subquadrata.
Eumetria marcyi.
Aviculipecten multilineatus.
Griffithides mucronatus.

[1] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept. for 1888, vol. 4, pp. 49–53. 1891.

Stratigraphic relations.—The Pitkin limestone overlies the Fayetteville shale and rests upon beds at different horizons in different parts of the area. Such a relation is suggestive of a stratigraphic break at the base of the Pitkin, but no further evidence indicating such a break has been observed in the area. It rests upon the upper shale of the Fayetteville in places near Wesley, on Drakes Creek, on War Eagle and Wharton creeks southeast of Huntsville, near Kingston, southwest of Gaither, west and northwest of Jasper, and on two or three mountains west of Yardelle. On Sulphur, Boat, and Pilot mountains it rests upon the Wedington sandstone member. Possibly in many places where the Wedington is wanting it rests upon the lower shale of the Fayetteville. The Pitkin is unconformably overlain by the Hale formation, the lowest of the Pennsylvanian series. The evidences of this unconformity are a heavy conglomerate in places at the base of the Hale, the upper irregular surface of the Pitkin, its northward thinning, and its serrated northern border. The unconformity rapidly disappears southward, for there is little evidence of it in the southern part of the areas herein discussed or in the adjoining areas on the west and southwest.

PENNSYLVANIAN SERIES.

Only the lower part of the Pennsylvanian series is represented in the quadrangles. The strata consist of shale, sandstone, and limestone, with some conglomerate, and comprise three formations, of which the lower two constitute the Morrow group.

MORROW GROUP.

HALE FORMATION.

Definition.—The Hale formation was named by J. A. Taff from Hale Mountain, in the western part of the Winslow quadrangle, where it is well developed.[1] In the reports of the Geological Survey of Arkansas it is known as the Washington shale and sandstone. It consists of shale, sandstone, limestone, and conglomerate, all more or less interbedded and limited in distribution. The character and diversity of the beds are graphically represented by figure 12, which consists of eight sections of the Morrow group. The formation ranges in thickness from 80 to 300 feet, the thinnest exposure being near Compton, in the Harrison quadrangle, and the thickest on Diera Mountain, in the Eureka Springs quadrangle.

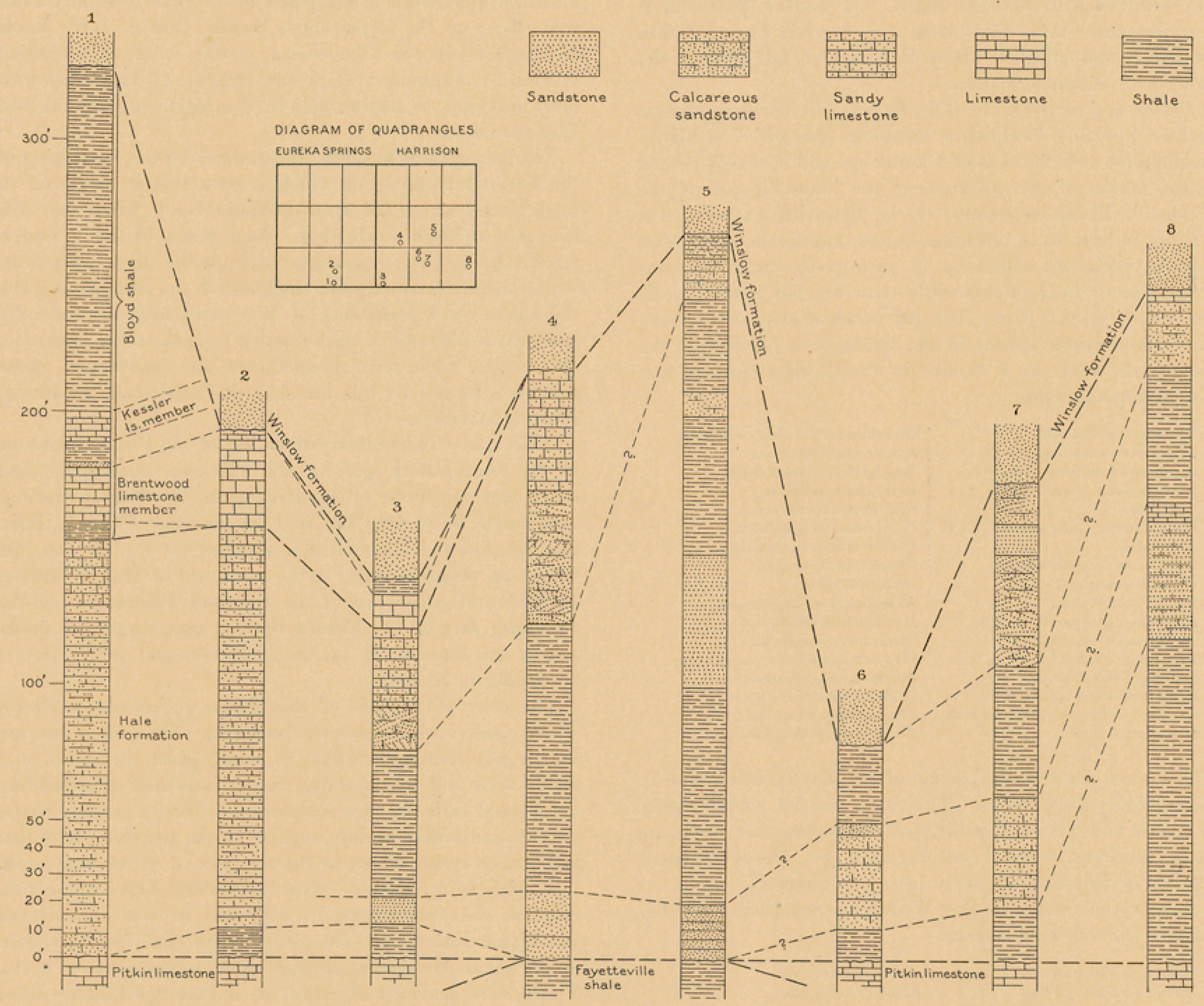

FIGURE 12.—Sections of the Morrow group in the Eureka Springs and Harrison quadrangles.

1, Composite section 5 miles south of Huntsville; 2, composite section 2¼ miles south of Huntsville; 3, section in southwest corner of Harrison quadrangle in sec. 31, T. 16 N., R. 23 W.; 4, section somewhat generalized at localities near Osage post office; 5, section at north end of Gaither Mountain near Capps; 6, section 2 miles northeast of Compton; 7, section 4 miles east of Compton; 8, section on Pinnacle Mountain, south of Bellefonte. Vertical scale shown at the left of the section.

Distribution.—The formation occupies the surface of considerable areas in the southern part of the Eureka Springs quadrangle and caps the summits of knobs in the central and northwestern parts. In the Harrison quadrangle it outcrops in belts on the slopes in the southwestern third of the area and on the mountains in the southeastern part. The interbedded shales and sandstones of the formation, in spite of the fact that they are exposed on rather steep slopes, produce in many places the bench and bluff type of topography, the sandstones outcropping in bluffs or escarpments and the shales in narrow benches. Outcrops are numerous in the belts where this formation is the surface rock, though most parts are covered with residual material from the Hale itself or with more or less débris from the Winslow formation. Furthermore, these belts, with the exception of those parts of the benches or slopes that have been cleared for farming, are covered with forest.

Character.—Where the Hale formation rests upon or near the truncated edges of the Pitkin limestone, there is at its base a bed of conglomerate consisting of well-rounded limestone pebbles, about an inch in diameter, in a matrix that is chiefly ferruginous limestone but that also contains brown sandy lenses. The screwlike stems of the fossil bryozoans of the genus *Archimedes* are present in the conglomerate at many places and are either embedded in the limestone pebbles or loose in the matrix; if loose, they always show some evidence of being waterworn. The character of the pebbles and the presence of this fossil plainly show that they were derived from the Pitkin limestone. Possibly the best exposures of the conglomerate are near Kingston and on War Eagle Creek east of Huntsville, in the Eureka Springs quadrangle, where it reaches 10 feet in thickness. Near Spring Valley, in that quadrangle, the basal conglomerate is 1 foot thick and is composed largely of well-rounded chert pebbles an inch or less in diameter, which were probably derived from areas of the Boone limestone to the north. At the base of the formation but invariably overlying the conglomerate, where that is present, there is a bed of black clay shale containing thin ripple-marked sandy layers and ranging from 10 to 30 feet in thickness. This bed is probably represented in the southeastern part of the Harrison quadrangle by a similar bed 120 feet in thickness.

Above the basal conglomerate and shale the formation consists of interbedded sandstone, shale, and limestone. The shale is confined mainly to the middle portion, the lower and upper parts being sandy and calcareous. The lower part, from 6 to 50 feet thick, is composed of thin to massive bedded sandstone. The thin beds are gray, fine grained, and noncalcareous. The massive beds, which are 20 feet thick in places, are gray to brown, coarse grained, cross-bedded, and in many parts of the areas calcareous. Some portions of the sandstone contain numerous limestone lenses and other portions are interbedded with limestone layers several feet thick. In some places the noncalcareous outcrops of this part of the formation produce bluffs, above which are narrow benches, as near Osage post office and Carrollton. The bluffs appear where the rock is undermined by the weathering of the shale beneath, which causes huge blocks to break off and fall to the slope below. Weathered surfaces of the sandstone generally show cross-bedding, and owing to the calcareous nature of some of the sandstone, which readily weathers into pits and lenticular cavities, these surfaces at many places assume a honeycombed or cavernous appearance.

The thickness of the middle part of the formation is irregular and ranges from 20 to more than 200 feet. It is least in the Eureka Springs and greatest in the Harrison quadrangle. This part of the formation is largely shale, but it contains a good deal of sandstone. Much of the sandstone is hard, gray, thin bedded, and ripple marked; but in places it is soft, brown, cross-bedded, and calcareous. The shale is black, thinly fissile clay shale and contains numerous thin sandy plates that are particularly conspicuous in the red clay to which it weathers.

The upper part of the formation closely resembles the lower, except that it is much more calcareous. In the Eureka Springs quadrangle it is from 20 to 150 feet thick and in most places outcrops in well-rounded hills or smooth hill slopes. In the Harrison quadrangle its thickness is from 5 to 100 feet and it outcrops in steep slopes or escarpments. The differences in the topography of its outcrop in the two quadrangles are attributed to differences in the proportions of this upper part and of the middle or shaly part of the formation. The sandstone, like much of that in the lower part, is brown, soft, massive, cross-bedded, and calcareous, and on weathering becomes exceedingly cavernous. Thin beds of black shale are common in this upper part.

Limestone as lenses and as more or less distinct beds occurs in all parts of the sandstone, the upper beds of which are distinctly calcareous and at the top grade into limestone. This limestone is persistent in the Eureka Springs quadrangle, except at a few localities along the eastern border south of Kingston and near the head of Tate Hollow. Its eastward extent in the Harrison quadrangle is roughly limited by a line drawn southward through the center of the area, though it is locally absent in the west half of the quadrangle. This limestone is 6 to 50 feet thick and is massive, cross-bedded, coarsely crystalline, highly fossiliferous, and of light-gray to rusty-gray color. In places it contains a few feet of compact bluish-gray noncrystalline limestone. In most places its outcrops are in bluffs or steep slopes, and it weathers by exfoliation into thin rusty plates parallel to the bedding.

Fossils and correlation.—The passage from the Mississippian to the Pennsylvanian is marked in northern Arkansas by a pronounced faunal break. Nevertheless, the earlier Pennsylvanian formations were for a number of years placed in the Mississippian. David White was the first to assign them correctly and correlate them with the Pottsville. His conclusions were based on the fossil flora of the "coal-bearing" shale of the Geological Survey of Arkansas that lies between the Brentwood and Kessler limestones—a flora which he determined as of late middle or early upper Pottsville age. Later, because the fauna of the Hale formation and of the Brentwood limestone proved to be closely related to the fauna of the Kessler limestone the Hale and the Brentwood also were placed in the Pottsville. The Hale, Brentwood, and Kessler faunas are all closely related to one another and, though of Pennsylvanian age, they are conspicuously different from the familiar Pennsylvanian faunas of Kansas, Missouri, Illinois, and other States, most of which, indeed, are geologically younger. Many of the species are undescribed, and for this reason mere lists do not give an adequate idea of these faunas. Two collections from the Hale formation contain the following species:

Pachypora oklahomensis.	Edmondia aff. E. gibbosa.
Michelinia sp.	Sanguinolites costatus.
Cladochonus fragilis.	Nucula parva.
Lophophyllum sp.	Leda bellistriata?
Pentremites angustus.	Deltopecten aff. D. coxanus.
Glyptopora crassistoma.	Acanthopecten carboniferus?
Cystodictya aff. C. morrowensis.	Myalina perniformis.
Cystodictya aff. C. flexuosa.	Conocardium sp.
Coscinium fayettevillensis.	Parallelodon carbonarium.
Streblotrypa sp.	Parallelodon tenuistriatum.
Chainodictyon sp.	Euphemus n. sp.
Crania modesta.	Bellerophon aff. B. crassus.
Schizophoria altirostris.	Bucanopsis aff. B. textilis.
Productus morrowensis.	Phanerotrema aff. P. grayvillense.
Productus pertenuis?	Straparollus aff. S. spergenensis.
Productus welleri.	Straparollus aff. S. quadrivolvis.
Pustula semipunctata.	Trachydomia n. sp.
Pustula aff. P. nebraskensis.	Naticopsis aff. N. nana.
Rhynchopora magnicosta.	Zygopleura n. sp.
Dielasma subspatulatum.	Meekospira aff. M. peracuta.
Spirifer rockymontanus var.	Sphaerodoma aff. S. fusiformis.
Squamularia perplexa.	Sphaerodoma aff. S. ventricosa.
Spiriferina mesicostalis.	Platyceras aff. P. parvum.
Spiriferina pottsvillica.	Pseudorthoceras knoxense?
Composita subtilita.	Endolobus? sp.
Cliothyridina orbicularis.	Gastrioceras 4 sp.
Hustedia brentwoodensis.	Griffithides sp.
Hustedia aff. H. mormoni.	Paraparchites sp.

Stratigraphic relations.—From the border of the Pitkin limestone northward the Hale formation rests unconformably on the rocks beneath, lying successively upon the Pitkin limestone, the upper part of the Fayetteville shale, the Wedington sandstone member, and the lower part of the Fayetteville

[1] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), 1905

shale, the particular formation underlying it at any place depending upon the amount of erosion that preceded its deposition at that place. Not far south of the serrated northern limit of the outcrop of the Pitkin limestone the Hale is thought to be everywhere conformable with the subjacent rocks.

Where the section is fully represented the Hale formation is overlain by the Bloyd shale. Where the Bloyd is absent the Winslow formation rests unconformably upon the Hale.

BLOYD SHALE.

Definition.—The Bloyd shale was named by the senior author from Bloyd Mountain, near West Fork, Washington County, Ark.,[1] where it is typically developed. It consists of carbonaceous clay shale, containing two limestone members, the Brentwood below and the Kessler above. The relations of these different beds are represented in the first section of figure 12.

The Kessler was named by F. W. Simonds[2] from Kessler Mountain, southwest of Fayetteville, Ark., and the Brentwood from Brentwood, Washington County, Ark. In the reports of the Geological Survey of Arkansas the Brentwood is known as the "Pentremital" limestone because the rather striking fossil *Pentremites angustus* is widely distributed in it. In the reports of that survey the shale between the two limestones is termed the "Coal-bearing" shale from the fact that in places in Arkansas west of the quadrangles herein described it contains a thin seam of coal. The shale below the Brentwood is included in the "Washington shale and sandstone" and that above the Kessler in the "Millstone grit formation."

Distribution.—The Bloyd shale in the area is confined almost wholly to the Eureka Springs quadrangle. It is wanting in places near Kingston and Mayfield and east of Marble. It is exposed on the higher mountains north of Drakes Creek and in small areas near Mayfield, Huntsville, Marble, and Kingston, the outcrops forming narrow belts, generally on upper slopes. Such belts are forested and are covered with débris, though rock exposures are common. It occurs in the southwest corner of the Harrison quadrangle on the heads of Dry and Sweden creeks, west of Buffalo Fork of White River, on the heads of South Fork of Osage and Possumtrot creeks, and on the north end of Saffer Mountain, at all of which places its outcrop is on the steep upper slopes.

Thickness.—In the Eureka Springs and Harrison quadrangles the formation ranges in thickness from a feather edge to 176 feet, the maximum occurring at the head of War Eagle Creek near the southern border of the Eureka Springs quadrangle. From that locality it becomes thinner toward the west, north, and east. Its maximum thickness in the Harrison quadrangle occurs near Ponca, where it is 70 feet.

Character.—The formation, as already defined, consists of shale and of two limestone members, the Kessler and the Brentwood, the relations of which are shown in figure 12. In these quadrangles the Kessler member lies 10 to 20 feet above the Brentwood, the intervening rock being thinly fissile black clay shale with thin layers of sandstone near its base. Beneath the Brentwood and separating it from the Hale formation is from 6 to 10 feet of thinly fissile black clay shale, which is exposed on War Eagle Creek near the southern border of the Eureka Springs quadrangle and also 2½ miles north and 4 miles northeast of Drakes Creek. Elsewhere in the quadrangles this shale is absent or is not exposed, though it is persistent in the Winslow quadrangle. Within the area herein treated the shale overlying the Kessler limestone is the least widely distributed of the beds of the formation. It occurs at many places southeast and southwest of Huntsville and southwest of Kingston, but probably at no place in the Harrison quadrangle. It consists of thinly fissile, very black clay shale, which on weathering changes to an unusually plastic yellowish or reddish clay. Thin sandy plates and numerous clay ironstone (siderite) concretions, which commonly weather to limonite, are found at some places.

The following sections of the Bloyd shale show the character and diversity of the formation:

Section of Bloyd shale on War Eagle Creek at the south border of the Eureka Springs quadrangle.

	Feet.
Winslow formation:	
Cross-bedded sandstone in heavy ledge.	
Bloyd shale:	
Black, thinly fissile clay shale containing a good many clay ironstone concretions, which on their surface are partly changed to limonite	130
Porous, highly fossiliferous gray to chocolate-brown limestone, conglomeratic at top (Kessler limestone member)	10
Black, thinly fissile clay shale with thin sandstone layers near its base	10
Massive, highly fossiliferous compact gray limestone (Brentwood limestone member)	20
Black, thinly fissile clay shale	6
Hale formation:	
Gray to rusty cross-bedded sandy porous limestone.	

[1] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (No. 154), 1907.

[2] Simonds, F. W., The geology of Washington County: Arkansas Geol. Survey Ann. Rept for 1888, vol 4, pp. 103–105, 1891.

Section of Brentwood limestone member on south end of the mountain in sec. 15, T. 16 N., R. 26 W.

	Feet.
Winslow formation:	
Millstone grit in massive ledge.	
No exposures on slope for 4 or 5 feet.	
Bloyd shale:	
Brentwood limestone member (massive fossiliferous compact to slightly porous gray limestone)	30
Hale formation:	
Sandy cross-bedded ferruginous and more or less porous gray limestone	25
Compact bluish-gray limestone	3
Calcareous sandstone, weathering to red clay and sand.	

Brentwood limestone member.—In the Eureka Springs quadrangle the Brentwood limestone outcrops on the slopes of the mountains north of Drakes Creek and also near Huntsville and Wharton; it is wanting south of Kingston, east of Marble, and at places west of Mayfield. In the Harrison quadrangle it outcrops on the upper slopes of the mountains on the headwaters of Dry, Sweden, South Fork of Osage, and Possumtrot creeks; on the west side of Buffalo Fork of White River from the vicinity of Compton southwestward; and on the north end of Saffer Mountain.

Over much of the quadrangles the limestone consists of only one bed, but south of Compton, in the Harrison quadrangle, there are two beds separated by 6 feet of shale. The thickness ranges from 3 to 30 feet, the maximum being reached near Huntsville, in the Eureka Springs quadrangle, and the minimum near Ponca, in the Harrison quadrangle. The rock is heavy bedded, bluish to gray, highly fossiliferous, partly crystalline, slightly porous to compact, and in parts somewhat rusty. The surfaces become rounded and smooth on weathering, except for small protrusions formed by fossils.

Kessler limestone member.—The Kessler limestone member is less widely distributed than the Brentwood, its only exposures in the quadrangles being along the south border of the Eureka Springs quadrangle, west, southwest, south, and southeast of Huntsville, though a small outcrop occurs 1½ miles northeast of that place. Its thickness is generally 2 to 4 feet and nowhere exceeds 10 feet. Its color ranges through gray, brown, and chocolate. It is compact, fossiliferous, and in places conglomeratic. It is thin and is generally covered by débris, but it can be found nearly everywhere by careful search at the proper horizon. It is overlain at some places by a few feet of soft coarse-grained sandstone, but a slight escarpment indicates its exact position on the hillside. Where not conglomeratic this limestone closely resembles the Brentwood, but it weathers into characteristic shaly plates, which sometimes assist in its identification.

Fossils and correlation.—The Brentwood limestone member is in places highly fossiliferous, and the fauna obtained from it is large and varied. Nearly all the larger groups of invertebrate organisms are represented by many species. The Hale fauna, which preceded it, agrees essentially with the Brentwood fauna. This fauna is in large part undescribed, and it is difficult to characterize it by a faunal list, for most of the genera are the same as those of the Mississippian below and the higher Pennsylvanian above. Very few of the species are identical with those of the upper Mississippian rocks, but many are closely related to them. Some are identical with well-known Pennsylvanian species; some are similar to or possibly identical with rarer Pennsylvanian species; and many are undoubtedly new.

The following list shows the species contained in a collection from the Brentwood member:

Michelinia sp.	Squamularia perplexa.
Pentremites rusticus?	Composita subtilita.
Septopora reversispina?	Cliothyridina orbicularis.
Orthotetes sp.	Hustedia brentwoodensis.
Schizophoria altirostris.	Pectinopsis unguis.
Productus morrowensis.	Pectinopsis morrowensis.
Productus cora.	Paleolima inaequicostata.
Productus welleri.	Myalina perniformis.
Pustula semipunctata.	Straparollus n. sp.
Pustula aff. P. nebraskensis.	Sphaerodoma sp.
Pustula globosa.	Platyceras aff. P. parvum
Rhynchopora magnicosta.	Endolobus sp.
Dielasma subspatulatum.	Gastrioceras sp.
Spirifer rockymontanus var.	Griffithides sp.
Ambocoelia planiconvexa.	

The following list shows the species found in a collection from the Kessler limestone member:

Pentremites angustus?	Composita subtilita.
Cystodictya brentwoodensis?	Cliothyridina orbicularis.
Lingula sp.	Hustedia brentwoodensis.
Lingulidiscina minuta.	Nucula parva?
Crania modesta?	Aviculipecten? interlineatus.
Schizophoria altirostris.	Crenipecten herzeri.
Productus morrowensis.	Pectinopsis morrowensis.
Productus welleri.	Acanthopecten carbonifer.
Productus cora.	Paleolima inaequicostata.
Pustula nebraskensis?	Myalina perniformis?
Pustula globosa.	Astartella alata?
Dielasma subspatulatum.	Sphaerodoma sp.
Spirifer rockymontanus var.	Platyceras aff. P. parvum.
Squamularia perplexa.	Orthoceras sp.
Spiriferina mesicostalis.	Griffithides ornatus.
Spiriferina pottsvillica.	Bairdia sp.

Stratigraphic relations.—The Bloyd shale succeeds the Hale formation conformably, and is overlain unconformably by the Winslow formation, as is shown by the northward and eastward thinning of the beds of the Bloyd shale. As a result of this thinning, the Winslow rests in some places upon the Kessler limestone member, in others upon the Brentwood limestone member, and where the Brentwood is absent it rests upon the Hale.

WINSLOW FORMATION.

Definition.—The Winslow formation consists of alternate beds of sandstone and shale. The name is taken from Winslow, Washington County, Ark., at the summit of the Boston Mountains, on the St. Louis & San Francisco Railroad. In the reports of the Geological Survey of Arkansas the Winslow is known as the Millstone grit formation.

Only the lower part of the Winslow is represented in the areas under discussion, the upper part having been removed by erosion. The thickness of the remaining part ranges from a few feet on the outlying knobs, where it is thinnest, to at least 500 feet where it is thickest. It is found in greatest thickness in the Eureka Springs quadrangle, where it is the surface rock in the large area east of Drakes Creek. Its greatest thickness in the Harrison quadrangle is on Gaither Mountain, where it is about 400 feet thick.

Distribution.—In the Eureka Springs quadrangle the Winslow formation caps Diera, Big Sandy, and Phillips mountains, and two lower prominences west of Mayfield, besides others near Kingston, Huntsville, and Drakes Creek, all of which are in the southern part of the quadrangle. It has been displaced downward by faulting over a rather large area east of Drakes Creek, where it outcrops in the stream beds as well as on the slopes and crests of the mountains. It occupies most of the highest points in the southern two-thirds of the Harrison quadrangle, forming the summits of the northward extensions of the Boston Mountains, among which are Saffer, Dodson, Gaither, and Sherman mountains, and a good many hills of circumdenudation, conspicuous among which are Bradshaw, Round, Blacklick, Pine, Kennedy, Pilot, Sulphur, Boat, and Pinnacle mountains. The most northward occurrence of the formation in the quadrangles, as well as in Arkansas, is on the point of Bradshaw Mountain, 2 miles south of Green Forest.

The Winslow is the surface rock of the summits of the Boston Mountains, about whose northern border its basal bed is exposed in a precipitous descent known as the Boston Mountains escarpment. This basal bed is in places 100 feet thick and almost everywhere forms a sinuous and inaccessible bluff, above which in the area here considered it forms a fairly even table-land, as near Compton and Hilltop, though dissected here and there by narrow valleys. The rather large area of Winslow east of Drakes Creek, where the formation has been displaced downward by faulting, is no less rugged than many other parts of the Boston Mountains. The summits of the mountains, which are under forest cover except where they have been cleared for farming, display numerous outcrops of rock, and the bluffs and steeper slopes everywhere afford excellent exposures.

Character.—The formation consists of shale alternating with thin layers and massive beds of sandstone. The basal bed of sandstone is very persistent in the quadrangles and is the most prominent bed in the formation, as it almost everywhere produces an unclimbable escarpment. The weathering of the shale and other beds less resistant than this sandstone causes it to break off in enormous blocks that lie scattered over the lower slopes and that leave a vertical-faced ledge. This basal sandstone is gray to brown, coarse grained, and cross-bedded, and in many parts it contains well-rounded pebbles of white quartz half an inch or less in diameter. Such pebbles occur also in the higher beds of sandstone, but there they are more sparingly distributed. It is these pebbles in the sandstone that have suggested its local name, the "Millstone grit."

The beds of sandstone above the basal bed are similar to it but are not so thick. They are made up of medium-sized grains of quartz and are generally brown, cross-bedded, and more or less micaceous. They are remarkably similar in character, each grading from sandy shale at the base upward into massive sandstone layers, so that, with the exception of the basal ledge, it is impossible to identify the same bed at different places.

The thin layers of sandstone that are associated with the shale are gray, compact, micaceous, and ripple marked. The shale beds constitute probably 75 per cent of the formation. As a rule they are black and carbonaceous, though less so than those of the Morrow group. Some of the beds in the upper and middle parts of the formation are sandy, micaceous, and brown to drab in color, with streaks of black carbonaceous matter.

No coal has been observed in this formation by the authors, but a thin seam is reported to have been found in a well 2 miles northwest of Compton.

Fossils and correlation.—In the Boston Mountains and in small adjoining areas in the Arkansas Valley and the Prairie Plains, the term Winslow has been applied to a composite formation which is the equivalent of one or more formations exposed farther south in this valley and in the Ouachita Mountains. The Winslow formation has nowhere yielded sufficient fossils for paleontologic correlation, so that its age has been determined from its stratigraphic relations to the Bloyd shale beneath, which is of Pottsville age, and to the overlying and equivalent strata exposed in the deep synclinal trough of the Arkansas Valley south of the area herein described, where the Winslow passes beneath the surface. In southeastern Oklahoma, where it rises in the south side of the Arkansas Valley and against the Ouachita Mountains, the equivalent section of the Winslow, according to J. A. Taff, has a thickness estimated at 8,000 feet, and in the Ouachita area in that State the equivalent strata are underlain by the Wapanucka limestone, which is probably the equivalent, in part at least, of the Morrow group.[1] In that area, according to Taff, the stratigraphic representatives of the Winslow are divisible into three formations, the Atoka formation, the Hartshorne sandstone, and the McAlester shale. In the Tahlequah quadrangle, which is mainly in Oklahoma, the topmost strata of the Winslow have been described by Taff[2] as the Akins shale member, which he states represents the upper part, approximately the upper third, of the McAlester shale. In the Winslow quadrangle, which is mainly in Arkansas and contains the type locality of the Winslow, this formation,[3] as defined by the senior author, includes strata which in the southern part of this quadrangle have been divided by A. J. Collier[4] into the Atoka formation and the Hartshorne sandstone and which (according to Collier's map) include the lower part of the Spadra shale. This shale is the lowest formation of the McAlester group as exposed in the Arkansas Valley in Arkansas. Neither the Atoka nor the Winslow has yielded fossils that afford good ground for accurate correlation. The McAlester group, however, as shown by its fossil flora, corresponds in age to the lower part of the Allegheny formation of the Appalachian trough. David White[5] states that the flora of the Coal Hill coal, which lies in the rocks immediately above the Hartshorne sandstone and is commonly called the Hartshorne coal, indicates its basal Allegheny age but adds that the bed contains some Pottsville forms, particularly *Mariopteris* and *Neuropteris*. Probably the lower 1,500 feet or more of the Winslow in the Winslow quadrangle, its lower 600 to 800 feet in the Tahlequah quadrangle, and 200 to 400 feet of it in the Muskogee quadrangle are the stratigraphic equivalent of the Atoka formation, which in the Arkansas Valley in Arkansas reaches a thickness of 7,000 to 8,000 feet, in Oklahoma a thickness of 6,000 to 7,000 feet, and in the Caddo Gap quadrangle, on the southern border of the Ouachita Mountains, a thickness of 6,000 feet. This part of the Winslow and its equivalent, the Atoka formation, which lie beneath a basal Allegheny flora, are doubtless of Pottsville age. In the quadrangles here considered only the basal part of the Winslow formation has escaped erosion, the higher strata being exposed farther south, and this part probably comprises no rocks of later age than the Atoka formation or the Pottsville epoch.

Stratigraphic relations.—The Winslow formation rests unconformably upon the upper or the lower parts of the Bloyd shale or upon the Hale formation, the horizon of its floor at any given place depending upon the amount of erosion that there preceded its deposition. At many places in the Harrison quadrangle it rests upon the Hale formation and at others upon the lower part of the Bloyd. In the Eureka Springs quadrangle it rests at different places upon different horizons of the Bloyd shale, except near Mayfield, east of Marble, and near Kingston, where its floor is formed by the Hale formation. Where it rests upon the shale in the Bloyd formation, the nature of the contact can not be determined, as the lower part of the Winslow is itself shaly, but where it rests upon the Brentwood or the Kessler limestone members or the limestone of the Hale formation the contact is distinct and the surface of the limestone is covered with small irregularities and in places is weathered.

STRUCTURE.

GENERAL FEATURES.

Definition.—The strata in the Eureka Springs and Harrison quadrangles, which must have been deposited in a nearly horizontal position, have undergone little deformation. The general doming of the beds in the Ozark region has given those of this area a slight dip to the south, which is apparent in the Eureka Springs quadrangle but is largely disguised in the Harrison quadrangle by minor folding.

Most of the minor anticlinal flexures form small domes, and the synclinal flexures form basins, but one anticlinal fold is several miles long. In the southern part of the quadrangles the strata are faulted to some extent, but faulting is not general throughout the area.

Modes of representation.—The structure of the quadrangles is represented on the structure-section sheet by eight cross sections, which have been so located as to illustrate both the structure of the quadrangles and, so far as possible, the manner in which the structure has been developed. The sections represent the strata as they would appear in the sides of deep trenches cut across the country. The scale to which these sections are necessarily drawn is too small to show the minor undulations and details of structure and these are therefore somewhat generalized. Faults are indicated by heavy lines, whose inclination shows the probable dip, and by arrows that show the relative directions in which the rocks have been moved.

The structure of the quadrangles is also represented by a contour map (fig. 13) of the deformed surface of the Boone limestone, the formation most widely exposed in the quadrangles. Although the surface of the Boone was exposed to erosion before the sediment of the Batesville sandstone was deposited, the irregularities produced on its surface are probably not so marked as greatly to affect the determination of the structure from it. The deformation map does not necessarily represent exactly the structure of the other formations, because most of them are not persistent throughout the quadrangles, because none are everywhere of uniform thickness, and because in a general way the folding is more accentuated in the lower rocks than in the Pitkin limestone and the higher formations. The relief of the deformed surface in any part of the quadrangles is shown by the contour lines, which on figure 13 represent vertical intervals of 50 feet, the numbers showing elevations above the sea. Faults are shown as heavy black lines.

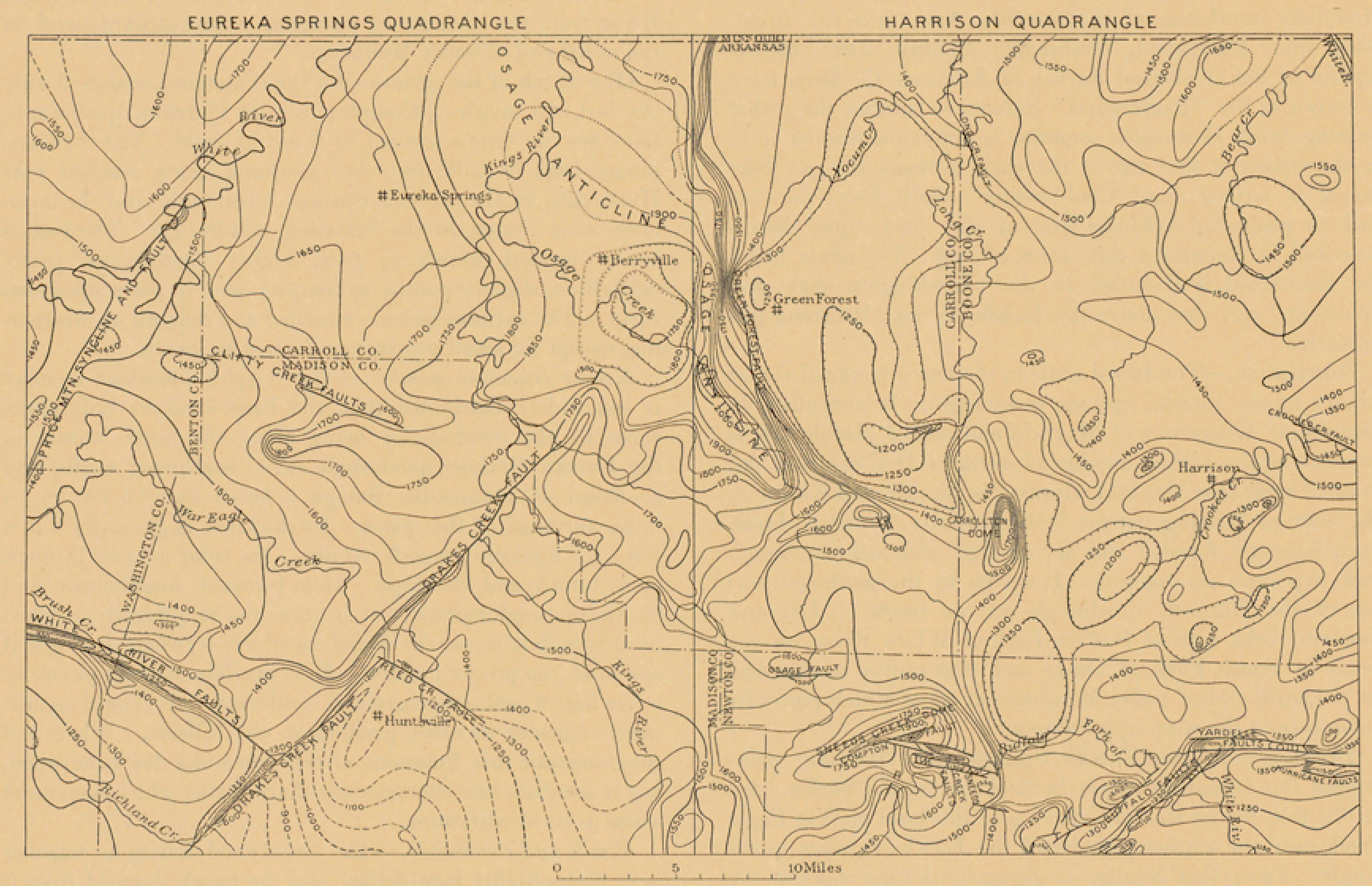

FIGURE 13.—Structure contours on the deformed upper surface of the Boone limestone as determined by the outcrops of the Boone and overlying formations.

Contour interval, 50 feet. Datum plane is mean sea level. Depression contours are hachured. Contours are dashed where Boone limestone is deeply buried beneath later rocks and dotted where the Boone has been removed by erosion over large areas. Faults are shown by heavy lines.

FOLDS.

General features.—The general dip of the beds in the Eureka Springs quadrangle is toward the south, and the dip of most of the beds in much of the Harrison quadrangle is in the same direction, but along the western border of the northern half of the Harrison quadrangle and near the middle part of its southern half there is a marked eastward dip of the Batesville sandstone and the underlying rocks. The large monocline-like folds are not simple, for their more or less gradual slopes are locally interrupted by irregular domes and basins and by transverse flexures, all of which are cut by faults. The folding as a rule is more pronounced in the lower beds than in the upper ones. In fact, at many places the structure of the higher formations, particularly that of the Hale and Winslow formations and to a certain degree that of the Pitkin limestone, does not conform at all to the folds in the lower beds. All, however, were equally affected by the faulting and by the folding of the last period, which was later than the deposition of the material that composes the Winslow formation.

A striking relation between the present drainage lines and the undulations in the strata has been observed in many parts of the quadrangles. On ascending some of the larger streams, and possibly most of the smaller streams, one finds that the strata rise from the mouth of the stream toward its head, any particular bed thus showing a practical parallelism with the bottom of the valley. The great number of places at which this relation was observed suggests that the structure of the strata has in some degree controlled the location of the minor drainage lines. Although the contour map of the deformed surface of the Boone limestone (fig. 13) appears to show on the whole no striking relation between the structure and the general drainage, it is believed that if this map were reconstructed with a much smaller contour interval than 50 feet the parallelism noted above would be shown for a large part of the quadrangles.

Although most of the flexures are so small or so poorly defined as to make their description impracticable, a few are sufficiently pronounced to need special mention. The most prominent of these are the Osage anticline and the Sneeds Creek and Carrollton domes. Sections B–B, C–C, D–D, E–E, F–F, and G–G on the structure-section sheet and the contour map (fig. 13) give an idea of these flexures.

Osage anticline.—The Osage anticline extends southeastward from the northeastern part of the Eureka Springs quadrangle into the southern part of the Harrison quadrangle, where it dies out beyond Osage post office. It is named from Osage Creek, which runs nearly along the axis of the fold. The part of the anticline in the Eureka Springs quadrangle is broad and flat and embraces the undulating basin round about Berryville. Farther southeast, in the Harrison quadrangle, the limbs converge and become flatter, causing the anticline to disappear. The east limb is a well-marked monocline that extends from a point near the northwest corner of the Harrison quadrangle southward to a point west of Green Forest and thence southeastward to the head of Bobo Creek. Near Green Forest it is broken by a normal fault between 5 and 6 miles long. The southwest limb, which is also a distinct monocline, extends from the vicinity of Osage post office, in the Harrison quadrangle, northwestward to Pension Mountain, in the Eureka Springs quadrangle. (See sections A–A, B–B, C–C, and D–D.)

If the Boone had not undergone erosion its surface on the crest of the Osage anticline would have stood a little more than 2,050 feet above sea level, or about 800 feet above the surface of the Boone at Green Forest and about 850 feet above it at Carrollton. These differences in elevation are greater than others that have been noted in other areas adjacent to the anticline, especially to the southwest. The maximum arching of the Hale and Winslow formations is a little less than half that of the Batesville sandstone and the lower rocks, but the arching of the Cotter dolomite in places near the crest of the anticline is a little more accentuated than even that of the Boone. One area where the Cotter is thus affected is on Boat Mountain northeast of Eureka Springs and another is west and northwest of Green Forest. The Powell limestone, which overlies the Cotter in other parts of the quadrangles, is absent from both these areas.

Sneeds Creek dome.—The Sneeds Creek dome is an elliptical anticlinal area comprising 12 to 15 square miles on Sneeds Creek and the head of South Fork of Osage Creek. Its longer axis extends southwestward from the vicinity of Compton toward the corner of the quadrangle. The Batesville sandstone and the underlying rocks are arched to a height of about

[1] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), p. 5, 1905; Muskogee folio (No. 132), p. 4, 1905.

[2] Idem, p. 5.

[3] Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (No. 154), 1907.

[4] Collier, A. J., The Arkansas coal field: U. S. Geol. Survey Bull. 326, p. 12, 1907.

[5] White, David, Report on fossil plants from the coal measures of Arkansas: U. S. Geol. Survey Bull. 326, pp. 24–31, 1907.

400 feet above their level in adjacent areas within 6 miles to the north, west, and south of the crest and to a height of about 650 feet above their level 3 miles east of the crest, but the Hale and Winslow formations are arched to a height of only 250 feet within corresponding distances in the directions indicated. (See sections F–F and G–G.)

Carrollton dome.—The Carrollton dome, which is 4 or 5 miles southeast of Carrollton, is another elliptical anticlinal area of about 4 square miles. Its longer axis extends north and south and its slope is rather steep in all directions but less steep on the southwest. The highest point of the Boone limestone on the dome lies a little more than 1,700 feet above sea level or about 500 feet above the level of the Boone at Carrollton and about 400 feet above that of the Boone a mile east of the dome. The Batesville sandstone appears to be no less influenced by flexing than the Boone. The base of the Hale formation on the dome is arched to a height of about 150 feet, but the base of the Winslow is arched much less. (See section E–E.)

Minor folds.—Among the minor folds there are several that deserve mention. Near the center of the Eureka Springs quadrangle there is an irregularly shaped dome, where the surface of the Boone before erosion attained an elevation of 1,800 feet above sea level. A small dome stands just north of Jasper in the Harrison quadrangle, where the surface of the Boone before erosion was a little more than 1,600 feet above sea level. Another dome is in the northeast corner of the Harrison quadrangle, but its extent is not known, because the Boone, owing to erosion, is absent over a considerable area in this part of the quadrangle. The upper surface of this dome, however, if it had not been eroded, would have reached an elevation of 1,650 feet or more above sea level. The Powell limestone, which is absent from some places on the Osage anticline, is absent also over at least a small area on this dome, and in this area also, as on the Osage anticline, the doming of the Cotter dolomite is more accentuated than that of the Boone.

Several basin-like depressions in the surface of the Boone occur in both quadrangles, though they are larger and occur in greater number in the Harrison quadrangle. The largest basin extends northward through Green Forest, is of irregular shape, and is about 15 miles long.

FAULTS.

GENERAL FEATURES.

Faults are abundant in the southern part of the quadrangles and a few occur in other parts. Some are so close together as to make it doubtful whether they should be regarded as one or more, but there are at least 7 faults in the Eureka Springs quadrangle and 26 in the Harrison. Many of them have already been in part described by J. C. Branner and T. C. Hopkins in reports of the Geological Survey of Arkansas. Most of them are of the normal type, but in three the displacement is almost horizontal. Block faulting has occurred at several places. These faults may be divided into three sets, according to their direction, one set extending northwestward, one northeastward, and one eastward. They were doubtless produced by tension that accompanied the doming of the Ozark region about the close of the Carboniferous period.

NORTHWESTERLY FAULTS.

White River faults.—The most conspicuous of the northwesterly faults lies along Brush Creek in the Eureka Springs quadrangle. It is 25 miles long, but somewhat more than half of this is in the Fayetteville quadrangle, where it swings around to the northeast. This part of the fault is described in the Fayetteville folio, in which it is called the White River fault. The downthrow is on its south side and is about 300 feet at the west border of the area, the Winslow formation there being on a level with the Boone; but probably it is less than 100 feet at the east end, where it terminates against the Drakes Creek fault. In the eastern part of the Fayetteville quadrangle and the western part of the Eureka Springs quadrangle the main fault is paralleled by a secondary fault half a mile to the south. The downthrow of the secondary fault is on its north side and does not much exceed 100 feet. Between the two faults there is a keystone-like block, which is lower than the corresponding rocks on either side and is tilted to the north, but throughout much of its length it is synclinal.

Reed Creek fault.—The Reed Creek fault is 2 miles northeast of Huntsville. It is between 4 and 5 miles long, and its west end is on the line of disturbance of the Drakes Creek fault. (See section A–A.)

Clifty Creek faults.—A series of faults extends from the head of Rockhouse Creek, in the Eureka Springs quadrangle, northwestward to Little Clifty Creek, on the Benton-Madison county line. The faults are not distinguishable throughout the distance, probably because along most of their course the surface rocks are all of one kind, a fact that makes the detection of displacements difficult. The downthrow of the fault at the head of Rockhouse Creek is on its north side and that on Little Clifty Creek is on its south side. These are probably two separate faults.

Green Forest fault.—West of Green Forest, in the Harrison quadrangle, a fault between 5 and 6 miles in length extends along the northeast limb of the Osage anticline. The downthrow is on its northeast side and is about 300 feet at the end of Bradshaw Mountain, from which point it decreases in both directions. (See section C–C.)

Long Creek fault.—There is a short fault on Long Creek 2½ miles northeast of Denver, in the Harrison quadrangle. The downthrow is small and is on its southwest side.

Crooked Creek fault.—On Crooked Creek there is a fault which lies for 3 miles in the eastern part of the Harrison quadrangle and which extends into the Yellville quadrangle on the east. The downthrow is small and is on its northeast side.

NORTHEASTERLY FAULTS.

Price Mountain fault.—In the Eureka Springs quadrangle, in Walnut Township, Benton County, there is a fault extending from Red Bluff on White River to a point 3 miles to the northeast, where it crosses a high point in a bend of White River. The downthrow is 100 feet and is on its southeast side. This fault was not seen in the bluffs about Larue on the south side of White River but was observed at the head of Pine Creek at the crossing of the roads, in the west part of sec. 33, T. 19 N., R. 28 W. At the mouth of Pine Creek it passes into a syncline. It is described in the Fayetteville and Winslow folios as the Price Mountain fault and syncline. Its total length in the three quadrangles is 55 miles.

Drakes Creek fault.—The most persistent fault in the two quadrangles extends northeastward from the south border of the Eureka Springs quadrangle through the town of Drakes Creek to the northern part of Pension Mountain, 5 miles south of Berryville. Its length in the Eureka Springs quadrangle is 27 miles, and it extends southwestward outside the quadrangle. Through most of the 27 miles the displacement is evident, but between the mouth of Holman Creek and the head of Moody Hollow the structure is apparently monoclinal. The fault is plainly visible throughout most of its course south of War Eagle Creek, along Lake Hollow, where it crosses Kings River, and in Sugarcamp Hollow. At the mouth of Canfield Hollow it passes into a syncline, but it again appears as a fault on the north part of Pension Mountain. The downthrow is on its southeast side, and in the southern part of the quadrangle it probably approaches 400 feet. At the mouth of Lake Hollow and where it crosses Kings River the downthrow is about 100 feet. (See section A–A.)

Buffalo faults.—A fault along Little Buffalo Fork, in the southern part of the Harrison quadrangle, extends from Jasper northeastward for a distance of about 7 miles, crossing Big Buffalo Fork in the southeastern part of sec. 8, T. 16 N., R. 20 W. For a part of its course it is a branching fault, the intervening narrow block having relatively dropped down. The displacement is nowhere very great, and as a whole the downthrow is on its southeast side. A mile northwest of this fault and parallel with it there is another fault which shows a maximum displacement of 300 feet, the downthrow being on its southeast side. Near the southwest end of this fault there are three short faults, which extend in general northeastward. The downthrow of the northern fault is on its west side and that of the middle one is on its south side; the southern one shows only horizontal displacement. On the south side of sec. 14, T. 16 N., R. 21 W., there is a short fault, parallel to the principal faults of the group, with a downthrow of 50 feet on its northwest side; and farther northeast along this line of disturbance, on the south side of Buffalo Fork of White River, there is a fault half a mile long, with a downthrow of 100 feet on its northwest side. (See section H–H.)

Ponca faults.—North of Ponca, in sec. 18, T. 16 N., R. 22 W., there are three small faults. The downthrow of the southern one is on its southeast side and is about 40 feet. The displacement in the northern two, which are very near together, is horizontal. A mile west of the mouth of Sneeds Creek there are two very short northeasterly faults, which have a slight downthrow on their southeast sides. A mile and a half farther upstream there is a similar fault, which shows a downward displacement to the northwest.

Compton fault.—Two miles southwest of Compton, near the head of Sneeds Creek, there is a fault 2 miles long. The maximum displacement of this fault somewhat exceeds 300 feet, and the downthrow is on its southeast side. The displacement continues southwestward as a monocline, which is well marked on the head of South Fork of Osage Creek.

EASTERLY FAULTS.

Dry Creek fault.—Near the southwest corner of the Harrison quadrangle, on Dry Creek, there is a fault less than a mile long, which ends at the west margin of the quadrangle. The displacement is slight and the downthrow is on its south side.

Osage fault.—A fault somewhat more than 2 miles long crosses South Fork of the Osage, in secs. 21, 22, and 23, T. 17 N., R. 23 W. The downthrow is about 100 feet and is on its south side.

Sneeds Creek faults.—On Buffalo Fork of White River near the mouth of Sneeds Creek four parallel faults lie close together. The downthrow of the southern one is on its north side and that of the northern one on its south side. The displacement of the group is complicated and can best be understood by referring to sections F–F and G–G of the structure-section sheet. The faults are closely associated with the Sneeds Creek dome and are terminated at the east by a short northward-trending fault and monocline. On a high point overlooking the river a mile and a half south of the east end of this group of four faults there are two short faults, the northern one having a downward displacement of about 50 feet on its south side, and the southern one a displacement of more than 100 feet on its north side at the east end, the block between them having relatively subsided that much.

Yardelle faults.—Two faults that lie a quarter of a mile to half a mile apart extend westward from a point near Yardelle, in the southeastern part of the quadrangle. The southern one is 7 miles and the northern one 5 miles long. At this place the intervening block has relatively sunk a distance equal to the thickness of the Boone limestone, which is about 300 feet.

Hurricane faults.—The two Hurricane faults enter the quadrangle from the Yellville quadrangle on the east. They have a total length of 13 miles, 3 miles of which is in the Harrison quadrangle, and they are a quarter to half a mile apart. The intervening block is displaced downward somewhat more than 200 feet.

GEOLOGIC HISTORY.

GEOLOGIC RECORD.

The geologic history of the Eureka Springs and Harrison quadrangles is recorded in the plains, hills, and valleys and in the numerous layers of rock at and below the surface. The geologic events now to be related have been therefore disclosed by a study of the topographic features and the rocks. The geologic record in the quadrangles is far from complete, but much of their history may be inferred from studies made in other parts of the Ozark region, for the same processes that operated in these quadrangles operated also and affected somewhat similarly a large region around them. Much of the history of the smaller area is therefore deduced from the more complete record found in the Ozark region as a whole.

The oldest formation exposed in the quadrangles is the Cotter dolomite, of Lower Ordovician age. Still older Ordovician strata are exposed farther east in Arkansas, and older Ordovician and Upper Cambrian beds and pre-Cambrian crystalline rocks are exposed farther northeast, in Missouri. It is from the results of studies made in those areas, chiefly by others than the authors, that the earliest geologic events in these quadrangles are inferred.

PALEOZOIC ERA.

CAMBRIAN AND EARLY ORDOVICIAN DEPOSITION BEFORE COTTER TIME.

At the opening of the Paleozoic era probably all the surface of the Ozark region had been above the sea for a long time and had undergone great erosion, but late in the Cambrian period the region was gradually submerged. The first deposit laid down in the encroaching sea consisted of sand and pebbles, which later formed sandstone and conglomerate, respectively. Then followed the deposition of magnesium and calcium carbonates, which subsequently hardened into dolomites and magnesian limestones. From time to time more or less sand and mud were delivered to the sea, but the rocks formed from these terrigenous deposits are only a small part of those now exposed. The submergence lasted through the early part of the Ordovician period except during intervals when parts or all of the region became land, as is attested by conglomerates and sun cracks.

ORDOVICIAN SEDIMENTATION DURING AND AFTER COTTER TIME.

Cotter deposition.—During Cotter time, while some Beekmantown deposits were being formed in the north-middle Appalachian region, the sea occupied at least the southern and eastern sides of the Ozark region. If it extended over the whole province the rocks formed in the northern part were subsequently removed. However, the sea occupied much of the upper Mississippi Valley, where it received deposits that formed the Shakopee dolomite, with the lower part of which the Cotter dolomite is correlated. The chief deposits were calcium-magnesium carbonates, which formed dolomite, but some mud and considerable quantities of sand were also at many times brought into the sea. A large quantity of silica that was deposited contemporaneously with the other materials has in many places produced chert. The great preponderance of dolomite implies a sea of clear water adjacent to land of low altitude. That the water was shallow is apparent from ripple marks of short wave length. At times parts of the region were elevated into land, and then sun cracks were formed on exposed mud flats and pebbles and other detrital material were carried from the eroded areas into the sea by running water. It is uncertain whether the sea was then the abode of animals whose shells supplied the large quantity of calcareous material that now forms limestone of this age or whether this material was deposited as a chemical precipitate, but probably the limestone was formed, at least in large part, by chemical precipitation. Nevertheless, the few fossil remains preserved in certain beds show that the seas of this time contained some marine life. A withdrawal of the sea as a result of uplift, accompanied by a warping of the rocks into broad, flat folds, brought Cotter deposition to a close, and the area was exposed to erosion that removed the tops of the folds.

Powell deposition.—Later in the Beekmantown epoch the southern and eastern parts of the Ozark region, as well as areas in the upper Mississippi Valley, were again submerged, but there is no evidence that the northern part of the Ozark region was under water at this time. The first deposit of Powell time in the quadrangles consisted of scattered beds of more or less rounded pebbles, but the character and arrangement of some of the material at the base of the Powell limestone indicate that it is a residual mantle recemented in place. Low reefs of white quartz sand were built up in the western part of the Eureka Springs quadrangle. When the shore receded farther from the areas or when the water became less agitated calcium carbonate, some magnesium carbonate, and a little mud were laid down. These sediments on solidifying formed earthy magnesian limestone. The forms of marine life, if we may judge from the remains preserved in certain beds, were chiefly gastropods, trilobites, and cephalopods. The paucity of such remains, which constitute only a very small part of the limestone, and the fact that the conditions were not unfavorable to the preservation of fossils, suggest that most of the rock was probably formed by chemical precipitation. An uplift, which was accompanied by a slight warping of the southern Ozark region and an accentuation of the old arches, brought Powell deposition to a close and exposed the area to denudation, which removed much of the limestone.

Everton deposition.—After the uplift just mentioned, at least the southern part of the Harrison quadrangle and parts of the adjoining Yellville quadrangle were covered by the sea, the submergence taking place in post-Beekmantown and possibly pre-Chazy time. At first, fragmental materials from the Powell limestone were laid down here and there in the encroaching sea, but as the shore line advanced and the water became clearer calcium carbonate, some magnesium carbonate, and a little sand were laid down. This material formed the sandy magnesian limestone that constitutes the Sneeds limestone lentil. Marine life was obviously meager, for only a few fossils have been found in the lentil, and these have been obtained from the basal conglomerate in the Yellville quadrangle. An elevation and a relatively short interval of erosion followed and was succeeded by a more widespread submergence of the base-leveled land, which included at least the Eureka Springs, Harrison, and Yellville quadrangles and other parts of the southern Ozark region, besides much of the eastern flank of the region. While the sea in its advance, presumably toward the north, was still shallow, sand that locally contained pebbles and afterward sand without pebbles accumulated to a depth reaching 40 feet in places in the Eureka Springs quadrangle and to a less depth in the Harrison and Yellville quadrangles. This supplied the material for the Kings River sandstone member. In this epoch the sea water was clear and some sand and perhaps a very little mud were deposited. The unusual roundness of the sand grains indicates that they had been much handled by wind on the beach before the land was submerged, and the purity of the sandstone suggests that as submergence went on the sand was washed over and over by the waves until all its finer material had been carried away in suspension.

As the shore advanced and the water released its sand the deposition of sand and gravel was followed by the deposition of calcareous material, which in places formed as much as 100 feet of limestone, but considerable quantities of white sand were still frequently delivered to the sea. When the sand was most abundant it alone was deposited, subsequently becoming sandstone, and when it was scarce it was laid down simultaneously with calcareous material, the two producing sandy limestone. An intraformational conglomerate found at some places in the basal part of the limestone overlying the Kings River member indicates agitated shallow water or possibly a local retreat of the water at such places. Marine animals, chiefly ostracods, pelecypods, and gastropods, were abundant at times during the later part of Everton deposition.

At the close of Everton time the sea withdrew, presumably to the south, and the uplifted land underwent considerable erosion, by which the Everton was entirely removed from the northern part of the quadrangles and possibly from other parts of the Ozark region. The limestone over much of the quadrangles was channeled by ground-water solution, as well as by streams that in places cut to a depth of 10 feet or more. The sands that formed the St. Peter sandstone buried this irregular surface, which is well and interestingly exposed in many of the bluffs. Besides the Eureka Springs and Harrison quadrangles a considerable part of the Ozark region, if not the entire province, was at this time land, as is shown by the eroded surface of the strata overlain by the St. Peter sandstone, which succeeds the Everton limestone.

St. Peter deposition.—The period of uplift and erosion just described was followed by a period of depression during which the sea readvanced, probably from the south. The water was shallow and sand that subsequently formed the St. Peter sandstone was deposited over the quadrangles, as well as over much of the rest of the Ozark region and a large part of the upper Mississippi Valley. This sandstone-making epoch was like the Kings River epoch. The sea was clear and it received from the land much quartz sand, which was assorted by the water after it had been thoroughly rounded on the beach by the wind. The sand deposited in St. Peter time was probably not laid down along a single permanent shore from which it was derived, but along a shore line that advanced across the area as the land was gradually submerged, so that the exact age of the formation varies from place to place.

Joachim deposition.—The Joachim limestone, the next formation in order of age, is widespread about the borders of the Ozark region and represents, according to E. O. Ulrich, an offshore deposit formed during the last half of the time consumed in the tangential deposition of the beach sands of the St. Peter. Nevertheless, some quartz sand, like that in the underlying beds of heavy sand, continued to be delivered to the sea and was at places laid down with calcareous material and a small amount of magnesium carbonate, which together produced sandy limestone. At other places the sand was sufficient in quantity to form sandstone that included but little calcareous material. The paucity of fossils indicates that marine life was then meager. The slightly irregular contact between the Joachim limestone and the succeeding Jasper limestone suggests that deposition of the Joachim may have been terminated by a retreat of the sea from the Harrison quadrangle.

Jasper deposition.—A shallow sea at the beginning of Jasper time is indicated by sandstone at the base of that formation. If a land interval preceded that time the sands that formed the basal bed of the Jasper, like those that formed the Kings River and the St. Peter sandstones, were probably spread along the shore of an advancing sea. In Jasper time, as in Kings River and St. Peter time, the water of the sea was clear and shallow. The sand may have been derived from the eroded Joachim limestone or even from older formations. When the water became freer of detrital sediment calcareous material was deposited and formed limestone beds, but at intervals thin layers of pure sand were also laid down. Perhaps, as suggested by the presence of the fossil of the genus *Raphistomina*, which is common in the Everton limestone, the Jasper limestone represents the final stage of the series of deposits (the Everton limestone, the St. Peter sandstone, and the Joachim limestone) which, according to E. O. Ulrich, represents a time interval between the Beekmantown and the Chazy of the New York section. Marine animals, principally ostracods, gastropods, cephalopods, and pelecypods, lived in the sea at this time, but the relative scarcity of their remains shows that they were not numerous. The contact between the Jasper limestone and the succeeding Fernvale limestone is not exposed at the single locality in the Harrison quadrangle at which the Fernvale outcrops, but the Plattin and Kimmswick limestones of Black River age, which, according to Ulrich, were deposited farther east in Arkansas after the Jasper and before the Fernvale, have been found nowhere in the quadrangles. This fact, in addition to the faunal evidence that the Jasper is possibly of pre-Chazy age and that the Fernvale is of Richmond age, indicates a stratigraphic break between them, which means that at least the part of the Ozark region comprised in the Harrison quadrangle was above water after Jasper time. Furthermore, the unconformable relations of the Plattin to the Joachim farther east in Arkansas indicate that much of the southern Ozark region outside the Harrison quadrangle was land during or after the close of Jasper deposition.

Fernvale deposition.—At the beginning of Richmond time probably all the Ozark region was land, but during this time the sea submerged much of the southern and eastern flanks of that region as well as other areas in the Mississippi Valley. The first deposit during this submergence in northern Arkansas was the calcareous material now constituting the Fernvale limestone. The numerous fossils found in this limestone show that marine life was then abundant. Although this formation is exposed in the quadrangles at only one locality, near Jasper, it is exposed over rather large areas in Arkansas farther east. After Fernvale time the sea receded from the submerged areas, which were thus exposed to denudation.

Cason deposition.—A comparatively short erosion interval followed Fernvale time, and then the sea readvanced over parts of the land and received a thin deposit of phosphatic conglomerate in which numerous minute marine shells are preserved; later, fine waste from the land was laid down as calcareous mud, which subsequently formed the Cason shale. Farther north in the Mississippi Valley the sea was at this time receiving the mud that became the Maquoketa shale. At the close of Cason time there was a widespread uplift and local folding of the Ozark region and a long period of erosion, which in the Eureka Springs and Harrison quadrangles apparently continued throughout Silurian and early Devonian time.

SILURIAN SEDIMENTATION.

Throughout the Silurian period these quadrangles and most other parts of the Ozark region were land that was undergoing erosion. This land may at first have stood several hundred feet above sea level, but it was eventually reduced to a low, featureless plain, truncating the Ordovician formations down to and including the Powell limestone of Lower Ordovician age. The eastern and southern borders of the Ozark province were covered by the sea in Medina and Niagara time. There is no reason to believe that the sea at these times occupied any part of the quadrangles, but its shore lay not far away from them, for the limestone known as the St. Clair, which was then formed, is exposed in the southern part of the adjoining Yellville quadrangle.

DEVONIAN SEDIMENTATION.

Clifty deposition.—In early Devonian time the geography of the area was apparently not essentially different from that of the Silurian period, but in Middle Devonian time a narrow arm of the sea extended into the west-central part of the Eureka Springs quadrangle. The extent of this submergence is not known. In fact, all the known exposures of Middle Devonian rocks on the southern flank of the Ozark region are found within an area of about half a square mile on East Fork of Little Clifty Creek. Well-rounded quartz sand, most of which was probably derived from the Kings River sandstone, was spread out upon that sandstone as a layer which nowhere exceeded 18 inches in thickness and to which some calcareous material as well as the remains of marine invertebrates were added. When the water became freer of sand fine-grained limestone was formed. Clifty deposition, which was probably of short duration, was ended by an uplift of the region, by which the waters of the sea were forced beyond its borders, and the parts that had been submerged were exposed to denudation.

Chattanooga deposition.—Late in the Devonian period the sea transgressed upon much of the southern and eastern flanks of the Ozark region and possibly upon the whole of the Eureka Springs and Harrison quadrangles. Although the Devonian strata are unconformable with those beneath, the unconformity shows clearly that the surface upon which they were deposited was even and that it stood so low that but slight change in the level of either the land or the sea was required to submerge it. The first deposit of Chattanooga time consists of well-rounded quartz sand derived from several Ordovician beds that were exposed along the shore, and this sand was spread out in a thin bed which subsequently formed the Sylamore sandstone member. The next deposit consisted of fine black mud, which on solidifying formed the Chattanooga shale. The sea then receded from the area, leaving it as a flat, low-lying, featureless plain, which was not greatly altered by erosion.

Some of the sandstone mapped as the Sylamore sandstone member in those parts of the quadrangles where there is no overlying shale of the Chattanooga may represent the first deposit of early Mississippian time. Though the absence of fossils in this sandstone leaves its age in doubt it is similar in lithologic character and stratigraphic position to the Sylamore. If it is of Mississippian age Chattanooga deposition may have taken place in embayments whose shore lines did not extend far beyond the present borders of this shale; if it is of Devonian age it is necessary to assume the removal by erosion of considerable areas of the overlying shale. The authors hold the view that in most if not all parts of the quadrangles this sandstone is of Devonian, not Mississippian age.

CARBONIFEROUS SEDIMENTATION.

MISSISSIPPIAN SEDIMENTATION.

Boone deposition.—Boone deposition began on the readvance of the sea, after a brief recession indicated by a conglomerate that lies here and there above the Chattanooga shale, by the probable erosion of the Chattanooga from parts of the quadrangles, and by general absence of deposits representing the earlier divisions of the Kinderhook group. Before the close of the Kinderhook epoch much of the Ozark region, including these quadrangles, was again submerged. By this advance and the consequent deepening of the sea the distance of this area from the shore was increased, and limy deposits were laid down instead of fine mud and sand. These deposits were almost everywhere put down in layers of uniform thickness, indicating quiet waters; but overlap phenomena and cross-bedding in the St. Joe limestone at Yardelle, in the Harrison quadrangle (see fig. 11, p. 11), and the overlap of rocks of Keokuk or late Burlington age on irregularly bedded strata of Fern Glen age, overlying the St. Joe, on War Eagle Creek, in the Eureka Springs quadrangle (see Pl. VIII), indicate agitated waters in restricted areas. Truncation of the beds beneath the overlap at those places is perhaps due to submarine erosion.

During the Burlington, Keokuk, and Warsaw epochs there was an admixture of the limy deposits with silica which produced the chert in the Boone limestone. Marine animals, chiefly crinoids, though these were accompanied by great numbers of brachiopods, bryozoans, and other forms, were abundant, and their remains are well preserved at several horizons in the formation. The broad extent of this submergence, which continued through the Keokuk epoch and into the Warsaw epoch, is shown by the presence of the Boone all along the southern and western flanks of the Ozark region and of correlative formations along the northern and eastern flanks.

A retreat of the sea at the close of Boone deposition again brought the area above water. The erosion that followed and continued until Chester time in the Eureka Springs and Harrison quadrangles did not produce marked irregularities in the surface of the Boone limestone, but in southwestern Missouri and northeastern Oklahoma the erosion at this time was accompanied by underground solution, the result being the formation of sink holes in which later deposits were laid down.

Batesville deposition.—In the early part of the Chester epoch the land comprised in the Eureka Springs quadrangle and most of that of the Harrison quadrangle, besides extensive areas to the west and northwest, subsided and were covered by a shallow limestone-making sea in which the Hindsville limestone member was formed. From time to time more or less quartz sand, which later became sandstone, was at some places carried to the sea and at other times and places was mixed with calcareous material and cemented into sandy limestone. At the beginning of the submergence chert fragments, some of them well rounded and others angular, were deposited here and there. It seems probable that the Hindsville limestone marks only the beginning of the submergence of this area and that it was not laid down over the whole of it, for there is neither physical nor faunal evidence of any succeeding erosion that would have removed it from areas where it is wanting.

Later in the Chester epoch, when the southern and eastern flanks of the Ozark region were more widely submerged, large quantities of quartz sand were brought from some land area whose position is not known and were spread out over the sea bottom, forming the Batesville sandstone, which in the quadrangles is thickest to the northeast and thinnest to the southwest. This sand contained some calcareous material, and the combination formed a calcareous sandstone. The general occurrence of cross-bedding in the sandstone indicates shallow water. The Batesville sandstone, like the Hindsville limestone, probably marks the limits of a stage of submergence, for it is absent from considerable areas in the southwest corner of the Eureka Springs quadrangle and farther west, in Arkansas and eastern Oklahoma. Certain invertebrate marine forms were common while the material of the Hindsville limestone was undergoing deposition but more rare while that of the overlying sandstone of the Batesville formation was being laid down.

Fayetteville deposition.—With the continued advance of the sea on the southern and southwestern borders of the Ozark region during the Chester epoch a bed of black mud was laid down, which, on solidifying, formed a shale known as the Fayetteville shale. The deposition of this mud was interrupted by a bed of sand that formed the Wedington sandstone member. This sand was delivered to the sea probably as the result of an elevation of the land that supplied it. There were also brief periods at and near the beginning of Fayetteville time and near its close during which the water was sufficiently clear to permit limestone to be formed. The oscillations of the land evidently flexed the rocks in parts of the area of deposition, as is indicated by the varying thickness in northern Arkansas of both the lower and the upper shales and of the Wedington member. The most prominent flexures produced, in part, at this time are the Osage anticline and the Carrollton and Sneeds Creek domes. But this anticline, and probably the two domes, had their incipiency at a much earlier date, between early Ordovician and late Devonian time.

A short period of erosion may have followed Fayetteville deposition, a probability suggested by the overlapping relations of the Pitkin limestone, which at some places rests upon the upper shale, at others upon the Wedington sandstone member, and at still others possibly upon the lower shale. However, no traces of an unconformity, such as a conglomerate or an irregular surface, have been observed at this horizon. As has been suggested, the varying thickness of the beds of the Fayetteville appears to be due in large measure to unequal sedimentation over a flexed, undulating surface.

Pitkin deposition.—After the mud of Fayetteville time had been laid down calcareous deposits were formed over a wide area. These deposits represent a time of minimum deposition of detrital material and consequently a time when the sea was clear. It was during this epoch that the Pitkin limestone was formed. Marine invertebrate animals lived in great numbers, especially bryozoans, corals, crinoids, and brachiopods, which denote Chester age for the limestone, wherein their remains are well preserved.

Mid-Carboniferous erosion and deformation.—The Pitkin limestone was the last deposit of Mississippian time, at the close of which probably all the Ozark region that had been submerged became land, except, possibly, small areas along the southern border of the quadrangles and larger areas farther south. The rather uniform thickness and even surface of the top of the Pitkin limestone over these southern parts of the quadrangles suggest that little if any erosion took place there, but in areas farther north the Pitkin and the upper part of the Fayetteville shale were truncated by erosion. In southwestern Missouri and toward the center of the Ozark uplift the Boone limestone shows evidence of mid-Carboniferous erosion, and the depressions in its surface still contain remnants of Pennsylvanian conglomerates and shales. In the region farther north Pennsylvanian deposits rest upon Ordovician rocks.

The folds or flexures which were started earlier were accentuated at this time, as is shown by the absence of the Pitkin limestone and the marked thinning of the Fayetteville shale over the Osage anticline, the Carrollton dome, and the Sneeds Creek dome, which are the most conspicuous flexures in the quadrangles.

PENNSYLVANIAN SEDIMENTATION.

During Pennsylvanian time the sea again transgressed upon the land, submerging all of northern Arkansas and parts of southern Missouri, besides the western, northern, and eastern flanks of the Ozark region and other large areas in the interior of the continent.

Hale deposition.—The first rocks formed during the Pennsylvanian epoch constitute the Hale formation, which is the lowest formation of Pottsville age exposed in the Ozark region. A basal conglomerate consisting of rounded pebbles derived from the Pitkin limestone was laid down here and there along the advancing shore and was overlain by sand, mud, and calcareous material, forming sandstone, shale, and limestone, respectively. The rather coarse grained, cross-bedded calcareous sandstone of this formation, which contains fossil wood and lenses of limestone and shale, was undoubtedly formed near the shore. Into some parts of it sand was carried, into others mud, and into still others organic matter, all of which were more or less thoroughly mixed by the undertow, waves, and littoral currents.

Bloyd deposition.—The varying conditions of Hale time were followed, later in the Pottsville epoch, by conditions that were more uniform over the areas and resulted in the deposition of mud which on hardening formed the Bloyd shale, but early in this time the turbid waters twice became clear and at these two times material was deposited that formed the Brentwood and Kessler limestones. In the time between the deposition of these two limestones swamps existed farther west in Arkansas, where vegetal matter accumulated that was later changed to coal.

After the deposition of the Bloyd shale these quadrangles and much of the rest if not all of the southern Ozark region again became land. During the period of erosion thus begun the shale was removed from much of the Harrison and from parts of the Eureka Springs quadrangles, the erosion causing an unconformity there, by which the succeeding Winslow formation rests in places upon the Hale formation. This unconformity has been observed by J. A. Taff in the Tahlequah and Muskogee quadrangles of Oklahoma, but if it occurs in the intervening Winslow and Fayetteville quadrangles it is not conspicuous. The northward extent of this emergence and the erosion producing this unconformity can not be determined, for the rocks by which it could have been disclosed have been removed by erosion.

Winslow deposition.—Sandstone in itself is considered a shallow-water deposit, but the fact that the heavy sandstone beds of the Winslow formation were laid down in shallow water in which there were shifting currents is further shown by the common occurrence of cross-bedding and ripple marks. Furthermore, some of the numerous beds of shale that constitute so large a part of the Winslow formation contain thin layers of cross-bedded sandstone, and this and their numerous ripple marks of short wave length show that they too are shallow-water deposits. The alternating layers of sandstone and shale are the combined result of crustal movements beneath the sea and on the land and of shifting littoral currents caused by changes in the contour of the shore line and the profile of the ocean beds.

The Winslow in the Eureka Springs and Harrison quadrangles is probably of Pottsville age. Its age and relations outside these areas have been briefly discussed on pages 15–16.

POST-CARBONIFEROUS DEFORMATION.

Although the youngest rocks in the southern Ozark region belong to the Pennsylvanian this part of the region was doubtless permanently added to the land before the close of that epoch. C. E. Siebenthal has expressed the opinion that the emergence took place about the close of the Allegheny or middle of the "lower Coal Measures" time, but the region to which he refers as being thus affected is southwestern Missouri.[1] Probably a much wider area than that, perhaps all the rest of the southern Ozark region, including the Eureka Springs and Harrison quadrangles, was raised above water at this time. The region, however, was affected by increased uplift of the land, which may have raised some submerged parts above the sea, and which was accompanied by the widespread crustal movement that occurred at the close of Carboniferous time. No record remains that this area was again the seat of sedimentation, except possibly for a brief time when the waters of the Upper Cretaceous and Tertiary seas, which covered the eastern part of Arkansas and adjacent areas, may have encroached upon its southeastern slope. The forces that elevated the land and folded the rocks south of Arkansas River here lifted the region bodily upward. Therefore the rock beds, except in the small areas that exhibit flexures, are horizontal or dip at very low angles over the Ozark Plateau and the northern part of the Boston Mountains. These forces, however, accentuated some of the old folds, notably the Osage anticline and the Sneeds Creek dome. The Carrollton dome was but little affected. The faulting of the strata took place near the close of the Carboniferous period and was probably contemporaneous with the flexing.

MESOZOIC AND CENOZOIC ERAS.

Had the region not suffered erosion after uplift it would have stood much higher than it stands now and the surface of the quadrangles would have been nearly level, though broken here and there by irregularities due to faulting and slight flexing of the strata; but no sooner did the region become land than subaerial and subterranean erosion began to reduce it. At least 1,000 feet of material has been removed from those parts of the quadrangles over which the Boone limestone is the surface rock, and 1,400 to 1,700 feet from those parts where the Cotter dolomite is the surface rock.

During this period of erosion in northern Arkansas three structural plains—the Boston Mountain Plateau, the Springfield Plateau, and the Salem Plateau—were formed. Each of them has an undulating surface that is cut by canyon-like valleys, and above the lower two stand isolated remnants of the next higher slowly vanishing upland surface.

The erosion that formed these physiographic features doubtless has not continued at a uniform rate from the time of the emergence of the region to the present but has been at times retarded by a reduction of the area to moderate relief and at other times accelerated by a new uplift, which began a new cycle. How many such cycles the region has undergone is not known.

The rather even summits of the Boston Mountains, which form essentially a plateau, suggest that they represent a former peneplain or base-leveled surface, but the authors of this folio are inclined to the view that their evenness does not imply a former base-level but has been determined by the preservation of the resistant beds of the Winslow formation. As a matter of fact, any existing evidence of a former peneplain would be difficult to detect in a region that was originally a nearly level coastal or structural plain. The rock strata are nearly horizontal over much of the Boston Mountain Plateau, and as denudation proceeded the same beds might well have been exposed throughout wide areas and have simulated a peneplain.

The Springfield Plateau in much of the Eureka Springs quadrangle and probably in parts of the Harrison is a southward and southeastward extension of the erosion surface in southwestern Missouri that has been described as a Cretaceous-Tertiary peneplain. If the recent erosion and canyon cutting in the surface of the Springfield Plateau were disregarded and only the flat-topped uplands of this plain and the Boston Mountains and their outliers were considered, the old graded surface would be practically reproduced over parts of the quadrangles, but it is not known just how far northward in the quadrangles the Boston Mountain Plateau extended during Cretaceous and early Tertiary time. This Cretaceous-Tertiary surface probably corresponds approximately to the upper surface of the Boone limestone, though in the northwestern part of the Harrison quadrangle, as well as in other areas where the surface of the Boone is relatively low, it may have been developed on higher formations that were afterward removed. The main drainage lines cut in the southern Ozark region at the time this erosion surface was formed were White River and Arkansas River, from which small tributaries gradually cut back toward the divide between the two. Many of the streams doubtless reached grade and developed meandering courses.

Not long after the deposition of the Eocene sediments in the Mississippi embayment, which includes parts of eastern Arkansas and southeastern Missouri, an uplift brought the Ozark region nearly to its present elevation. In this cycle the Salem Plateau in the quadrangles was formed and the surface of the Springfield Plateau was doubtless reduced, the extent of the reduction depending on the character of the rocks exposed. It is not known whether that part of the Salem Plateau within the quadrangles represents a former base-leveled area cut by rejuvenated streams or whether it is simply a structural plain due to the resistant strata that form most of its surface and to the

[1] Siebenthal, C. E., U. S. Geol. Survey Geol. Atlas, Joplin district folio (No. 148), p. 11, 1907, (reprinted in 1914).

removal by denudation during the present cycle of the softer strata overlying it. Further stratigraphic and physiographic study of this interesting problem outside the quadrangles is necessary before it can be solved. At present, however, the authors, in view of the evidence available in northern Arkansas, where they have studied this physiographic feature, hold to the view that this plateau is a structural plain due to resistant strata.

The sluggish meandering streams of Cretaceous and Tertiary time were rejuvenated by the uplift of the region at the close of the Eocene epoch and since then have been rapidly cutting their beds downward. At the same time they have shifted laterally by undercutting the outsides of their curves, thus greatly lengthening the original swings. A slight curve once begun may become a large curve in a vigorous, downward-cutting stream as well as in a weak, depositing one. That the curves of these streams, many of them bold and compressed, have been in large part formed since the Eocene epoch is at once evident from the slopes above the streams, which are long and gradual on the inside and precipitous on the outside. The inside slopes are strewn with more or less terrace gravel; the outside slopes are bluffs that commonly have a height of 200 to 300 feet, though one bluff is 500 feet high. (See Pl. I.)

The courses of the streams have been determined partly by the structure. The strata in this area have some major flexures and numerous minor ones. The larger flexures have determined the general courses of some of the streams, and probably the smaller flexures, which are "wobbles," have determined many minor bends. As the flexures are more pronounced in the older than in the younger rocks the streams are more and more influenced by them as they lower their beds. As a result of this influence of structure, possibly most of the smaller streams flow with the pitch of the folds, several of the larger streams flow in anticlinal valleys or synclinal troughs, and many curves of both the large and the small streams are in the depressions of the structural wobbles.

Though the structure of the area has determined or affected the minor features of the streams, yet, as may be seen by reference to the contour map of the deformed surface of the Boone limestone, there is no striking relation between the structure and the general drainage. White River, in the northwestern part of the area, follows a syncline, but it flows against instead of with the plunge. The upper part of War Eagle Creek flows across an anticline instead of following the Drakes Creek fault and joining Kings River or Richland Creek. Kings River flows for a part of its course along the strike of a monocline, and Keels Creek, one of its tributaries, flows against the dip. Osage Creek follows the Osage anticline for a part of its course but flows against the plunge of the anticline at its southeast end. Yocum, Long, Bear, and Crooked creeks and Buffalo Fork of White River follow their courses regardless of structure.

The present drainage is probably the result of numerous captures and other diversions of streams effected at the time they flowed over rocks that were long ago removed by erosion, their removal obliterating all clues to that part of the drainage history. It is not improbable, however, that the part of White River in northwestern Arkansas formerly flowed westward into Oklahoma through Illinois River and its tributaries but was captured by a stream working its way back southwestward from Missouri. Probably, also, the upper part of War Eagle Creek formerly flowed into either Richland Creek or Kings River and was captured by the main stream, and the upper part of Osage Creek formerly flowed either southwestward into Dry Fork or northward into Long Creek and was captured by the main stream working its way backward along the axis of the Osage anticline.

MINERAL RESOURCES.

The important mineral resources of the Eureka Springs and Harrison quadrangles consist of building stone, clay, lime, cement, road materials, glass sand, ores of zinc and lead, and bituminous shale.

STRUCTURAL MATERIALS.

Building stone.—Near Beaver, in the Eureka Springs quadrangle, building stone is quarried from the Cotter dolomite. It is compact gray magnesian limestone or dolomite, in beds from 2 to 4 feet thick. The best beds afford durable building stone of pleasing color.

In and about Eureka Springs, Harrison, and Jasper, the St. Joe limestone furnishes stone for retaining walls, buildings, and culverts. Usually the stone is selected from the red portion of the member and when put up as ashlar it makes an attractive building of massive appearance.

The stone of the calcareous beds in the Boone limestone above the St. Joe has a pleasing light-gray color, is compact, and is largely crystalline. Much of it would make superior building stone and it would be extensively used for that purpose if a demand existed. The Hindsville limestone member of the Batesville sandstone is firm, of a pleasing gray color, and would make good building stone. The limestone for the columns at the front entrance of the main building of the University of Arkansas, at Fayetteville, was quarried from this limestone on Brush Creek, in the Eureka Springs quadrangle.

Other formations that afford building stone are the Jasper limestone, the sandstone of the Batesville formation, and the Hale formation. The Jasper limestone makes a beautiful and durable building stone and is used at Jasper. The Batesville sandstone has a rather pleasing brown color and can be easily quarried in blocks having even faces, determined by bedding planes. It is used in Green Forest and Harrison and on farms. The thin-bedded sandstone of the Hale formation is used in constructing buildings at Hindsville and Huntsville and by farmers for foundations and retaining walls.

Clay.—The residual clays in the Boone limestone and in the Cotter dolomite will make good common bricks if properly worked. Some of them are used for making bricks to supply the local demand. The Fayetteville and other shales of the areas, as well as their residual clays, could be used for the same purpose.

Lime.—Small quantities of lime have been burned at several places in the quadrangles, but it is now burned only at Garfield and near Huntsville, in the Eureka Springs quadrangle, where a superior grade of lime is made from the Boone limestone. The lime made at Garfield is shipped, but that made at Huntsville is used only to supply the local demand. Besides limestone in the Boone and its St. Joe member, other limestones that are widely distributed and are sufficiently free from magnesium and other impurities for making lime are the Everton, the Jasper, the Pitkin, the Hindsville, and the Brentwood.

Cement.—Limestone suitable for making Portland cement can be obtained from the limestones just named, and shale for this purpose from the Chattanooga, the Fayetteville, and the Bloyd shales and the Hale and Winslow formations.

ROAD MATERIALS.

The chert of the Boone limestone is left in large quantity on the surface as a residual product. Under climatic influences it is broken up into small fragments that make admirable road material. In many places the fragments have collected in enormous quantities as talus at the base of the slopes, where the material could be easily loaded on wagons with a steam shovel.

OTHER NONMETALLIC MINERALS.

Much of the St. Peter sandstone and of the Kings River sandstone is saccharoidal and fragile and is composed of practically pure silica. It is well suited for the manufacture of plate glass.

The shales of the Chattanooga and the Sylamore sandstone member are in places phosphatic, but probably no part of these beds in the areas here considered is rich enough in phosphorus to be of value for making fertilizer.

Considerable money has been spent in northern Arkansas in drilling wells with the hope of finding oil or gas, but neither has yet been found in commercial quantity north of Crawford and Franklin counties. Furthermore, the character of the rocks does not indicate that either oil or gas will be found in commercial quantity in the quadrangles under discussion or in the adjoining parts of northern Arkansas and southern Missouri. However, any wells that are put down should be sunk on the domes. These are shown in figure 13 and in the section on the structure-section sheet. Oil may perhaps be distilled from the Chattanooga shale, which is sufficiently bituminous to give off the odor of petroleum when struck with a hammer, but such distillation will be profitable only after the prices of petroleum and its products become higher.

ZINC AND LEAD ORES.

In the Harrison quadrangle there are promising zinc prospects along Crooked Creek east of Harrison and in the southern part of the quadrangle. The ores along Crooked and Panther creeks, near Willcockson, and west of Yardelle are chiefly sphalerite; those near Ponca are sphalerite, smithsonite, and calamine—the last named in small quantity. Some galena is associated with the zinc near Ponca and on Panther Creek.

Some of the prospects along Crooked Creek are in the Everton limestone and some are in the Powell limestone. Those near Willcockson are in a brecciated zone of the Everton limestone, and the one west of Yardelle is in the Joachim limestone. Those on Panther Creek and in the vicinity of Ponca are in the chert member of the Boone limestone. All are on or near faults, and it is probably useless to prospect except on or near faults. The faults in the southern half of the Eureka Springs quadrangle, which are shown on the areal-geology map, may contain ores of zinc or lead in commercial quantities. In prospects where galena has been observed it occurs in the top part of the formation, near the Batesville sandstone. The Ponca region is described in the zinc and lead report of the Geological Survey of Arkansas as the Boxley district.

WATER RESOURCES.

Ground water.—Springs are common in all parts of the quadrangles, and their water is widely distributed by streams, most of which furnish a constant supply of excellent quality. The chief water-bearing formations are the Cotter dolomite, Boone limestone, Batesville sandstone, Pitkin limestone, Hale formation, and Winslow formation, the Boone carrying the most water and the Winslow the least.

The water of the limestone beds is clear and cold, and is usually uncontaminated, as the region is sparsely populated. The water from the Cotter dolomite and the Pitkin limestone is hard. That from the Boone, the Batesville, and the Hale, though hard, does not contain so much lime as that from the Pitkin and the Cotter, because of the greater proportion of chert in the Boone and of sandstone in the Batesville and the Hale. The water from the Winslow, which comes from sandstone, is soft.

Strong springs are not uncommon where the Cotter dolomite is the surface rock, though they are not nearly so abundant as in the Boone limestone. Where spring water is not available from the Cotter a good supply of water at moderate depth can be obtained from wells.

The Boone limestone is an excellent water-bearing formation, for it is thick, bears a great deal of chert débris on its surface, which checks the run-off, and is much fractured and jointed. Scores of strong, sparkling springs issue from it, especially at its base. Water from this formation supplies the springs at Eureka Springs, where, as in other places where the Chattanooga shale is present, the springs emerge at the top of the shale and the base of the St. Joe limestone member. Where the shale is absent, however, they emerge at the top of the Sylamore sandstone member. Where the Boone limestone is the surface rock over rather level areas, such as those around Spring Valley, Hindsville, and Oak Grove and at places south of Harrison and Bellefonte, springs are rarer and water must be procured by means of wells, which as a rule need not be dug or drilled to a depth exceeding 70 feet. In much of the upland of the northern half of the area, where the Boone lies high above the streams, it is not practicable to dig wells nor usually to drill them, because of the great depth to ground water from the crests of the hills.

Where the Batesville sandstone is the surface rock it is an important water-bearing bed, because the calcium carbonate that makes it compact and impervious in other places has been leached out. Small springs issue from it here and there along the hill slopes, but over the more nearly level areas of its outcrop, the largest of which is around Green Forest, a sufficient supply of water for general farm and domestic use can be obtained from wells.

The Fayetteville shale, on which the Pitkin limestone rests, prevents the water from passing downward from the limestone, through which it moves along joints in small underground streams and from which it issues here and there along the hillsides in strong springs.

The sandstone of the Hale formation, having been generally made open or porous by the leaching out of the calcium carbonate it once contained, forms an excellent water reservoir, along whose outcrop many fine springs issue in the southern part of the quadrangles. Where the Hale is the surface rock over considerable areas water is obtained from it by shallow wells.

The springs that emerge from the Winslow formation are few and small. The sandstone of the formation, however, furnishes abundant water to wells of moderate depth, even on the summits of the highest mountains. The inhabitants of the areas in which this is the surface rock rely almost wholly on wells for their domestic supply.

Water power.—The fall on White River from Jennings Ford to the State line in Carroll County, 39 miles along the stream, is 98 feet, equivalent to an average fall of only 2.5 feet to the mile.[1] But the fall from Habberton, Washington County, Ark., to the State line, a distance of 87 miles along the stream, is 360 feet, equivalent to an average fall of a little more than 4 feet to the mile. The water power available in this stretch of the stream can be utilized by building dams 10 to 12 feet high at intervals of 5 or 6 miles and installing at each dam suitable hydroelectric generators.

The fall on Buffalo Fork of White River from Boxley, a little more than a mile south of the Harrison quadrangle, to the mouth of Little Buffalo Fork, a distance of 32 miles, is 323 feet, equivalent to an average fall of a little less than 10 feet to the mile.[2] Measurements made July 26, 1910, in sec. 8, T. 16 N., R. 20 W., on Buffalo Fork of White River above the mouth of Little Buffalo, gave a flow of 85 cubic feet a second. Calculations based on this flow and the fall of 323 feet in the part of the stream considered show that there was available in that stretch about 2,500 horsepower.

[1] Gladson, W. N., A preliminary report on White River and some of its tributaries: Arkansas Geol. Survey, p. 10, 1911.

[2] Idem, p. 11.

Streams that are dammed at several places in the quadrangles furnish power for small grist and saw mills. Water from a few of the larger springs and that at some of the low waterfalls is used for generating power.

SOILS.

The surface of large parts of the quadrangles is rough, and much of the soil in such parts is unfit for cultivation. This is especially true of the southern part of the area. Practically all the soils of the region are residuary. The stream valleys are narrow and contain but little alluvium. Even along White River, the largest stream in the area, there are no large flood-plain deposits. Where the Boone limestone is exposed over level areas, as about Hindsville, in the Eureka Springs quadrangle, and in the east-central part of the Harrison quadrangle, it makes a good soil, but where the surface is rough the soil derived from that formation is thin and unproductive, because most of it is removed by erosion. For the same reason the soil over most of the area in which the Ordovician rocks are exposed is unproductive. The Batesville sandstone, the largest exposures of which are in the Harrison quadrangle, forms a moderately good soil. The considerable areas of the Hale formation in the southern part of the Eureka Springs quadrangle have fairly good soil, which is well adapted to fruit culture. The soil on the flat mountains in the southern part of the two quadrangles is derived from the Winslow formation and is not very productive, but with care it can be made good fruit land.

TIMBER.

Most of the commercial timber in the northern half of the two quadrangles is pine, from which much lumber is cut. The timber of the southern half of the area is mainly oak and hickory. There was formerly a good deal of black walnut, but most of this has been removed. There is a little cherry and cedar and much black locust.

June, 1915.

NAMES AND EQUIVALENTS OF FORMATIONS IN NORTHERN ARKANSAS AND ADJOINING PARTS OF OKLAHOMA.

[The assignment of the formations to systems and series and their correlation with the composite general section at the left are indicated by horizontal arrangement of names; the assignment by different authors of the formations to systems and to the Pennsylvanian and Mississippian series is indicated by the heavy rules.]

System.	Series.	Composite general section showing the standard equivalents of formations in northern Arkansas and adjoining parts of Oklahoma.	Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (No. 202), 1917.	Branner, J. C., and Williams, H. S., Arkansas Geol. Survey Repts. published in 1900 and previous years.	Ulrich, E. O., U. S. Geol. Survey Prof. Paper 24, 1904.	Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tahlequah folio (No. 122), 1905.	Adams, G. I., and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (No. 119), 1905.	Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (No. 154), 1907.
Carboniferous.	Pennsylvanian.	Allegheny.				Winslow formation: Akins shale member.		Winslow formation.
		Pottsville.	Winslow formation.	Millstone grit. [Shales and sandstone.]	Late Pottsville: Winslow formation.		Winslow formation.	
					Early Pottsville: Morrow formation: Shale.	Morrow formation.	Morrow formation.	
			Morrow group: Bloyd shale: Kessler limestone member.	Boston group: Kessler limestone.	Kessler limestone.		Kessler limestone lentil.	Morrow group: Bloyd shale: Kessler limestone lentil.
				Coal-bearing shale.	Coal-bearing shale.			
			Brentwood limestone member.	Pentremital limestone.	Brentwood limestone.		Brentwood limestone lentil.	Brentwood limestone lentil.
			Hale formation.	Washington shale and sandstone.	Washington shale and sandstone.	Hale sandstone lentil.		Hale formation.
	Mississippian.	Chester.	Pitkin limestone.	Archimedes limestone.	Chester: Pitkin limestone.	Pitkin limestone.	Pitkin limestone.	Pitkin limestone.
			Fayetteville shale: Wedington sandstone member.	Shaly sandstone.[a]	Fayetteville formation: Wedington sandstone member.	Fayetteville formation: Wedington sandstone member.	Fayetteville formation: Wedington sandstone member.	Fayetteville shale: Wedington sandstone member.
				Marshall shale.[b]				
			Batesville sandstone: Hindsville limestone member.[c]	Batesville sandstone.	Batesville sandstone.	Absent.	Batesville sandstone.	Absent.
			Absent.	Spring Creek limestone.[d] Fayetteville shale.[e] Wyman sandstone.[f]	Meramec: Moorefield shale (including Spring Creek limestone).[d]		Absent.	
		Warsaw. Osage (Keokuk, Burlington). Kinderhook.	Boone limestone.	Osage.[g] Boone chert and limestone: Cherty beds. Carrollton limestone. St. Joe marble.	Osage: Boone limestone.[c]	Boone formation.[h]	Boone formation.[c h]	Boone limestone.[h]
			St. Joe limestone member.		St. Joe limestone member.		St. Joe limestone member.	Not exposed.
Devonian.	Upper Devonian.	Portage.[i]	Chattanooga shale.[j]	Eureka shale (typical).	Kinderhook: Noel shale.	Chattanooga formation.	Chattanooga formation.	
		Genesee.	Sylamore sandstone member.	Sylamore sandstone. Eureka shale, in part.	Neo-Devonian: Sylamore formation.	Sylamore sandstone member.	Sylamore sandstone member.	
	Middle Devonian.	Hamilton.	Clifty limestone.	Not known.	Not known.	Absent.		
Silurian.		Niagara.	Absent.	Niagara: St. Clair limestone.	Niagaran: St. Clair limestone.	Niagara: St. Clair marble.		
		Medina.[k]		Cason shale.				
Ordovician.	Upper Ordovician.	Richmond.	Cason shale. Fernvale limestone.	Trenton and Cincinnati: Polk Bayou limestone.[l]	Cason shale.	Absent.		
		Lorraine.			Cincinnatian: Polk Bayou limestone.			
	Middle Ordovician.	Trenton. Black River.	Absent.			Tyner formation.[m]	Absent.	Not exposed.
	Lower Ordovician.	Chazy and possibly older beds not represented in the New York section.	Jasper limestone.[n]	Izard limestone.[n]	Izard limestone [n]	Absent.		
			Joachim limestone. St. Peter sandstone. Everton limestone: Kings River sandstone member. Sneeds limestone lentil.	Calciferous: Saccharoidal sandstone and magnesian limestone.	Canadian: Key sandstone. [Everton confused with Izard limestone.]	Burgen sandstone. Not exposed.		
		Beekmantown.	Powell limestone. Cotter dolomite.		Yellville limestone.		Yellville formation.	

[a] This shaly sandstone of the Boston group seems to be the same as the Wedington sandstone, which F. W. Simonds, in his report on Washington County, calls the Batesville sandstone.

[b] The "Marshall" shale at the type locality is the same as the Fayetteville shale, but what Simonds called Marshall shale is only the upper member of the Fayetteville.

[c] In northwestern Arkansas, where the Moorefield shale is absent, the limestone corresponding to the Hindsville was apparently included in the Boone.

[d] The "Spring Creek limestone" is the basal part of the Moorefield shale.

[e] The Fayetteville shale really occupies the interval between the Pitkin ("Archimedes") limestone above and the Batesville sandstone beneath.

[f] The "Wyman" sandstone is the same as the Batesville sandstone.

[g] The limestone corresponding to the Hindsville was described by T. C. Hopkins as overlying the chert bed of the Boone, but it was considered by him as a part of the Boone.

[h] The upper part of the Boone of these areas may contain beds of Warsaw age.

[i] The Chattanooga shale is believed by many geologists to be in part the equivalent of the Genesee shale, but it is more doubtful whether the Portage is represented in it. E. O. Ulrich regards the Chattanooga as of lower Kinderhook age and assigns it to the Mississippian series.

[j] Along the northern border of the Eureka Springs and Harrison quadrangles the Chattanooga shale or its member, the Sylamore sandstone, rests upon the Powell limestone, and the intervening formations are absent

[k] The lower part of the St. Clair is referred to the upper Medina rather than to the Clinton by Ulrich, who states, however, that the middle or typical St. Clair is of Clinton age.

[l] The Polk Bayou limestone at its type locality consists of the Fernvale and Kimmswick limestones, which are separated by an unconformity that represents the time interval of the Lorraine and Trenton of New York.

[m] Fossils from the Tyner formation, as stated in the Tahlequah folio, indicate two horizons, one of lower Trenton or Black River age and the other of Lorraine age. Beds of Richmond and Chazy age are apparently absent.

[n] The Jasper limestone is of Chazy age or older and is absent at the type locality of the Izard limestone.

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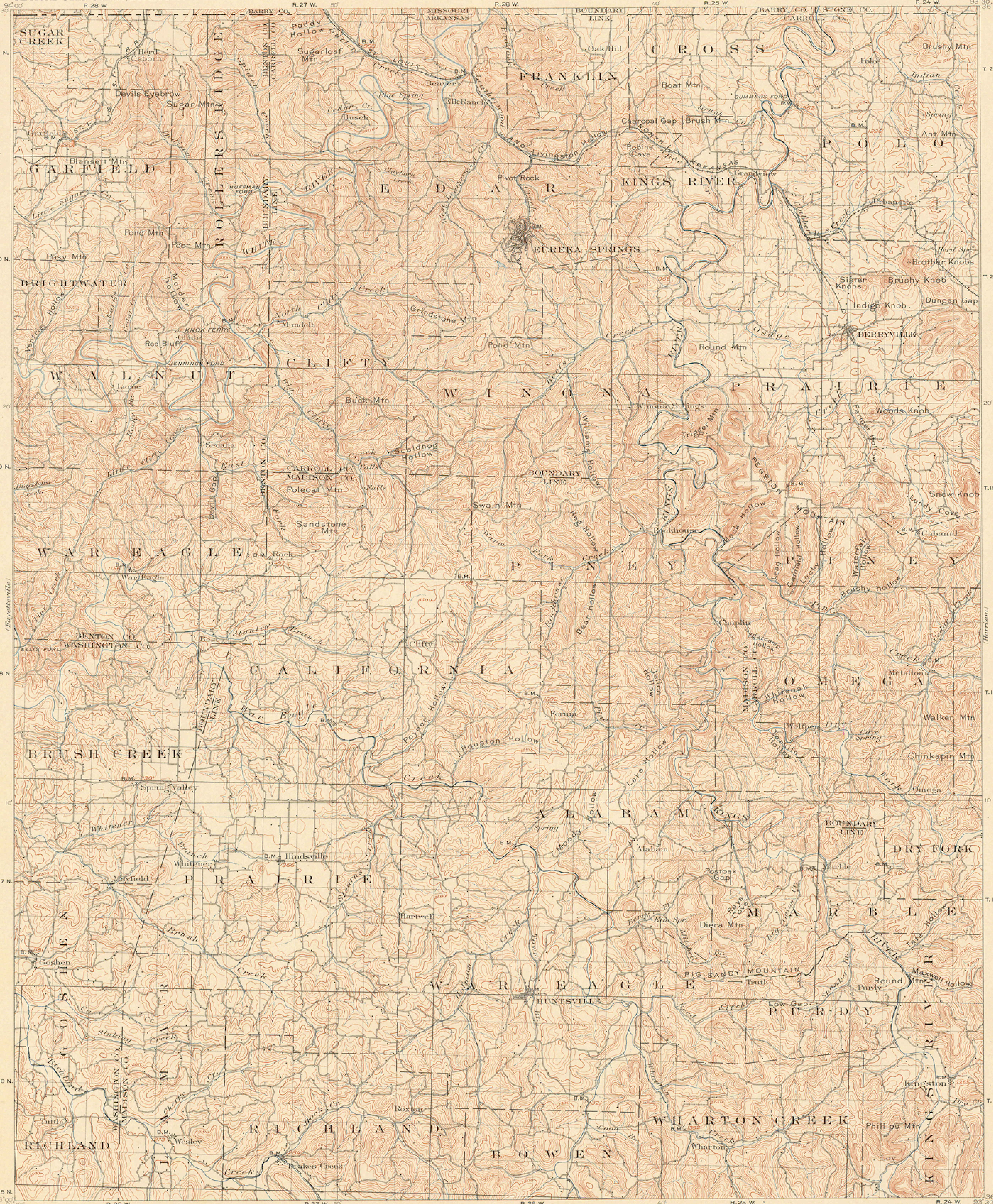
TOPOGRAPHY

ARKANSAS - MISSOURI
EUREKA SPRINGS QUADRANGLE



LEGEND

RELIEF *printed in brown*

Altitude *above mean sea level instrumentally determined*

Contours *showing height above sea, horizontal form, and steepness of slope of the surface*

DRAINAGE *printed in blue*

Streams

Intermittent streams

Lake or pond

Spring

CULTURE *printed in black*

Roads and buildings

Church or schoolhouse

Private or secondary roads

Railroad

Tunnel

U.S. township and section lines

State line

County line

Township line

Triangulation station

Bench mark

Jno. H. Renshawe, Geographer in charge.
Triangulation by Geo. T. Hawkins.
Topography by H. B. Blair.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1912.

Scale $\frac{1}{125000}$

5 Miles

5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

Edition of Oct. 1901, reprinted Oct. 1913.

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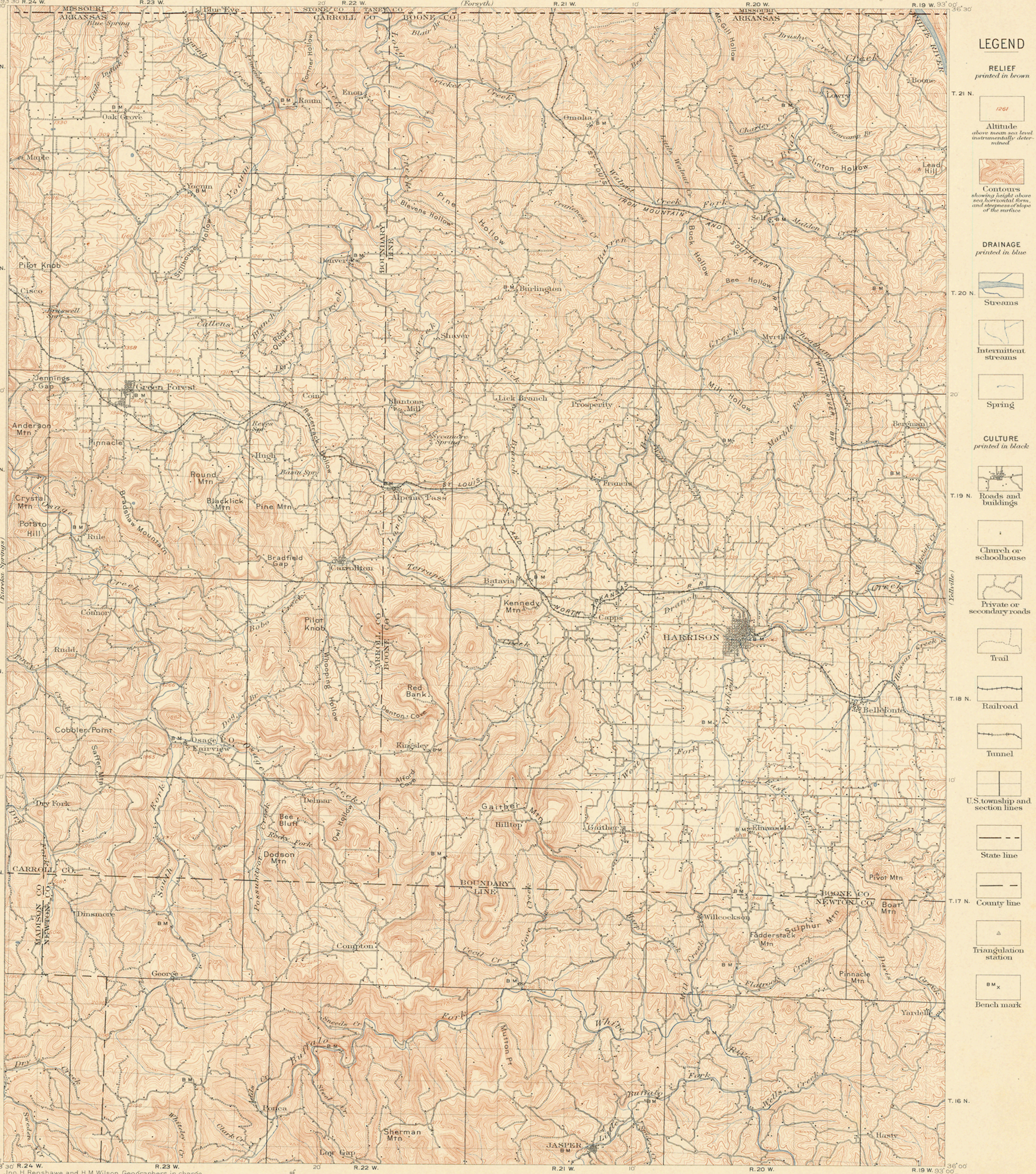
TOPOGRAPHY

ARKANSAS - MISSOURI
HARRISON QUADRANGLE



Jno. H. Renshawe and H.M. Wilson, Geographers in charge.
Topography by H.B. Blair, Duncan Hannegan, and C.L. Sadler.
Triangulation by Geo. T. Hawkins.
Surveyed in 1902-1904.

APPROXIMATE MEAN DECLINATION 1902.

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

Edition of Oct. 1905, reprinted Oct. 1913.

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AREAL GEOLOGY

ARKANSAS - MISSOURI
EUREKA SPRINGS QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines)

CARBONIFEROUS

Pennsylvanian series

Cwl — Winslow formation *(black platy shale and thin-bedded and massive sandstones)*

UNCONFORMITY

Morrow group

Ck, Cb, Cbr — Bloyd shale with Brentwood, Cbr, and Kessler, Ck, limestone members *(black clay shale with thin fossiliferous gray limestone beds)*

Chl — Hale formation *(black platy clay shale and brown calcareous sandstone with limestone lenses)*

UNCONFORMITY

Mississippian series

Cp — Pitkin limestone *(massive gray fossiliferous limestone)*

Cwt, Cfv — Fayetteville shale with Wedington sandstone member, Cwt *(black fissile shale with limestone concretions and fine-grained gray sandstone near top)*

Cbv, Chv — Batesville sandstone with Hindsville limestone member, Chv *(gray to brown, in part calcareous, even-bedded sandstone with gray oolitic fossiliferous limestone at base)*

UNCONFORMITY

Cbn, Csj — Boone limestone with St. Joe limestone member, Csj *(fossiliferous gray chert and crystalline limestone with gray to pink coarsely crystalline limestone at base)*

UNCONFORMITY ?

DEVONIAN

Ds — Chattanooga shale with Sylamore sandstone member, Ds *(black fissile clay shale, in part phosphatic, and white to rusty sandstone, in part pebbly and phosphatic)*

UNCONFORMITY

Dcy — Clifty limestone *(gray compact sandy limestone; exposed only near Sedalia)*

UNCONFORMITY

ORDOVICIAN

Osp — St. Peter sandstone *(massive saccharoidal sandstone)*

UNCONFORMITY

Oet — Everton limestone *(dove-colored compact limestone and friable white sandstone)*

UNCONFORMITY

Op — Powell limestone *(greenish-gray to light-gray magnesian limestone)*

UNCONFORMITY

Oc — Cotter dolomite *(gray dolomite, containing banded nodular chert and thin beds of saccharoidal sandstone)*

Faults

Quarries, *Lime and building stone*

Economic data: *Glass and building sands can be obtained from* Osp *and lower part of* Oet*; building sand from* Ds*; limestone for lime and cement from* Oet, Csj, Cbn, Chv, Cp, *and* Cbr*; shale for brick and cement from* Dc, Cfv, Chl, Cb, *and* Cwl*; stone for building, ballast, and road material from most of the formations in the area. Stream deposits yield sand and gravel; residual clays are suitable for brick.*

Jno. H. Renshawe, Geographer in charge.
Triangulation by Geo. T. Hawkins.
Topography by H. B. Blair.
Surveyed in 1900.

APPROXIMATE MEAN DECLINATION 1912.

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.

Edition of Oct. 1914.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Geology by A. H. Purdue,
assisted by H. D. Miser,
R. D. Mesler, and Storer Leverett.
Surveyed in 1903, 1905, and 1910.

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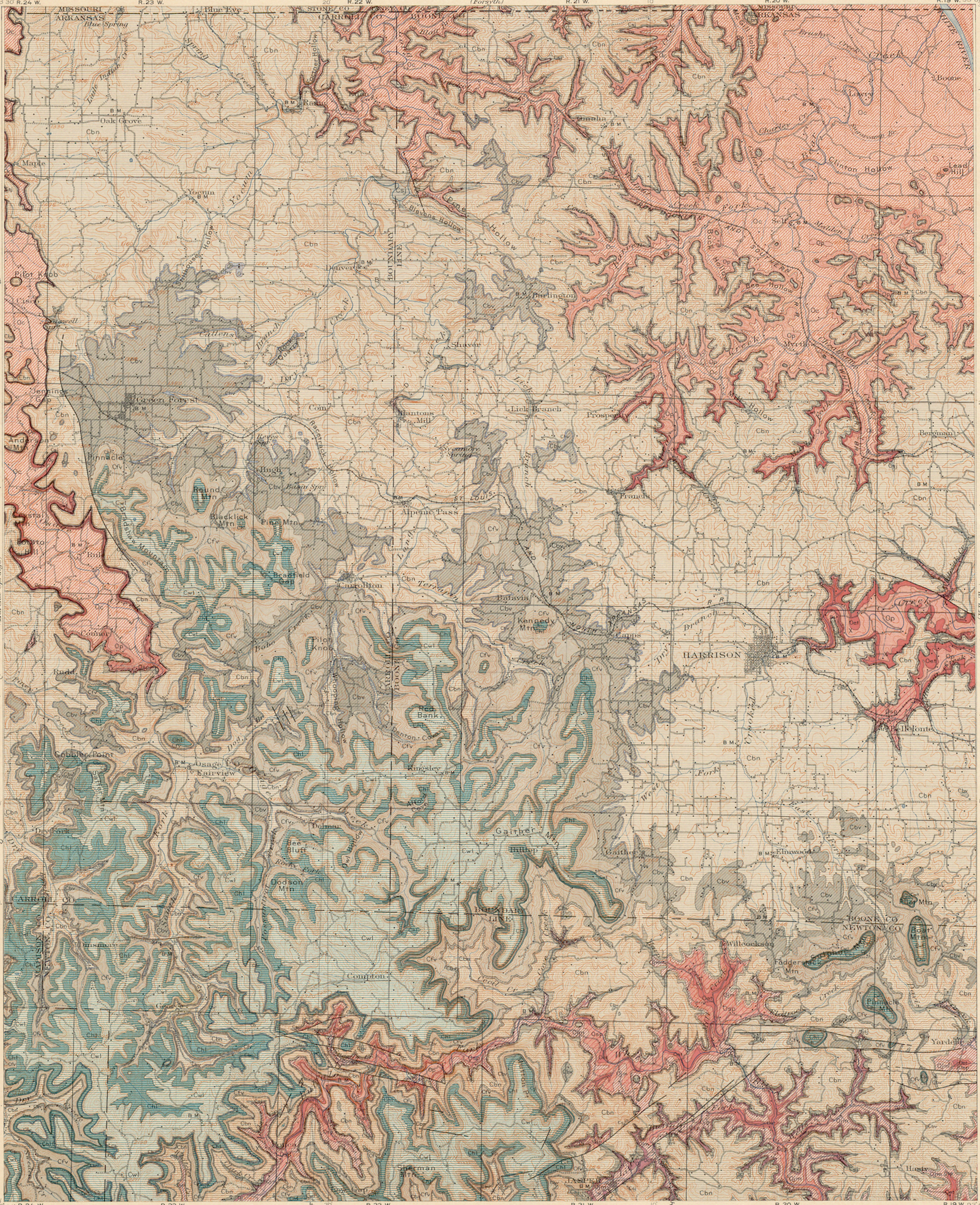
GEORGE OTIS SMITH, DIRECTOR

AREAL GEOLOGY

ARKANSAS - MISSOURI
HARRISON QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines)

CARBONIFEROUS

Pennsylvanian series

Cwl — Winslow formation *(black platy shale and thin-bedded and massive sandstones)*

UNCONFORMITY

Morrow group

Cb, Cbr — Bloyd shale with Brentwood limestone member, Cbr *(black clay shale with thin fossiliferous gray limestone beds)*

Chl — Hale formation *(black platy clay shale and brown calcareous sandstone with limestone lenses)*

UNCONFORMITY

Mississippian series

Cp — Pitkin limestone *(massive gray fossiliferous limestone)*

Cfv, Cwt — Fayetteville shale with Wedington sandstone member, Cwt *(black fissile shale with limestone concretions and fine-grained gray sandstone near top)*

Cbv, Chv — Batesville sandstone with Hindsville limestone member, Chv *(gray to brown, in part calcareous, even-bedded sandstone with gray oolitic fossiliferous limestone at base)*

UNCONFORMITY

Cbn, Csj — Boone limestone with St. Joe limestone member, Csj *(fossiliferous gray chert and crystalline limestone with gray to pink coarsely crystalline limestone at base)*

UNCONFORMITY

DEVONIAN

Dc, Ds — Chattanooga shale with Sylamore sandstone member, Ds *(black fissile clay shale and white to rusty sandstone, in part pebbly and phosphatic)*

UNCONFORMITY

ORDOVICIAN

Ocf — Cason shale and Fernvale limestone *(not separately mapped; gray platy calcareous shale and gray crystalline fossiliferous limestone; near Jasper only)*

UNCONFORMITY

Oj — Jasper limestone *(bluish-gray compact limestone)*

UNCONFORMITY ?

Ojm — Joachim limestone *(dark-drab compact sandy magnesian limestone)*

Osp — St. Peter sandstone *(massive saccharoidal sandstone)*

UNCONFORMITY

Oet — Everton limestone *(dove-colored compact limestone and friable white sandstone)*

UNCONFORMITY

Op — Powell limestone *(greenish-gray to light gray magnesian limestone)*

UNCONFORMITY

Oc — Cotter dolomite *(gray dolomite containing banded nodular chert and thin beds of saccharoidal sandstone)*

Faults

x *Prospects, Lead and zinc*

Economic data: *Zinc and lead ores fill fractures in bedded breccia and along faults in* Cbn, Oj, Ojm, Oet, *and* Op. *Glass and building sands can be obtained from* Osp; *limestone for lime and cement from* Oet, Oj, Csj, Cbn, Chv, *and* Cp; *shale for brick and cement from* Dc, Cfv, Chl, *and* Cwl; *stone for building, ballast, and road material from most of the formations in the area. Stream deposits yield sand and gravel, residual clays are suitable for brick.*

Jno. H. Renshawe and H. M. Wilson, Geographers in charge.
Topography by H. B. Blair, Duncan Hannegan, and C. L. Sadler.
Triangulation by Geo. T. Hawkins.
Surveyed in 1902-1904.

APPROXIMATE MEAN DECLINATION 1903.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

Edition of Oct. 1914.

Geology by A. H. Purdue, assisted by H. D. Miser, and R. D. Mesler.
Surveyed in 1906, 1908, and 1910.

U.S. GEOLOGICAL SURVEY
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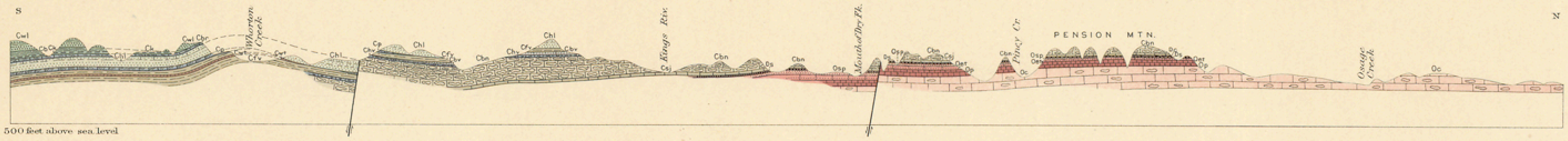
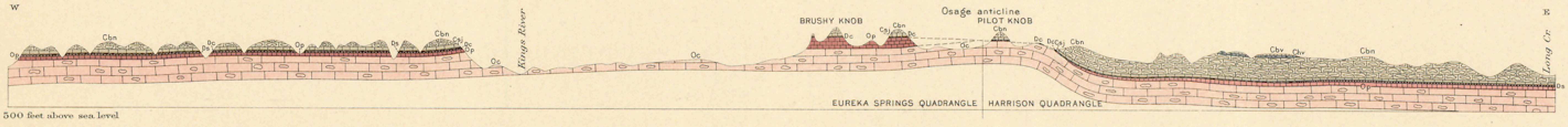
STRUCTURE SECTIONS

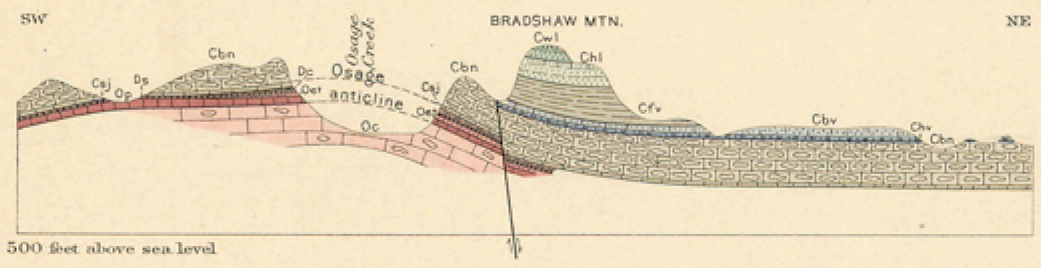
ARKANSAS-MISSOURI
EUREKA SPRINGS AND
HARRISON QUADRANGLES



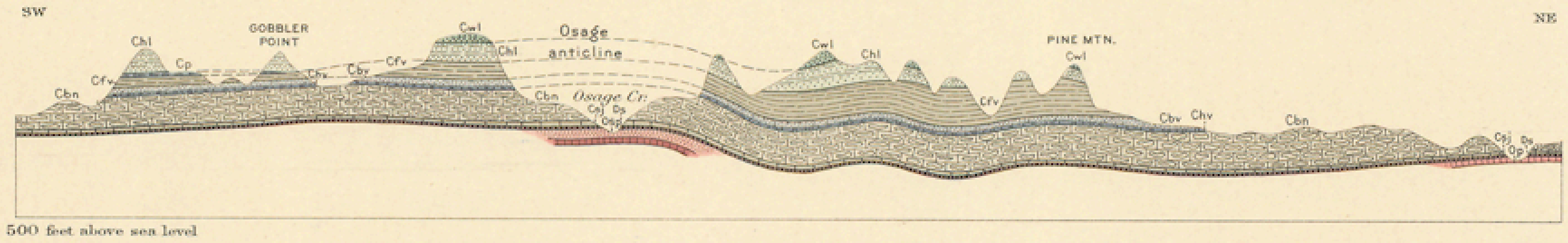
SECTION A-A



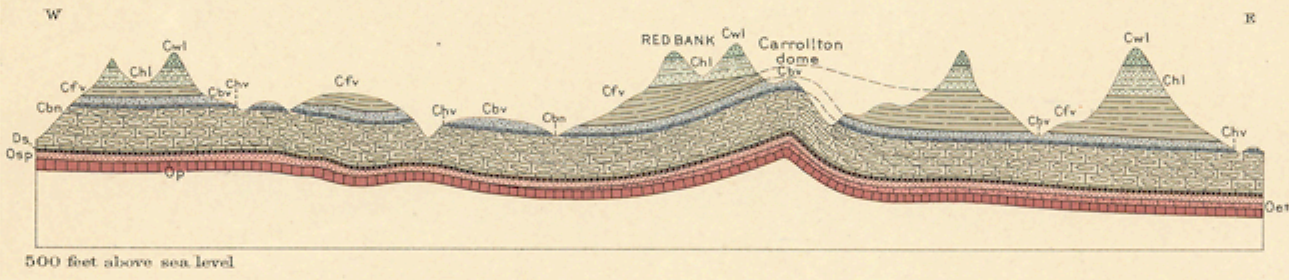
SECTION B-B



SECTION C-C



SECTION D-D



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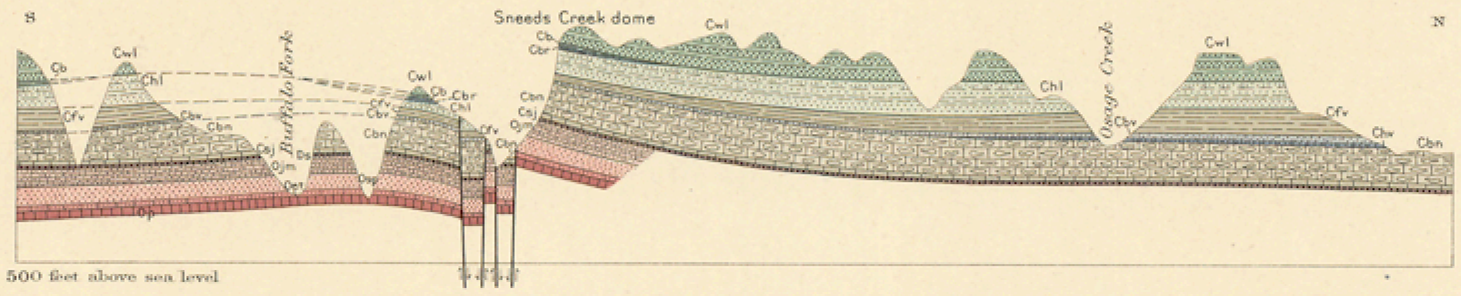

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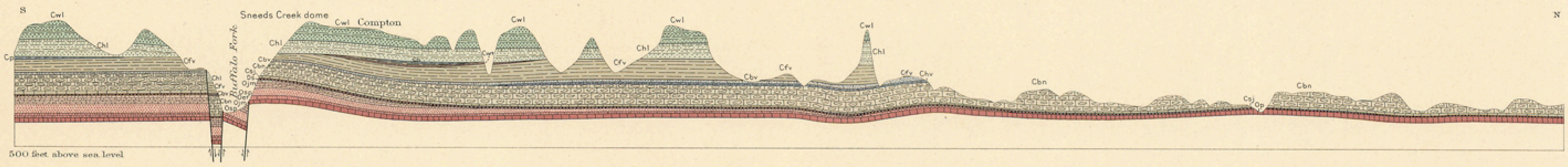

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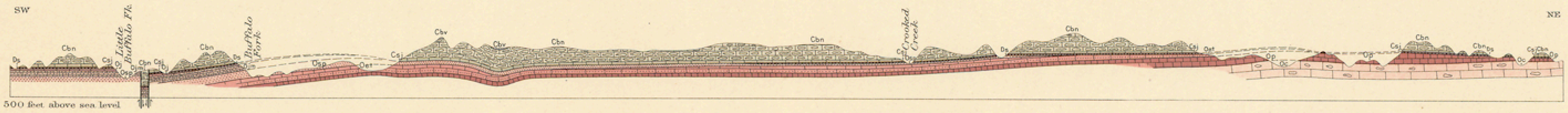


SECTION H-H

LEGEND

CARBONIFEROUS

Pennsylvanian series

Cwl — Winslow formation (black platy shale and thin-bedded and massive sandstones)

UNCONFORMITY

Morrow group

Cb — Bloyd shale with Brentwood, Cbr, and Kessler, Ck, limestone members (black clay shale with thin fossiliferous gray limestone beds)

Chl — Hale formation (black platy clay shale and brown calcareous sandstone with limestone lenses)

UNCONFORMITY

Mississippian series

Cp — Pitkin limestone (massive gray fossiliferous limestone)

Cfv — Fayetteville shale with Wedington sandstone member, Cwt (black fissile shale with limestone concretions and fine-grained gray sandstone near top)

Cbv — Batesville sandstone with Hindsville limestone member, Chv (gray to brown, in part calcareous, even-bedded sandstone with gray oolitic fossiliferous limestone at base)

UNCONFORMITY

Cbn — Boone limestone with St. Joe limestone member, Csj (fossiliferous gray chert and crystalline limestone with gray to pink coarsely crystalline limestone at base)

UNCONFORMITY

DEVONIAN

Dc — Chattanooga shale with Sylamore sandstone member, Ds (black fissile clay shale and white to rusty sandstone, in part pebbly and phosphatic)

UNCONFORMITY

Does not occur on sections — Clifty limestone (gray compact sandy limestone)

UNCONFORMITY

ORDOVICIAN

Do not occur on sections — Cason shale and Fernvale limestone (gray platy calcareous shale and gray crystalline fossiliferous limestone, near Jasper only)

UNCONFORMITY

Oj — Jasper limestone (bluish-gray compact limestone)

UNCONFORMITY ?

Ojm — Joachim limestone (dark-drab compact sandy magnesian limestone)

Osp — St. Peter sandstone (massive saccharoidal sandstone)

UNCONFORMITY

Oet — Everton limestone (dove-colored compact limestone and friable white sandstone)

UNCONFORMITY

Op — Powell limestone (greenish-gray to light-gray magnesian limestone)

UNCONFORMITY

Oc — Cotter dolomite (gray dolomite, containing banded nodular chert and thin beds of saccharoidal sandstone)

Faults

Horizontal scale

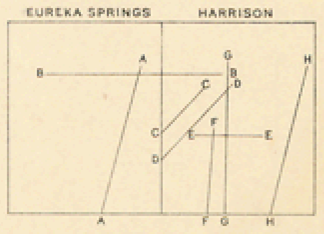
1 ½ 0 1 2 3 4 5 Miles

Vertical scale: 1 inch = approximately 1500 feet.

Edition of Oct. 1914.

Geology by A. H. Purdue,
assisted by H. D. Miser, R. D. Mesler,
and Storer Leverett.
Surveyed in 1903 to 1910.

Position of sections



COLUMNAR SECTION

GENERALIZED SECTION OF ROCKS EXPOSED IN THE EUREKA SPRINGS AND HARRISON QUADRANGLES, ARK.

SCALE: 1 INCH=200 FEET.

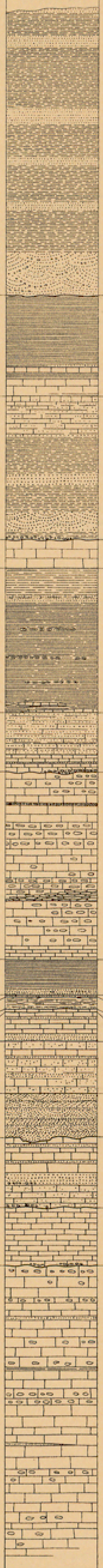
System.	Series.	Formation.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	PENNSYLVANIAN	Winslow formation.	Cwl		500+	Black clay shale containing sandy plates and interbedded flaggy sandstone.	Hilly upland with numerous rock outcrops; partly cultivated. Rocky and sandy red clay soil, suitable for fruit culture and grazing.
						Massive gray cross-bedded sandstone with white quartz pebbles.	Practically continuous bluff.
		UNCONFORMITY					
		Bloyd shale.	Cb		0-176	Black clay shale.	Uncultivated steep slopes. Poor soil, clayey, suitable for grazing.
		Kessler limestone member.	(Ck)		(0-10)	Brown and gray limestone, in part conglomeratic.	
		Brentwood limestone member.	(Cbr)		(0-30)	Compact gray fossiliferous limestone.	
		Hale formation.	Chl		80-300	Black clay shale containing sandy plates and some sandstones; brown cross-bedded calcareous sandstones; and sandy ferruginous limestone at top.	Well-rounded hills and slopes in Eureka Springs quadrangle; steep slopes in Harrison quadrangle; partly cultivated. Rich sandy soil suitable for general farming, grazing, and fruit growing.
		UNCONFORMITY					
	MISSISSIPPIAN	Pitkin limestone.	Cp		0-100	Massive gray fossiliferous limestone.	Benches and escarpments.
		UNCONFORMITY ?					
					(0-70)	Black clay shale.	Steep slopes.
		Wedington sandstone member.	(Cwt)		(0-45)	Fine-grained gray laminated sandstone, in part calcareous.	Benches and low escarpments, which show many outcrops.
		Fayetteville shale.	Cfv		10-400	Black carbonaceous fissile clay shale containing limestone and clay-ironstone concretions.	Gentle slopes cut by numerous ravines. Rocky, clayey wet soil, partly cultivated but mainly suitable for grazing.
		Batesville sandstone.	Cbv		0-100	Gray to brown calcareous even-bedded sandstone.	Benches and broad level areas. Sandy fertile soil, suitable for general farming and fruit growing.
		Hindsville limestone member.	(Chv)		(0-50)	Gray fossiliferous oolitic limestone and thin sandstone beds; chert-pebble conglomerate at base.	Rocky slopes suitable for grazing.
		UNCONFORMITY					
		Boone limestone.	Cbn		250-400	Gray fossiliferous crystalline limestone containing considerable gray fossiliferous chert.	Broad even-surfaced upland, hilly adjacent to streams; partly cultivated. Soil in upland is thin and suitable for fruit growing; in stream flats is rich and suitable for general farming. Hilly areas are rocky and suitable for grazing, fruit growing, and light farming.
		St. Joe limestone member.	(Csj)		(10-60)	Gray to pinkish crystalline fossiliferous coarse-textured limestone.	Escarpments and steep slopes.
		UNCONFORMITY					
DEVONIAN	UPPER DEVONIAN	Chattanooga shale.	Dc		0-50	Black fissile clay shale.	Gentle slopes.
		Sylamore sandstone member.	(Ds)		(0-10)	White to brown sandstone, in part pebbly and phosphatic.	Low escarpment; numerous rock exposures.
		UNCONFORMITY					
	MIDDLE DEV.	Clifty limestone.	Dcy		0-2+	Gray compact sandy limestone.	Many outcrops on slopes.
		UNCONFORMITY					
ORDOVICIAN	UPPER ORDOVICIAN	Cason shale.	Ocf		0-21	Platy gray calcareous shale.	Single exposure in bluff on Little Buffalo Fork.
		UNCONFORMITY					
		Fernvale limestone.			0-5+	Gray crystalline fossiliferous limestone.	Rock ledges at water's edge of Little Buffalo Fork.
		UNCONFORMITY					
	LOWER ORDOVICIAN	Jasper limestone.	Oj		0-50	Compact bluish-gray limestone and saccharoidal sandstone.	Slopes with numerous rock outcrops.
		? UNCONFORMITY					
		Joachim limestone.	Ojm		0-95	Dark-drab compact sandy magnesian limestone, calcareous sandstone, and a little white friable sandstone.	Steep slopes in which rock ledges are practically continuous. Scanty soil.
		St. Peter sandstone.	Osp		0-150	Massive, cross-bedded, and laminated saccharoidal sandstone.	Bluffs and steep slopes.
		UNCONFORMITY					
		Everton limestone.	Oet		(0-115	Compact dove-colored limestone interbedded with friable white sandstone.	Steep slopes and bluffs.
		Kings River sandstone member.			(0-40)	White friable sandstone in massive beds.	Continuous bluffs.
		Sneeds limestone lentil.			(0-50)	Massive dark-colored sandy magnesian limestone.	Steep slopes containing rock ledges.
		UNCONFORMITY					
		Powell limestone.	Op		0-200	Light-gray to greenish-gray magnesian limestone with limestone conglomerate locally at base.	Even slopes and narrow valleys containing rock outcrops. Scanty rocky soil.
		UNCONFORMITY					
		Cotter dolomite.	Oc		500+	Gray dolomite containing some chert and interbedded with a little saccharoidal sandstone and green shale.	Broad hilly areas and steep slopes showing numerous rock outcrops; partly cultivated. Rocky clay soil suitable for grazing and general farming.

PLATE I.—TOPOGRAPHY OF BOSTON MOUNTAINS. VIEW LOOKING SOUTHWEST FROM NORTH BLUFF OF BUFFALO FORK OF WHITE RIVER, 1¾ MILES EAST OF MOUTH OF SNEEDS CREEK.

St. Peter sandstone caps bluffs in right foreground. Pennsylvanian formations cap summits of the high hills in center and left distance, and Mississippian formations are exposed on their upper slopes. Photograph by W. N. Gladson.

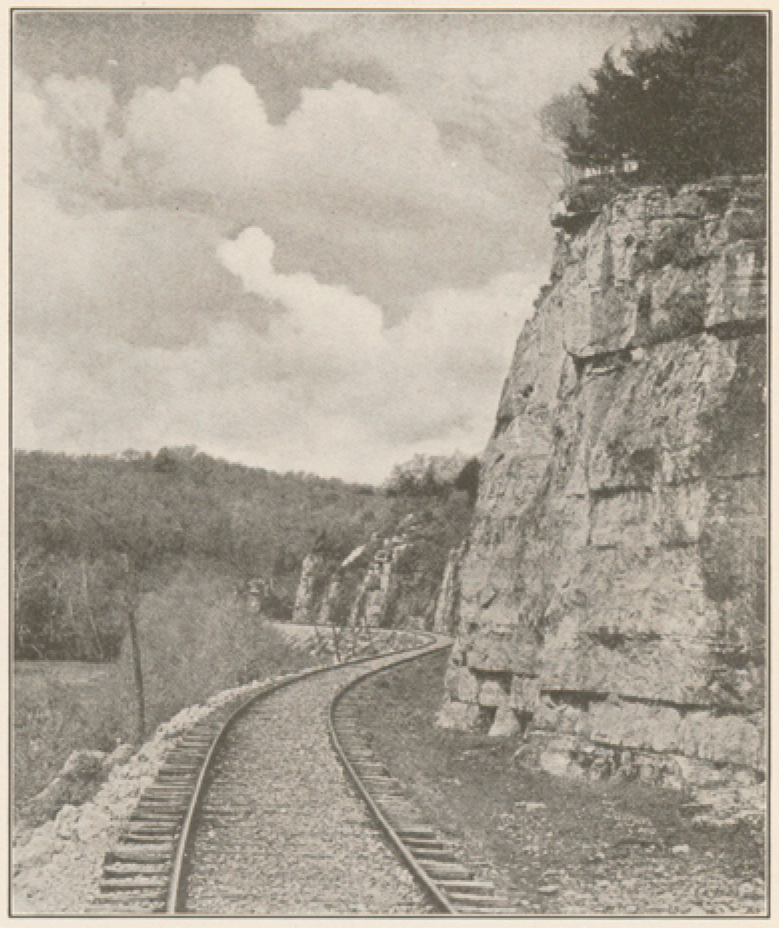


PLATE IV.—COTTER DOLOMITE IN CUT OF MISSOURI & NORTH ARKANSAS RAILROAD AT THE NARROWS, JUST EAST OF BEAVER.

Photograph by J. C. Branner.

PLATE II.—TOPOGRAPHY OF BOSTON MOUNTAINS. VIEW LOOKING SOUTHEAST UP VALLEY OF LITTLE BUFFALO FORK OF WHITE RIVER FROM A POINT NEAR JASPER.

Pennsylvanian formations cap summits of hills, and Mississippian formations are exposed on their lower slopes. Photograph by J. C. Branner.

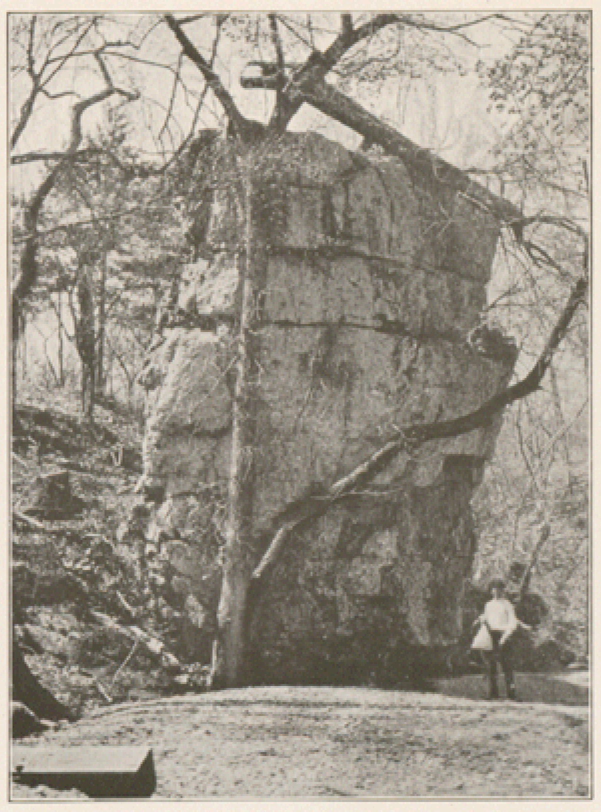


PLATE III.—SANDSTONE IN POWELL LIMESTONE NEAR MOUTH OF VENTRIS HOLLOW IN WESTERN PART OF EUREKA SPRINGS QUADRANGLE.

An isolated mass, left by erosion of inclosing limestone, which represents a deposit that filled a cave or sink hole in Powell limestone. Photograph by K. F. Mather.

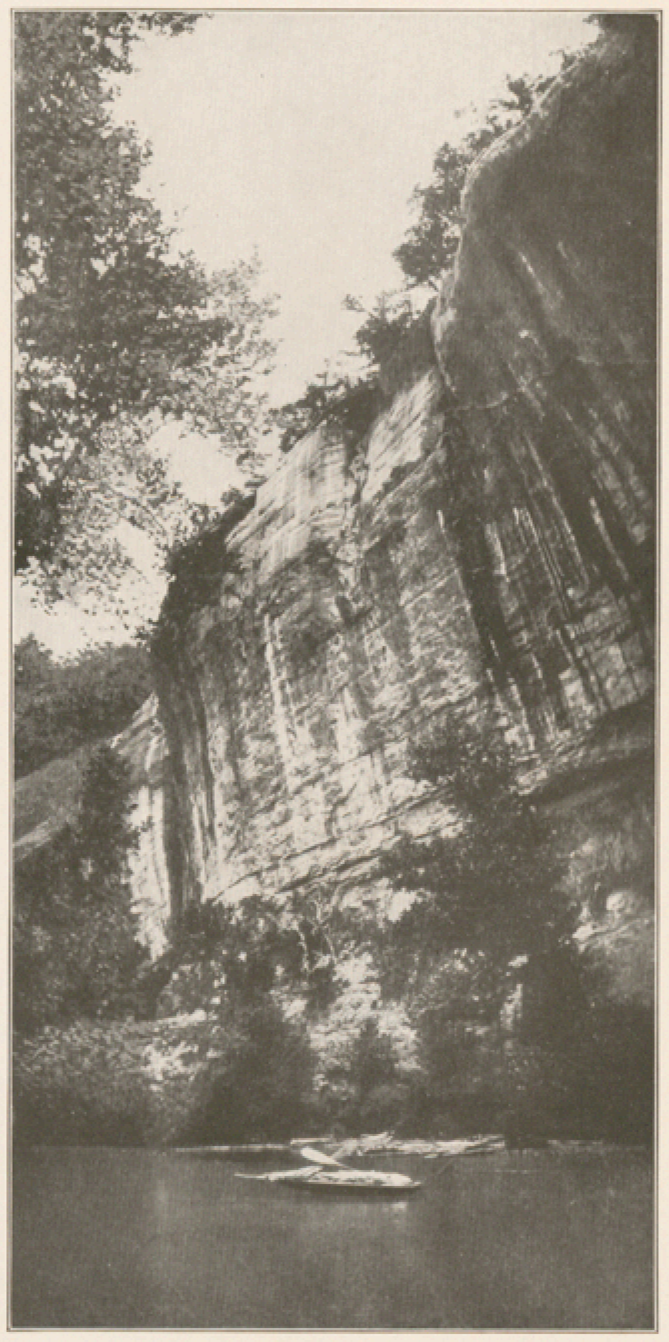


PLATE V.—ST. PETER SANDSTONE CAPPING NORTH BLUFF OF BUFFALO FORK OF WHITE RIVER, 1 MILE EAST OF MOUTH OF COVE CREEK.

St. Peter sandstone, 80 feet thick, is underlain by 90 feet of Everton limestone. Photograph by W. N. Gladson.

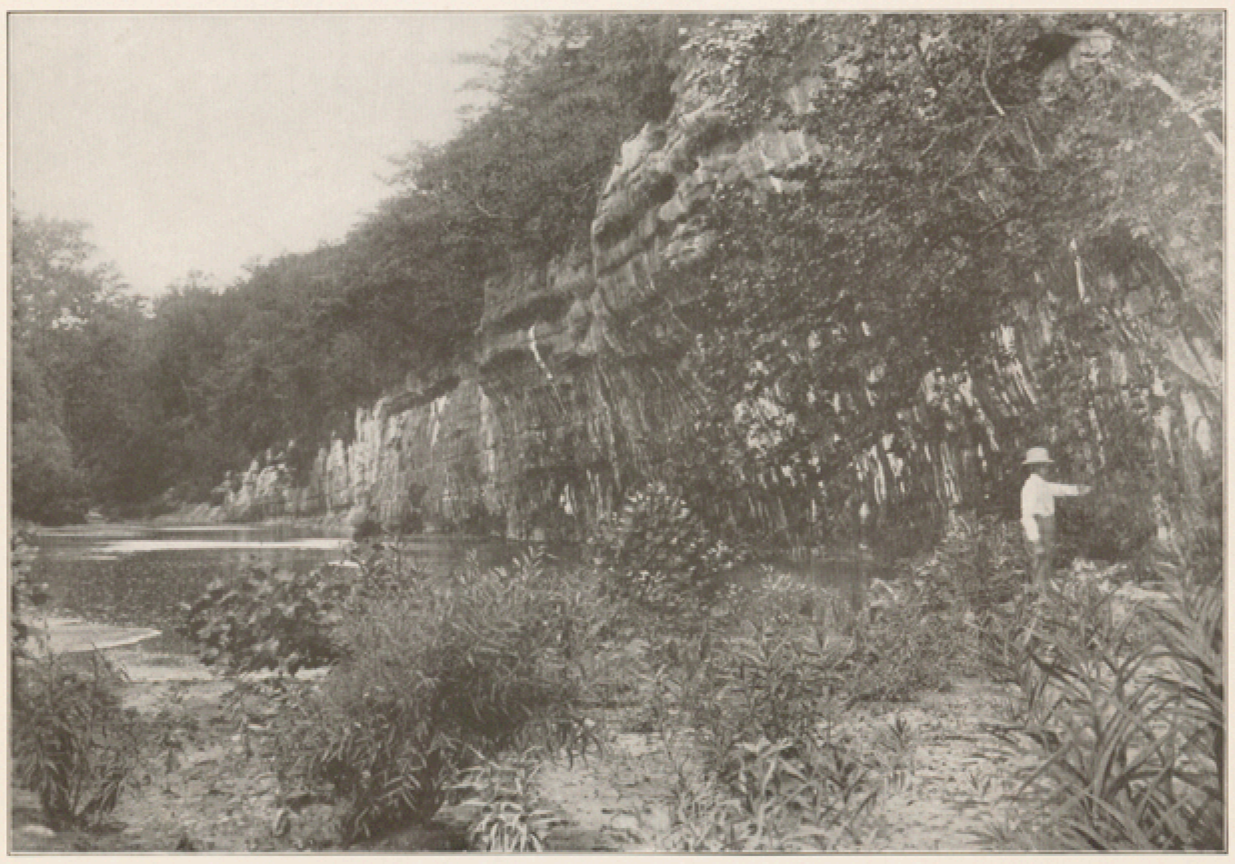


PLATE VI.—ST. PETER SANDSTONE IN BLUFF ON WEST SIDE OF BUFFALO FORK OF WHITE RIVER, ONE-FOURTH MILE NORTH OF MOUTH OF ADDS CREEK.

View looking south. The sandstone dips gently to the left, upstream. Photograph by J. C. Branner.

PLATE VII.—THIN-BEDDED ST. JOE LIMESTONE MEMBER OF BOONE LIMESTONE IN MARKLE HOLLOW, EAST OF HARRISON QUADRANGLE.

Photograph by G. I. Adams.

PLATE VIII.—UNCONFORMITY WITHIN BOONE LIMESTONE IN BLUFF ONE-HALF MILE WEST OF WAR EAGLE POST OFFICE.

Unconformity possibly represents submarine erosion of earlier deposits of the Boone overlapped by later deposits of the Boone. A few feet of thin-bedded limestone of the St. Joe member at base is overlain by about 90 feet of limestone and chert which contain a Fern Glen fauna; cherty limestone above the unconformity. Photograph by E. O. Ulrich.

PLATE IX.—SOLUTION VALLEY IN BOONE LIMESTONE, TYPICAL OF THE FORMATION IN THIS AREA.

Residual masses of white chert from the formation strew the surface.

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.

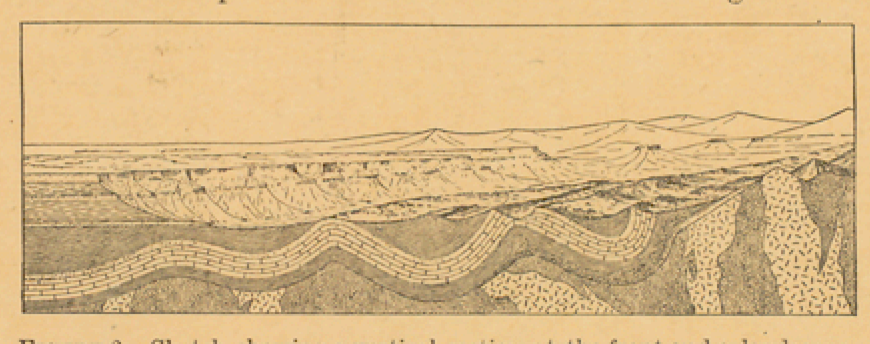


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.

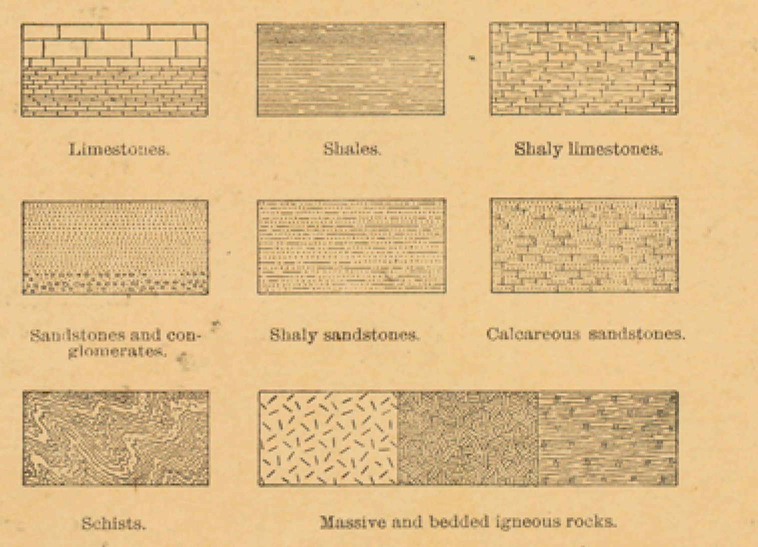


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

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.

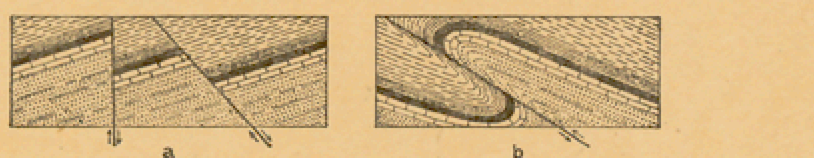


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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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‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
‡34	Buckhannon	West Virginia	
‡35	Gadsden	Alabama	
36	Pueblo	Colorado	5
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
‡40	Wartburg	Tennessee	
‡41	Sonora	California	
42	Nueces	Texas	5
‡43	Bidwell Bar	California	
‡44	Tazewell	Virginia-West Virginia	
‡45	Boise	Idaho	
46	Richmond	Kentucky	5
47	London	Kentucky	5
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
‡50	Holyoke	Massachusetts-Connecticut	
‡51	Big Trees	California	
‡52	Absaroka	Wyoming	
‡53	Standingstone	Tennessee	
‡54	Tacoma	Washington	
‡55	Fort Benton	Montana	
‡56	Little Belt Mountains	Montana	
‡57	Telluride	Colorado	
58	Elmoro	Colorado	5
‡59	Bristol	Virginia-Tennessee	
‡60	La Plata	Colorado	
‡61	Monterey	Virginia-West Virginia	
62	Menominee Special	Michigan	5
‡63	Mother Lode District	California	
‡64	Uvalde	Texas	
65	Tintic Special	Utah	5
‡66	Colfax	California	
67	Danville	Illinois-Indiana	5
68	Walsenburg	Colorado	5
69	Huntington	West Virginia-Ohio	5
‡70	Washington	D. C.-Va.-Md.	
‡71	Spanish Peaks	Colorado	
‡72	Charleston	West Virginia	
‡73	Coos Bay	Oregon	
‡74	Coalgate	Oklahoma (Ind. T.)	
75	Maynardville	Tennessee	5
76	Austin	Texas	5
77	Raleigh	West Virginia	5
78	Rome	Georgia-Alabama	5
‡79	Atoka	Oklahoma (Ind. T.)	
‡80	Norfolk	Virginia-North Carolina	
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	5
90	Cranberry	North Carolina-Tennessee	5
91	Hartville	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
‡94	Brownsville-Connellsville	Pennsylvania	
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5
97	Parker	South Dakota	5
98	Tishomingo	Oklahoma (Ind. T.)	5
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
101	San Luis	California	5
102	Indiana	Pennsylvania	5
103	Nampa	Idaho-Oregon	5
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	5
107	Newcastle	Wyoming-South Dakota	5
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
110	Latrobe	Pennsylvania	5
‡111	Globe	Arizona	
112	Bisbee (reprint)	Arizona	25
113	Huron	South Dakota	5
114	De Smet	South Dakota	5
‡115	Kittanning	Pennsylvania	
116	Asheville	North Carolina-Tennessee	5
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	5
‡120	Silverton	Colorado	
‡121	Waynesburg	Pennsylvania	
122	Tahlequah	Oklahoma (Ind. T.)	5
123	Elders Ridge	Pennsylvania	5
124	Mount Mitchell	North Carolina-Tennessee	5
‡125	Rural Valley	Pennsylvania	
‡126	Bradshaw Mountains	Arizona	
‡127	Sundance	Wyoming-South Dakota	
128	Aladdin	Wyo.-S. Dak.-Mont	5
‡129	Clifton	Arizona	
‡130	Rico	Colorado	
‡131	Needle Mountains	Colorado	
‡132	Muscogee	Oklahoma (Ind. T.)	
133	Ebensburg	Pennsylvania	5
‡134	Beaver	Pennsylvania	
‡135	Nepesta	Colorado	
136	St. Marys	Maryland-Virginia	5
137	Dover	Del.-Md.-N. J	5
‡138	Redding	California	
‡139	Snoqualmie	Washington	
140	Milwaukee Special	Wisconsin	5
‡141	Bald Mountain-Dayton	Wyoming	
‡142	Cloud Peak-Fort McKinney	Wyoming	
143	Nantahala	North Carolina-Tennessee	5
‡144	Amity	Pennsylvania	
‡145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	
146	Rogersville	Pennsylvania	5
147	Pisgah	N. Carolina-S. Carolina	5
148	Joplin District (reprint)	Missouri-Kansas	50
‡149	Penobscot Bay	Maine	
‡150	Devils Tower	Wyoming	
‡151	Roan Mountain	Tennessee-North Carolina	
152	Patuxent	Md.-D. C	5
‡153	Ouray	Colorado	
‡154	Winslow	Ark.-Okla. (Ind. T.)	
155	Ann Arbor (reprint)	Michigan	25
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‡157	Passaic	New Jersey-New York	
158	Rockland	Maine	5
159	Independence	Kansas	5
160	Accident-Grantsville	Md.-Pa.-W. Va.	5
‡161	Franklin Furnace	New Jersey	
‡162	Philadelphia	Pa.-N. J.-Del	
‡163	Santa Cruz	California	
‖164	Belle Fourche	South Dakota	5
‖165	Aberdeen-Redfield	South Dakota	5
‖166	El Paso	Texas	5
¶167	Trenton	New Jersey-Pennsylvania	5
‖168	Jamestown-Tower	North Dakota	5
¶169	Watkins Glen-Catatonk	New York	5
‖170	Mercersburg-Chambersburg	Pennsylvania	5
‖171	Engineer Mountain	Colorado	5
‖172	Warren	Pennsylvania-New York	5
‖173	Laramie-Sherman	Wyoming	5
‖174	Johnstown	Pennsylvania	5
¶175	Birmingham	Alabama	5
‖176	Sewickley	Pennsylvania	5
¶177	Burgettstown-Carnegie	Pennsylvania	5
‖178	Foxburg-Clarion	Pennsylvania	5
‖179	Pawpaw-Hancock	Md.-W. Va.-Pa	5
‖180	Claysville	Pennsylvania	5
‖181	Bismarck	North Dakota	5
‖182	Choptank	Maryland	5
‖183	Llano-Burnet	Texas	5
‖184	Kenova	Ky.-W. Va.-Ohio	5
§185	Murphysboro-Herrin	Illinois	25
§186	Apishapa	Colorado	5
§187	Ellijay	Ga.-N. C.-Tenn	25
§188	Tallula-Springfield	Illinois	25
189	Barnesboro-Patton	Pennsylvania	25
§190	Niagara	New York	50
§191	Raritan	New Jersey	25
192	Eastport	Maine	25
§193	San Francisco	California	75
194	Van Horn	Texas	25
195	Belleville-Breese	Illinois	25
196	Philipsburg	Montana	25
§197	Columbus	Ohio	25
198	Castle Rock	Colorado	25
199	Silver City	New Mexico	25
200	Galena-Elizabeth	Illinois-Iowa	25
§201	Minneapolis-St. Paul	Minnesota	25
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