DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

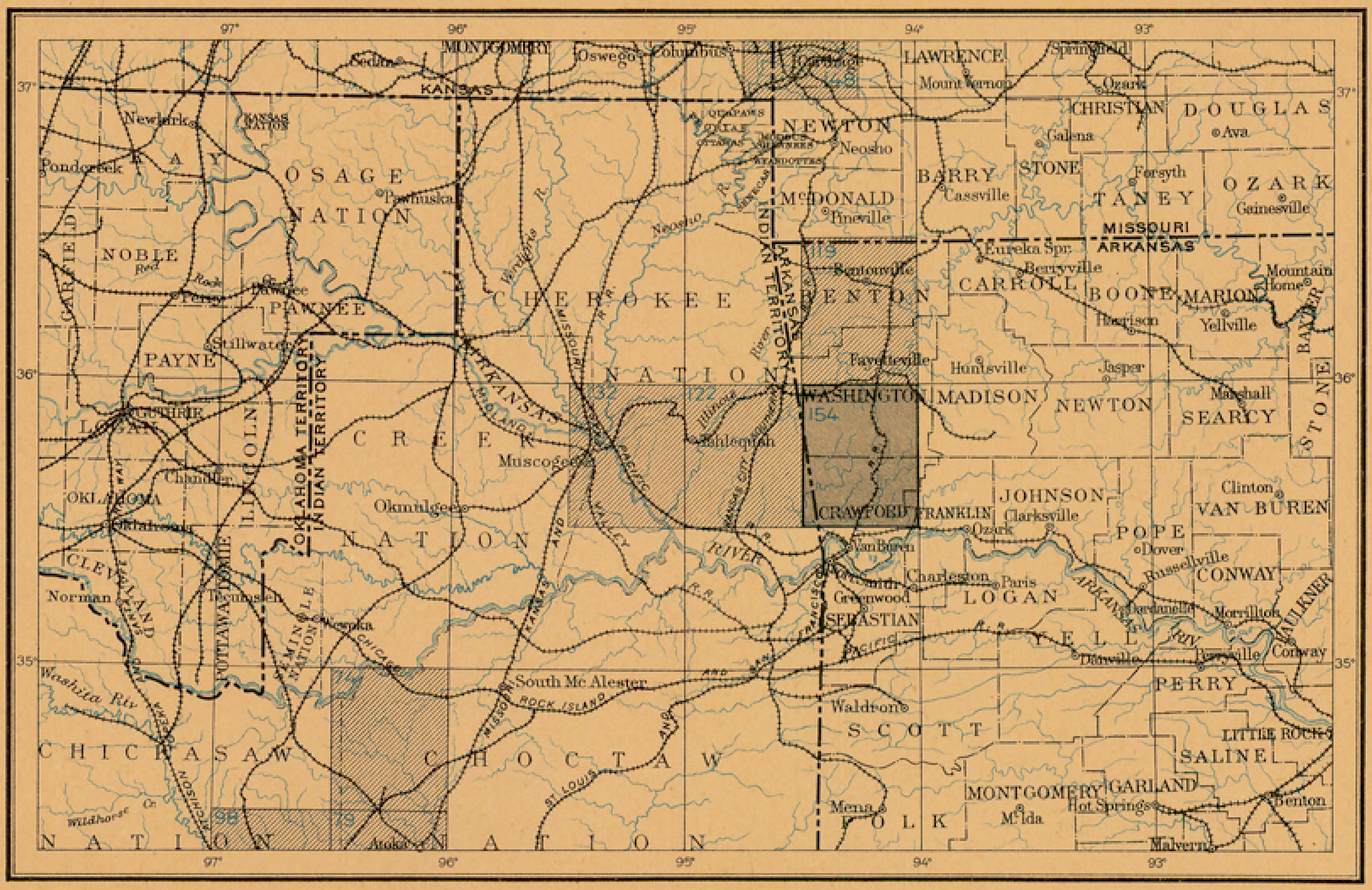
OF THE

UNITED STATES

WINSLOW FOLIO

ARKANSAS - INDIAN TERRITORY

INDEX MAP



SCALE: 40 MILES=1 INCH

WINSLOW FOLIO

OTHER PUBLISHED FOLIOS

CONTENTS

DESCRIPTIVE TEXT
TOPOGRAPHIC MAP
AREAL GEOLOGY MAP
COLUMNAR SECTION SHEET

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GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

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 which are most important 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 altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

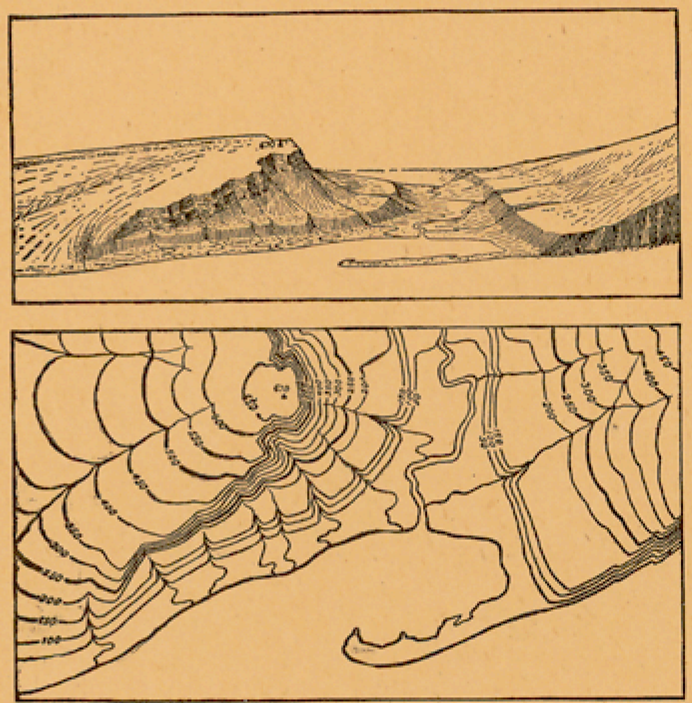


Fig. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours 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 sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while 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 sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise 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.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." 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 an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, 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 in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map 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 $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. 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 the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

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 the structure sections show their underground relations, as 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.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of 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. In smaller portion the materials are carried in solution, and the deposits are then 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 deposits 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*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *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 a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

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, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes 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 is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

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 the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

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*.

(Continued on third page of cover.)

DESCRIPTION OF THE WINSLOW QUADRANGLE.

By A. H. Purdue.

INTRODUCTION.

LOCATION AND AREA.

The Winslow quadrangle lies mainly in the western part of Arkansas, north of Arkansas River. It is bounded by parallels 35° 30′ and 36° and meridians 94° and 94° 30′. Its average width from east to west is about 28 miles and its length is about 34½ miles. Its area is almost 969 square miles. Nearly 29 square miles in the southwestern quarter of the quadrangle lie in Indian Territory. The area in Arkansas includes most of Crawford County, a small part of Franklin County, and the southern half of Washington County except a narrow strip along the eastern side.

GENERAL GEOGRAPHY OF THE OZARK REGION.

LIMITS OF THE REGION.

The Winslow quadrangle lies within the Ozark region, known in geologic literature as the Ozark uplift. This physiographic region extends from the lowlands bordering Missouri River southward to the Arkansas Valley, and from Neosho or Grand River, in Indian Territory, eastward to the Tertiary lowlands of southeastern Missouri and eastern Arkansas, its area comprising 40,000 square miles. In outline the region is roughly an ellipse whose major axis extends from the St. Francis Mountains of Missouri southwestward to the town of Wagoner, in Indian Territory, a distance of about 300 miles.

On the south the Ozark uplift is bounded by the Arkansas Valley, a synclinal trough extending east and west, which has been reduced by erosion to a plain about 30 miles wide having an average elevation of about 500 feet above sea level. Upon this plain stand Sugarloaf Mountains, Magazine Mountain, Mount Nebo, Carrion Crow Mountain, Petit Jean Mountain, and other elevations of less prominence, besides numerous low, parallel, east-west ridges. The highest point is the summit of Magazine Mountain, which stands 2800 feet above sea level.

DIVISIONS OF THE REGION.

The Ozark region consists of two areas, a northern and a southern, which differ greatly in size, in the nature of the rocks at the surface, and in surface features. The northern and larger of these areas is the Ozark Plateau, and the southern is the Boston Mountains. The Winslow quadrangle lies in the Boston Mountains, its exact location being shown in fig. 1.

THE OZARK PLATEAU.

Location and surface features.—The Ozark Plateau occupies all the Ozark region of Missouri, most of that of Indian Territory, and a strip about 40 miles wide in northern Arkansas. In the eastern part of this plateau there is a group of peaks collectively known as the St. Francis Mountains, among which are Iron Mountain and Pilot Knob. The highest part of the plateau lies in Webster and Wright counties, east of the city of Springfield. This area is roughly a broad, flat dome, with its maximum elevation in the southeastern part of Webster County, where it reaches a height of 1700 feet above sea level.

The surface of the Ozark Plateau slopes both to the northwest and to the southeast, the divide being roughly indicated by a line drawn from the St. Francis Mountains to Springfield, Mo., and from the latter place to Fayetteville, Ark. To the northwest the surface descends to Missouri River and its tributaries, along which the altitude is about 900 feet above sea level; to the southeast it descends to White River and its tributaries, which fall from about 1000 feet above sea level near their headwaters to about 250 feet above sea level at the eastern margin of the plateau. These slopes in general are rather uniform but are interrupted by certain escarpments which, though not pronounced, are significant topographic features.

The surface of most of that part of the plateau which lies in Missouri is low and well rounded between the streams, but in the vicinity of White River, both in Missouri and Arkansas, the streams have deep valleys with steep slopes, and the topography is rugged. In Arkansas, just within the southern margin of the plateau, several outliers of the Boston Mountains form conspicuous features of the landscape.

Drainage.—The direction of the drainage of the Ozark Plateau has been determined by the uplift of the region, and is therefore away from the axis, being in the main to the northwest and southeast. Most of the streams are small, only a few, such as Gasconade River on the northern slope and Current and White rivers on the southern slope, being of notable size.

White River, the largest stream in the region, rises in the Boston Mountains and flows northward, parallel to that portion of the divide which extends from Springfield to Fayetteville, turns eastward for a short distance in the southern part of Missouri, then flows southwestward, in conformity with the general slope of the plateau, to the lowlands of Arkansas, and thence into Arkansas River near its mouth. In Arkansas it receives Kings River from the south, Buffalo River from the west, and North Fork of White River from the north.

The course of White River is marked by numerous bold and graceful swings, giving it the appearance on the map of a meandering stream with a wide flood plain. In fact its valley is narrow, with steep sides. Alluvial deposits occur only here and there, forming narrow strips along the stream. The slopes of the valley on the inside of the curves are long and gradual enough to permit travel over them, but at the outer sides of the curves there are precipitous bluffs. It is evident from this that the curves have, at least in part, been produced by lateral shifting of the stream while it was cutting its bed downward.

THE BOSTON MOUNTAINS.

Location and surface features.—Along the southern border of the Ozark Plateau, at a higher elevation, stands a much dissected region known as the Boston Mountains, which form the southern as well as the highest part of the Ozark region. Their average width north and south is about 35 miles, and they extend east and west approximately 200 miles, from Grand River, in Indian Territory, to the Tertiary lowlands of eastern Arkansas. The highest part whose altitude has been determined is about in the middle of the east-west extent of the mountains, on the eastern border of the Winslow quadrangle, where the altitude somewhat exceeds 2250 feet above sea level.

This area is essentially a plateau, into which numerous streams have cut deep, narrow valleys. Along its northern border stretches an escarpment, which is indented at many places by northward-flowing streams. This escarpment is highest in its middle portion and gradually falls off eastward and westward to the borders of the area. If the Boston Mountains are viewed from the Ozark Plateau on the north, this escarpment appears to be more or less complicated by outliers or mountains of circumdenudation, which rest upon the Ozark Plateau and stand up to about the same height as the mountains from which they have been separated by erosion. The southern slope of the mountains is less precipitous, passing off rather gradually into the Arkansas Valley.

Drainage.—The Boston Mountains are drained northward almost wholly through White River and its tributaries and southward into the Arkansas. A little of the western part of the area is drained westward into Illinois River, a tributary of the Arkansas. The streams on both sides of the crest have cut their heads back so that they interlock, making a zigzag line of the water divide. The streams within the area are not large, but have cut deep, canyon-like valleys from 500 to 1000 feet below the highest points.

The streams south of the divide are swifter and therefore cut faster than those north of it, with the result that the valleys on the south are deeper and more precipitous. The slopes above the streams are interrupted by numerous nearly perpendicular escarpments produced by the differential weathering of the alternating hard and soft beds of rock. North of the divide these escarpments are practically horizontal, but south of it the dip of the rock gives them a pronounced southward slope.

TOPOGRAPHY OF THE QUADRANGLE.

RELIEF.

GENERAL FEATURES.

The Winslow quadrangle lies mainly in the western portion of the Boston Mountains, extending across them in a north-south direction. A small area near the northern border, about Prairie Grove, and a still smaller one in the northwest corner, about Summers, belong to the southward extension of the Ozark Plateau. These areas are level plains that stand about 1200 feet above sea level. A small area in the southeast corner belongs to the Arkansas Valley region. The remainder—about nine-tenths of the quadrangle—lies within the greatly dissected plateau that constitutes the Boston Mountains, and for the purpose of description may be divided into a northern area and a southern area.

THE NORTHERN AREA.

General description.—The northern area extends from the northern part of the quadrangle southward to about the latitude of Mountainburg, on the St. Louis and San Francisco Railroad. The numerous canyon-like valleys that so completely dissect the region, as well as the highest points of the quadrangle, occur in this division. Like the remainder of the region, it is deeply cut into by streams that form steep-sided, narrow, canyon-like valleys, leaving promiscuously distributed over the area many hills that stand up above the general level and are locally known as mountains. The tops of most of these hills are flat, of small area, and stand from 500 to 1000 feet above the adjacent valleys. Among these are Weedy Rough Mountain, Henderson Mountain, Gaylor Mountain, Cartwright Mountain, Meadow Mountain, Lockard Mountain, Kimes Mountain, Bald Knob, Chinkapin Knob, Grapevine Knob, and others.

The highest part of the area is near the eastern border, at the village of Sunset, which is somewhat more than 2250 feet above sea level, and from which the general surface gradually falls off toward the northern, western, and southern borders of the quadrangle. The highest points near the northern border are about 1750 feet, those near the western border 1950 feet, and those near the southern border 1150 feet above sea level.

So rugged is this division that the public roads extend along the valleys or the crests of the intervening ridges, and as most of the valleys run in a northerly or southerly direction, travel in an east-west direction is possible only by circuitous routes.

Escarpments and benches.—The slopes above the streams are interrupted by numerous escarpments, some of which are 50 feet or more in height. The most prominent and most persistent among these is the one formed by the basal ledge of the Winslow formation, to be described later. These escarpments have been formed by the weathering back of beds of soft or readily soluble rock that lie under beds of more resistant rock, mostly sandstone, which has in consequence broken off at places from want of support. The blocks thus broken off leave perpendicular bluffs of their parent rocks, along the base of which they form great heaps of talus. These talus heaps are in places bare, in others covered with soil, the result of their own disintegration, of sufficient depth to support a strong growth of vegetation. Below such escarpments there are benches or gradually sloping surfaces, few of them exceeding a quarter of a mile in width, and most of them much narrower. In the northern and middle portions of the area the escarpments in the main lie in horizontal planes, and the most prominent of them can be followed for miles; but in the southern part they slope southward with the dip of the rocks, so that any particular escarpment at length passes out of sight beneath those above.

The valleys extend northward, westward, and southward from the main summits, the heads of those from opposite slopes passing upward beyond the former water divide, causing an interlocking or interdigitation of the upper parts of the valleys and making the present water divide very sinuous.

The south slope of this division is much steeper than the north slope. From the railroad tunnel at Winslow southward to Chester, a distance of about 8 miles, the fall is 910 feet. From the same level to Greenland, on the north slope, a distance of about 14 miles, the fall is only 400 feet. As above stated, the valleys of the south slope are much deeper than those of the north slope, as a result of the greater declivity and consequent greater cutting power of the streams.

THE SOUTHERN AREA.

General description.—The northern area passes imperceptibly into the southern area, but there is a marked difference between the topography of the two. The southern area slopes gradually southward and for the most part has an even surface. It is well developed between the railroad and the eastern border of the quadrangle, where the uniformity of its surface is disturbed only by Winn Mountain, the shallow valleys of the southward-flowing streams, and a series of low, poorly defined east-west ridges along the southern border. The even surface is not so common over the area west of the railroad, which is dissected by deeper valleys, but it is well developed in the flat-topped divides between the streams, from Pine Mountain southward.

DRAINAGE.

General statement.—The streams of the quadrangle flow northward, westward, southwestward, and southward. The water of about one-sixth of the area passes into White River through West and Middle forks of that stream, the remainder into the Arkansas. The water divide is a crooked though well-defined line passing from Sunset, near the eastern border, through Winslow, thence northwestward and northward, roughly paralleling the St. Louis and San Francisco Railroad, to the northern border of the quadrangle.

Northward drainage.—About one-fifth of the quadrangle, in its northwestern part, drains northward and westward through Illinois River and its tributaries, Muddy Fork and Barren Fork. Evansville Creek, which flows westward across the western border of the quadrangle, turns northward in Indian Territory and joins Barren Fork, which enters Illinois River near Tahlequah. The Illinois enters the Arkansas about 35 miles west of the southwest corner of the Winslow quadrangle. In the northeastern part of the quadrangle are West and Middle forks of White River, which unite with East Fork in the southeastern part of the Fayetteville quadrangle, forming the main branch of White River.

Southward drainage.—The streams flowing southward and southwestward into the Arkansas are Lee Creek with its tributaries (Ellis Branch, Fall Creek, Cove Creek, Mountain Fork, and Webber Creek); Frog Bayou, formed by Howard Fork and Jones Fork, and receiving Cedar Creek at Rudy; and Mulberry River, which flows through the southeastern part of the quadrangle. Hurricane Creek, near the eastern border, is a tributary of Mulberry River.

Size of the streams.—Practically all the streams of the quadrangle head within it, and the distance is so short on either side of the divide to the borders of the quadrangle that no large streams are formed in it. However, the principal streams carry a constant supply of water, which, in their upper parts, passes over the escarpment-forming rocks as falls and rapids, while in their lower parts, at average stage, it filters from pocket to pocket through the large deposits of gravel and cobblestones that have accumulated in their beds.

Those streams on the south slope which have in part an east or west course receive, along such parts of their courses, comparatively long and well-defined streams from the north and practically none from the south. This fact is due to the rock structure and will be considered under "Influence of structure on the drainage," on page 6.

DESCRIPTIVE GEOLOGY.

ROCKS OF THE OZARK REGION.

The rocks of the Ozark region comprise strata representing all the systems from supposed Archean to and including the Carboniferous, with the possible exception of the Algonkian. The rocks classed as Archean are granitic rocks of igneous origin. Most of the surface rocks are of Cambrian and Ordovician age and consist mainly of sandstone and magnesian limestone. Over the southwestern part of the plateau the surface rock is principally limestone containing a large amount of chert, and is of Carboniferous age. The structural center of the uplift is the St. Francis Mountains, in which the supposed Archean rocks are exposed, and from which the younger rocks dip away in all directions. During the long time that has elapsed since the final uplift of the region from the sea a large amount of erosion has taken place over the entire area, removing such of the upper and younger beds as were deposited within the central part and leaving only the older rocks there exposed at the surface. But the dip of the strata away from the structural center of the uplift causes the younger rocks to appear in successive order away from it, their truncated edges being exposed in roughly concentric lines about it.

The rocks of the Ozark Plateau pass out of sight at the northern base of the Boston Mountain escarpment, and, because of their southward dip, do not reappear on the south slope. They are deeply buried beneath the rocks of the Arkansas Valley. The northern base of the Boston Mountains, up to the height of about 1500 feet, consists mainly of limestone and black, carbonaceous shale. These do not appear on the southern slope except in limited areas where the southward-flowing streams have cut down into or through them. Resting upon these and dipping southward are about 1500 feet of sedimentary rock, consisting of shales, usually black and carbonaceous, alternating with beds of brown sandstone. The sandstone strata are generally more or less massive in their upper parts, but gradually pass at the base through sandy shales into the black clay shales beneath. The shales greatly predominate over the sandstones. Probably not more than 350 out of a thickness of 1500 feet is sandstone. The main surface divisions of the Ozark region and the geologic structure and stratigraphy are shown in the sketch map and section forming figs. 1 and 2.

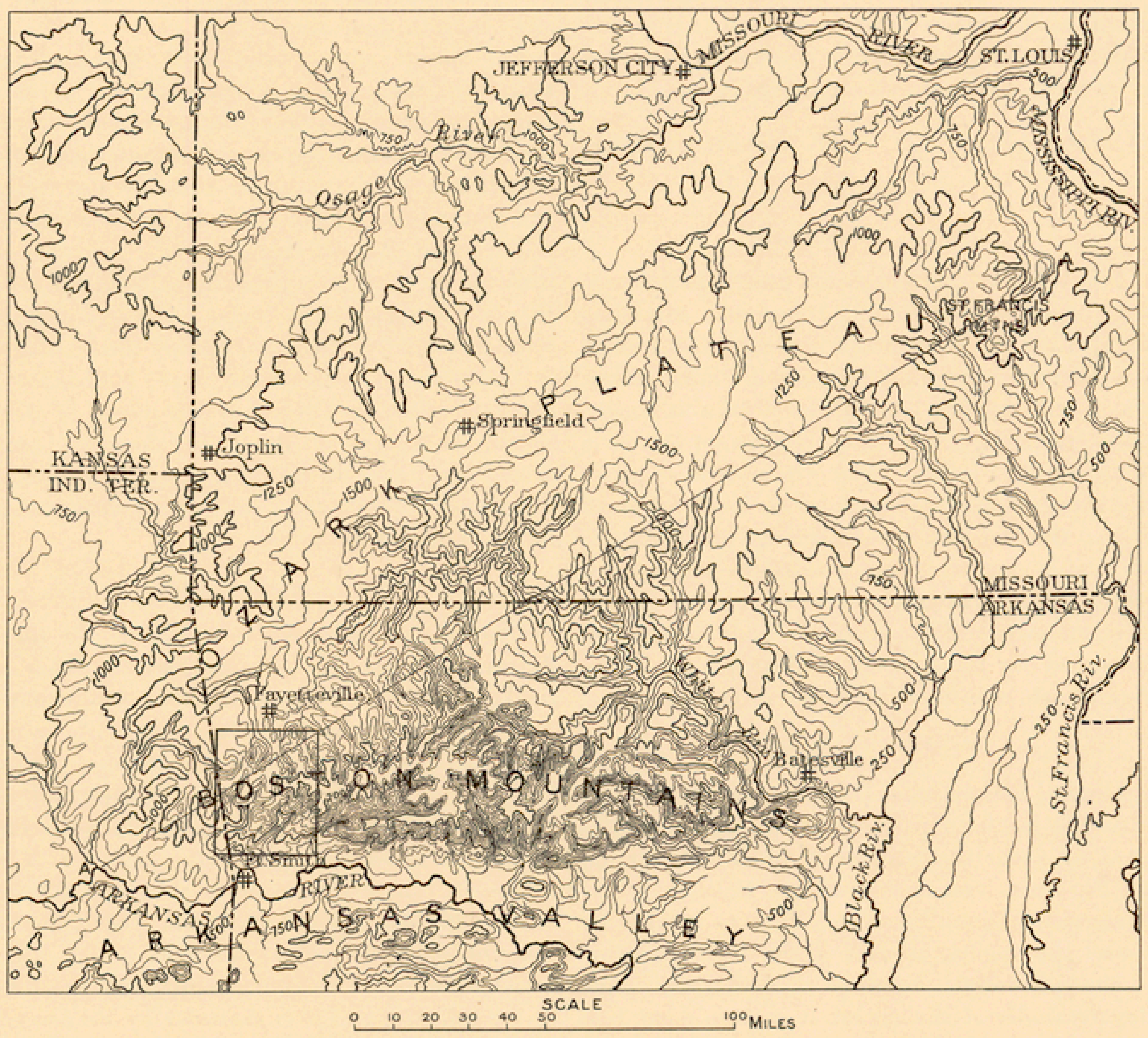


FIG. 1.—Sketch map of the Ozark region, showing the physiographic divisions.
Position of the Winslow quadrangle is shown by the rectangle in western Arkansas.

The aggregate thickness of the known Paleozoic rocks deposited over the area of Arkansas while it was submerged is estimated to be 28,000 feet. Of this amount it appears that about 5558 feet occur in northern Arkansas, including the Boston Mountains. The periods represented, with the formations and the maximum thickness of the rocks belonging to each, are shown below:

	Feet.
CARBONIFEROUS:	
Pennsylvanian:	
Winslow formation	1500
Morrow group { Bloyd shale { Kessler limestone, Brentwood limestone }; Hale formation }	460
Mississippian:	
Pitkin limestone	100
Fayetteville formation (including Wedington sandstone member)	300
Batesville sandstone	200
Moorefield shale	100
Boone formation (including St. Joe limestone member, 50 feet)	375
DEVONIAN:	
Chattanooga formation (including Sylamore sandstone member)	90
SILURIAN:	
St. Clair marble	18
ORDOVICIAN:	
Cason shale	15
Polk Bayou limestone	130
Izard limestone	280
St. Peter sandstone and underlying Cambro-Ordovician rocks	1990
	5558

The data relating to that portion of the section below the Izard limestone are taken from the reports of the Geological Survey of Arkansas, being derived from the record of a well at Cushman, Independence County. It may be that the rocks in the lower portion of the well are of Cambrian age.

FIG. 2.—Sketch section across the Ozark region, along the line A-A in fig. 1.
Shows the pre-Cambrian crystalline rocks of the St. Francis Mountains on the right, overlain by Cambrian, Ordovician, and Silurian limestones, and these by Devonian shale, Mississippian limestone, and Pennsylvanian sandstones and shales in the Boston Mountains on the left.

Nothing below the Boone chert appears at the surface within the Winslow quadrangle, and the Moorefield shale and Batesville sandstone are therein wanting above the Boone chert. All the other formations are represented.

ROCKS OF THE WINSLOW QUADRANGLE.

GENERAL STATEMENT.

All the rocks exposed within the Winslow quadrangle are of sedimentary origin, and consist of sandstones, shales, and limestones. The sandstones and shales were formed of detrital material that was carried from adjacent land areas by streams and spread out over the bottom of the sea when the Boston Mountains and neighboring regions were beneath sea level. The fine material, which at the time of deposition was mud, containing a large amount of carbonaceous matter, subsequently became consolidated, forming the shales; and the coarse material, which at the time of deposition was loose sand, became consolidated, forming the sandstones. The limestones were formed largely of shells and other parts of animals that lived in the seas at that time. The rocks are unmetamorphosed—that is, except that they have been consolidated, they have suffered little change since they were laid down. No igneous or volcanic rocks occur at the surface within the quadrangle.

Age and succession of the rocks.—The formations that occur at the surface in the Winslow quadrangle are all of Carboniferous age, both the Mississippian and the Pennsylvanian series being represented. Their positions in the time scale, and the corresponding terms used in adjacent areas and by the Geological Survey of Arkansas, are shown in the columnar section and the accompanying correlation table. The paleontologic determinations and descriptions are by E. O. Ulrich.

MISSISSIPPIAN SERIES.

The rocks in the Winslow quadrangle belonging to the Mississippian series consist, from the bottom upward, of about 300 feet of limestone, containing a large amount of chert, followed by from 200 to 300 feet of shale and sandstone, mainly, and this in turn by about 40 feet of limestone. These different formations are known as the Boone formation, the Fayetteville formation, and the Pitkin limestone, respectively.

BOONE FORMATION.

Extent and subdivisions.—The Boone formation was so named by the Geological Survey of Arkansas because of the prevalence of these rocks in Boone County, one of the northern counties of the State. It is the surface rock over wide areas in northern Arkansas, southern Missouri, southwestern Kansas, and northern Indian Territory. In the Winslow quadrangle it is the surface rock over only the two relatively small areas in the northwestern part of the quadrangle which belong to the Ozark Plateau and another small area about Dutch Mills. From these areas it passes out of sight below the younger rocks of the Boston Mountains, and reappears in only two small areas on their southern slope. One of these, probably not exceeding 100 acres, is in the upper part of Mountain Fork valley just east of the Arkansas–Indian Territory line; the other, still smaller, is somewhat more than a mile west, on Indian Creek, in Indian Territory. Where the entire thickness of this formation is exposed, it consists of two members, the lower one being named the St. Joe limestone.

St. Joe limestone member.—The St. Joe limestone member was so named by the Geological Survey of Arkansas, from the town of St. Joe in Searcy County, where it is well exposed. It is the basal member of the Boone formation, but is not exposed in the Winslow quadrangle. As seen elsewhere in northern Arkansas its thickness ranges from 15 to 40 feet or more, but is usually from 20 to 25 feet. It is a coarse-textured, crystalline limestone, full of crinoid stems, and varies in color from gray to red or chocolate. Much of it will take a good polish and is true marble.

The portion of the Boone limestone that lies immediately above the St. Joe limestone contains at many places a large amount of limestone similar to the upper part of the St. Joe. But it is usually an easy matter to determine the contact between the two on hillsides where both are exposed, because the St. Joe limestone commonly forms an escarpment above which the overlying Boone limestone retreats, forming a salient angle at their contact. The St. Joe limestone is practically free from chert, whereas the overlying beds always contain some, and at many places a large amount of chert.

Character.—At some places where the complete section of the Boone formation above the St. Joe is exposed, it somewhat exceeds 300 feet in thickness. The greatest exposure of this formation within the Winslow quadrangle occurs in the vicinity of Dutch Mills, near the western border of the quadrangle, where it forms about 200 feet of the base of the hills. It is composed of limestone and chert. The limestone is gray, compact, and rather free from impurities. Polished surfaces show that it is fossiliferous, its common fossils being crinoid stems. In places the limestone occurs in massive beds almost free from chert; in other places it occurs as lenses within the chert. The heavy beds make lime of excellent quality, as well as building stone. The chert varies from white or gray to blue in color, has a dull fracture, and occurs in lenses in limestone and in beds that range in thickness from 4 to 10 inches and have very uneven surfaces. In places the chert weathers to a white, easily pulverized material that would make good tripoli. Weathered débris on the surface shows fossil corals, brachiopods, and crinoids. The relative amounts of limestone and chert in the St. Joe member vary greatly, both horizontally and vertically. In places the formation is largely limestone, in others chert, while elsewhere it is a mixture of the two. The Boone limestone forms an even surface where it is removed from the influence of large streams; but where streams flow over it they form, by solution of the rock, numerous deep, steep-sided ravines, producing a very rough surface. Over the portion of the Winslow quadrangle where this rock is exposed the surface is mainly level and bears a great deal of chert débris, which in some places has accumulated to a thickness of several inches, while in other places it is mixed with clay soil. Both the chert and the clay are residual products, resulting from the solution and removal of the calcareous portion of the rock by ground water.

Fossils.—The chert in the middle and upper parts of the Boone formation is locally very fossiliferous. Most of the fossils are dismembered plates of crinoids and joints of their columns, but at some localities other fossils are associated with these. Among such the delicate "lace bryozoa" of the genera *Fenestella* and *Polypora*, and various brachiopods, especially *Spirifer logani*, are common.

Unconformity at top of Boone formation.—In the eastern part of the Paleozoic area of Arkansas the Boone formation is overlain by the Moorefield shale, and this in turn by the Batesville sandstone. In the central part of the area the Moorefield shale is absent, the Batesville sandstone resting upon the Boone formation. In the Winslow quadrangle the Moorefield shale and Batesville sandstone are both absent, and the succeeding formation, the Fayetteville, rests upon the Boone. So even was the surface of the Boone limestone on which the Fayetteville formation was laid down, and so nearly did this surface conform to the dip of the rock, that no irregularities were noticed in the contact between the two, though doubtless small ones exist.

FAYETTEVILLE FORMATION.

Extent.—The Fayetteville formation was named by the Geological Survey of Arkansas from the city of Fayetteville. It is widespread over northern Arkansas and Indian Territory, occurring everywhere at the northern base of the Boston Mountains and around their outliers. It is exposed on all the slopes in the northern part of the Winslow quadrangle, along the west side as far south as Evansville, in the valley of Cove Creek, in Low, Whitzen, and Garrett hollows, and in the upper parts of Mountain Fork and Indian Creek.

Character and subdivisions.—From 60 to 100 feet of the lower portion of the formation is a black, thin-fissile, carbonaceous clay shale, containing numerous dark, calcareous clay concretions of large size, which are much dissected by veins of calcite. Locally it includes, at or near its base, a bed of gray or bluish fossiliferous limestone. The clay shale passes by a rather abrupt though not well-defined transition into a brown ferruginous shale, which, over a considerable area in northwestern Arkansas, is underlain by 10 to 40 feet of sandstone, known as the Wedington sandstone. The total thickness of the formation ranges from about 150 feet east of Tolu to about 300 feet in the northwestern part of the quadrangle.

The upper part of the Fayetteville formation, which lies above the sandstone, where that is present, and is generally from 20 to 30 feet thick, is a bed of shale ranging in color from green to bluish. The layers composing it are, as a rule, thicker than those of the lower portion and contain numerous nodules, many of them 4 inches or less in diameter. Some layers are composed entirely of these nodules. Locally this portion of the formation contains gypsum in thin veins and small crystals.

Wedington sandstone member.—The Wedington sandstone, named from Wedington Mountain, in the Fayetteville quadrangle, constitutes a part of the Fayetteville formation, near its top, in the western part of the State. It outcrops on slopes in the northern part of the Winslow quadrangle and in the western part as far south as Evansville. In color it varies from a brown to a light gray. Thin beds of the sandstone show ripple marks and the more massive beds display cross-bedding. It is generally even bedded, and at many places can be quarried in beautiful, even-surfaced slabs of almost any thickness from 2 inches to 3 feet. Its ordinary thickness is about 10 feet, but south of Prairie Grove it is about 40 feet thick and, being undermined through the weathering and removal of the shale below, it breaks off in enormous blocks, leaving a steep escarpment. In the area of its outcrop this member is, as a rule, sufficiently prominent to permit its easy discovery, but in some places on the slopes it is so thin that it is completely hidden by débris.

Fossils.—Fossils are rarely found in the shale of the Fayetteville formation, but the limestone that occurs locally at its base and the calcareous shales above the Wedington sandstone generally afford a large and varied fauna. Fossils occur also, though sparingly, in the sandstone member and in the calcareous clay concretions found in the lower part of the shale. In the basal limestone perhaps the most striking and characteristic fossil is an undescribed crinoid related to *Eupachycrinus*, the thick and bulbous plates of which are in places thickly scattered through the rock. Associated with these crinoid fragments there are both finely and coarsely striated species of *Productus*, *Spirifer increbescens*, and other brachiopods, indicating that the rock is of Chester age. Bryozoa are rare in this bed.

The thin limestone plates in the upper shale are distinguished at once from the lower bed by the much greater abundance of bryozoa—chiefly of species of *Archimedes* and *Septopora*—and of both straight and coiled cephalopod shells.

PITKIN LIMESTONE.

Extent.—This formation is named from Pitkin, in the northern part of this quadrangle, where it is well exposed. In the reports of the Geological Survey of Arkansas it is known as the Archimedes limestone. Like the Fayetteville formation it is of wide extent, occurring everywhere along the northern slopes of the Boston Mountains. It outcrops on slopes in the northern part of the quadrangle, on those of the west side as far south as Evansville, in the valley of Cove Creek, in Garrett Hollow, Low Hollow, Whitzen Hollow, and in the upper parts of Mountain Fork and Indian Creek.

Character.—The Pitkin limestone is a gray, fossiliferous rock containing here and there small amounts of chert, and is in places somewhat conglomeratic. In the vicinity of Dutch Mills, in the northwestern part of the quadrangle, it is only 10 feet thick, but along Cove Creek, near the Washington-Crawford County line, where it probably reaches its maximum thickness, it is 45 feet thick. Its thickness along its northern outcrop in this quadrangle generally ranges from 20 to 30 feet. Within the Winslow quadrangle the Pitkin limestone rests upon the upper shale of the Fayetteville formation and is overlain by shales of the Hale formation. Its upper and lower surfaces are even, with no suggestion of unconformities, but beyond the northern limit of the Winslow quadrangle, in the Fayetteville quadrangle, this limestone occurs at some places in pockets and is conglomeratic, its character and relations indicating an unconformity at its base. There is also a distinct unconformity at the top of this limestone within the Fayetteville quadrangle.

The Pitkin limestone is so undermined by the weathering of the upper shale of the Fayetteville formation, on which it rests, that it breaks off in huge blocks, which rest upon the slopes below till they are disintegrated or dissolved through weathering. As a result of being thus undermined this formation generally outcrops as a steep escarpment, which is in many places impassable. The prominence and persistence of this escarpment are sufficient to distinguish this limestone from others in the area.

Fossils.—A study of the fossils from the different formations in this region shows that the Pitkin limestone here lies at the top of the Mississippian series and is overlain by the Pennsylvanian series of the Carboniferous system. The fossils are all of late Chester types and consist principally of species of brachiopods and bryozoans. Among the latter the solid axial screws of various species of *Archimedes* are common in most exposures.

PENNSYLVANIAN SERIES.

The rocks of the Pennsylvanian series constitute the great mass of the Boston Mountains. To this series belong all the rocks above the Pitkin limestone on the north slopes and all on the south slopes except those at a few places, of rather small area, where the older rocks have been cut into by the deepest gorges. The total thickness of the series as shown here approximates 2000 feet. The lower 300 feet is made up of shale, limestone, and sandstone; the upper 1700 feet of shales and sandstone, the shales greatly predominating. Probably less than 350 feet of the entire 1700 feet is sandstone. The series is divided into three formations, the Hale and Bloyd, comprising the Morrow group, and the Winslow.

MORROW GROUP.

GENERAL DESCRIPTION.

The Morrow group constitutes the base of the Pennsylvanian series, and everywhere within the Winslow quadrangle rests upon the Pitkin limestone. The nature of the lower contact has already been described under the heading "Pitkin limestone." At its upper limit, within this quadrangle, it is everywhere overlain conformably by the Winslow formation. It occurs along the northern base of the Boston Mountains, in the bases of their immediate outliers, and in the deep ravines on their southern slopes. In thickness it ranges from about 200 feet in the northern part of the quadrangle to somewhat more than 300 feet in the central part. The lower portion consists of shale and sandstone, and has been called by J. A. Taff the Hale formation, from Hale Mountain, in the western part of the Winslow quadrangle. The upper portion, named the Bloyd shale, consists of carbonaceous shale with two limestone lentils, the Brentwood and the Kessler.

HALE FORMATION.

Extent.—The Hale formation, besides occurring in the Winslow quadrangle, is present in the Tahlequah quadrangle, to the west; the Fayetteville quadrangle, to the north; and the Eureka Springs quadrangle, to the northeast. Its full eastern extent is not yet definitely known, though it probably occupies most of the Boston Mountain area. Within the Winslow quadrangle it everywhere rests upon the Pitkin limestone and is apparently conformable with it; but in the adjoining areas to the north the Pitkin limestone is locally absent and the Hale rests upon the Fayetteville formation. It is exposed on the northern slope of the Boston Mountains over considerable areas where the Pitkin limestone occurs, and also along Jones Fork and Schrader Branch, in the eastern part of the quadrangle; along Lee and Fall creeks, in the central part of the quadrangle; and over a small area south of Mountain Fork and north of Lee Creek, near the Arkansas-Indian Territory line.

Character.—The Hale formation ranges in thickness from about 100 feet to nearly 200 feet. Probably its thinnest part is in Sugar Hill, in the northwestern part of the quadrangle. Its thickest part is along Cove Creek. Its basal portion, usually about 50 feet thick, consists of sandy shale interbedded with thin layers of ripple-marked sandstone. The sandstone is variable in amount, and at some places is almost entirely wanting. Above its basal portion the Hale consists of more or less massive calcareous sandstone. The relative amounts of sand and lime are by no means constant, nor are the beds persistent in character, but change within short horizontal distances. Small lenses of rather pure limestone are common in the sandy layers; and throughout most of the sandstone, especially in its massive portion, there are spherical masses of calcareous material, the size of a walnut or smaller, which weather out, leaving the stone full of cavities and giving it a characteristic pitted appearance. Weathered surfaces of massive parts show cross-bedding.

The amount of lime in this member appears to increase southward. At the head of a small ravine leading into Lee Creek, 2½ miles north of Barcelona, the limestone of this member is at least 40 feet thick and some years ago was utilized for the manufacture of lime.

Fossils.—Locally the limestone in the Hale is highly fossiliferous. Its fauna has not been fully determined but is very clearly of later age than the Chester. Fenestellid Bryozoa, of species apparently distinct from those found in the Pitkin limestone, predominate in it, the Brachiopoda, Gasteropoda, and Pelecypoda being more sparingly represented. The most common form seems indistinguishable from the lower Pennsylvanian *Spirifer boonensis*. Some of the fossils appear to be confined to the Hale, but most of the species are represented in the later Brentwood limestone.

BLOYD SHALE.

General character.—The thickness of the Bloyd shale ranges from 100 to 220 feet. Its thinnest part is in the northeastern portion of the quadrangle. The thickest exposure noted is on the western slope of Hale Mountain, though it approximates 200 feet in all the ravines of the southern slope. With the exception of the Brentwood and Kessler limestone lentils and a bed of coal which is present in places, this formation consists almost entirely of black, thin-fissile, carbonaceous clay shale of uniform character. Locally the shale contains a small amount of sandstone in its lower part, but this is not common. Because of its softness, the shale rapidly wears away, forming long, sloping benches on the hillsides.

The coal occurs between the Brentwood and the Kessler limestones. It rarely exceeds 12 inches in thickness and is generally found not far above the Brentwood limestone. As a distinguishable vein it is only local, but streaks of coal ranging in thickness from a fraction of an inch to 2 inches are seen in fresh exposures.

A small fossil flora is occasionally associated with this coal bed. The plants resemble those characterizing the Sewell formation, of the Pottsville stage, in the southern Appalachian region.

Brentwood limestone lentil.—The Brentwood limestone, named from the town of Brentwood, in the Winslow quadrangle, lies near the base of the Bloyd shale, there being usually but from 5 to 10 feet of black shale between the limestone and the top of the Hale. This is known in the reports of the Geological Survey of Arkansas as the "Pentremital limestone." Within the Winslow quadrangle it generally consists of two, or, at some places, of three or more beds of gray fossiliferous limestone, each from 3 to 10 feet thick, separated by beds of the black shale in which it occurs. The upper part of the limestone is difficult to map, as it is hidden in most places, but its total thickness, including the intervening beds of shale, is from 40 to 50 feet.

Kessler limestone lentil.—The Kessler limestone was named by the Geological Survey of Arkansas from Kessler Mountain, in the Fayetteville quadrangle. It occurs in the upper part of the Bloyd shale, generally within 60 or 75 feet of its top. It is a compact, gray to chocolate-colored fossiliferous limestone, and is in places conglomeratic. In weathering the chocolate-colored portion passes into characteristic shalelike masses, which will at some places assist in distinguishing it from one of the beds of the Brentwood limestone. Being thin, it is here and there covered by débris, but it usually can be found by careful search at the proper horizon. It was not found, however, on Sugar Hill, in the northwestern part of the quadrangle, and was seen at only two places in the hill just east of Boonsboro. In some localities it is overlain by a few feet of sandstone, and at such places a slight escarpment shows its exact location on the hillside.

Fossils.—In both the limestone lenses of the Bloyd formation organic remains are abundant and specifically the same; but in the matter of variety of forms the two lentils are strikingly different, the number of species occurring in the Kessler being small as compared with the number found in the Brentwood.

A rather striking and widely distributed species of the Brentwood is *Pentremitus rusticus*, the fossil from which the old name of the bed—"Pentremital limestone"—was derived. A subramose, honeycombed coral, forming small masses, generally an inch or less across, and belonging to the genus *Michelinia*, is perhaps the most common and characteristic fossil of these limestone lentils. Certain layers of the Brentwood are locally filled with small gasteropods and pelecypods of many kinds; others are made up almost entirely of delicate branching and reticulated species of bryozoans.

While the fauna of these limestones is in large part new to science, critical comparisons with described species show clearly that it is more closely related to well-known Pennsylvanian faunas than to any known fauna in the Mississippian series. The fact that marine faunas of Pottsville age had been hitherto almost unknown imparts unusual interest to their occurrence in the calcareous portions of the Bloyd formation in Arkansas. At the same time it explains their strange aspect when compared with described faunas.

WINSLOW FORMATION.

The Winslow formation is named from the town of Winslow, at the summit of the Boston Mountains, on the St. Louis and San Francisco Railroad. It rests upon the Bloyd shale, and the rocks belonging to it are the only ones that outcrop along the summit of the Boston Mountains and on the southern slopes, except in the deepest ravines, where older ones have been exposed. Rocks of this formation also occur on the tops of the outliers immediately north of the Boston Mountains. Its total thickness in the Winslow quadrangle is indeterminable, but approximates 2300 feet.

Character.—The formation consists of alternating beds of sandstone and shale, with a few thin lenses of limestone. The sandstone is usually brown, composed of medium-sized grains, more or less micaceous, and occurs in beds that range in thickness from 3 feet to more than 50 feet. The thick beds are remarkably similar in character, passing from sandy shale at the base to massive layers at the top, so that it is impossible to recognize the same bed at different places, and impracticable to map any particular bed above the basal one. Within the Winslow quadrangle at least one of these beds is conglomeratic, containing waterworn quartz pebbles the size of peas and smaller. This bed lies not far above the base of the formation. In other portions of the Boston Mountains there are two or more such beds. Ripple marking is common in all the thin-bedded sandstones and cross-bedding in the more massive. These beds of sandstone, with the shale beneath, form a series of similar escarpments and benches on the slopes.

The shales, which constitute probably 75 per cent of the formation, are as a rule black and carbonaceous, though less so than those of the Morrow group. Some of the beds in the upper and middle parts are more or less sandy, micaceous, and brown to drab colored, with streaks of black carbonaceous matter.

Lenses of the limestone above mentioned occur at several places in the summit region of the western half of the quadrangle, but they are thin and apparently of small extent. The thickest lens observed was on the south slope, away from the summit region, on West Cedar Creek a half mile above its junction with East Cedar Creek. This lens is 8 feet thick, and passes gradually into sandstone above and below.

Coal occurs within this subdivision, but only in thin beds. The thickest bed reported—2 feet thick—was penetrated by a well drilled just south of Rudy. A thin seam was struck in an open prospect hole at Chester, and other seams are reported from Lee Creek and Hurricane Creek above Plymouth.

Subdivisions.—It was not found practicable to divide the formation in the Winslow quadrangle, because of the general similarity of the rocks from its base to its top, yet it is elsewhere subdivided into two parts, which here pass imperceptibly into each other. The upper portion may correspond to the Akins shale member of the Winslow, described in the Tahlequah folio.

The lower portion of the Winslow contains most of the sandstone of the formation, and the sandstone comprised in it is lighter in color and freer from mica than that of the upper part. The base of the Winslow formation consists of 20 to 60 feet of massive sandstone underlain by about 20 feet of shaly sandstone. Unweathered portions of the shaly sandstone present a massive appearance, but on exposure the bedding planes are developed and the shaly appearance follows. The rapid weathering of this rock and the shales beneath it undermines the massive layers and forms the steepest and most pronounced escarpment of the region, which conspicuously marks the dividing line between the Morrow group and the Winslow formation. The mode of occurrence of the basal layer of the sandstone, with its sandy shales beneath, is repeated in the several sandstone beds above it. In none of the others is the massive portion so thick, however, as in the basal one, except in certain beds about 100 feet thick in the upper portion along Frog Bayou, just south of Lancaster. As beds of this prominence are not exposed elsewhere, it appears that at the point mentioned they are the result of local thickening.

The thickness of the lower portion is not determined, but it probably exceeds 1500 feet. There are 900 feet exposed northwest of Bidville, near the eastern border of the quadrangle. In Lockard Mountain the thickness is at least 1000 feet. A mile south of Rudy, near the railroad, a well was drilled to the depth of 1449 feet, apparently without reaching the Bloyd formation beneath.

The upper portion of the Winslow formation is the surface rock in the southeastern part of the quadrangle from Plymouth southward, extending westward beyond Rudy, on the railroad. It also occurs south of Stattler and east of Lee Creek, in the southwestern part of the quadrangle. It consists of thick beds of dark carbonaceous shales containing dark micaceous sandstone. The amount of sandstone is relatively smaller than in the lower division. Coal from 3 to 8 inches thick is found in the shale but it has not been observed at a sufficient number of points to determine whether it occurs at only one horizon or at more than one. The thickness of this subdivision within the Winslow quadrangle is not determinable from present data, but it probably reaches 800 feet.

STRUCTURAL GEOLOGY.

STRUCTURE OF THE OZARK REGION.

Structure of the Ozark Plateau.—The general structure of the Ozark Plateau is simple. As stated above, the structural center of the Ozark uplift is the St. Francis Mountains. From this structural center the rocks dip to the north, west, and south. The dip is at most places so low that it can not be detected in single exposures, but it is sufficient to carry the older rocks, which outcrop around the central portion of the uplift, far beneath the surface in northern Arkansas.

Near the northern base of the Boston Mountains faulting is common. A line of faults extending in a general east-west direction runs from near the western border of Arkansas to the eastern border of the plateau. This line of faulting is crossed at intervals by faults of a system whose general course is northeast and southwest. All the faults are probably of the normal type, though some of them locally have the appearance of overthrusts. Slickensiding on the fault planes at some places shows that the movement was mainly horizontal. The vertical displacement is generally small, but at some places is as much as 500 feet.

Structure of the Boston Mountains.—The rocks of the northern and middle portions of the Boston Mountains probably are mainly horizontal. The very low arching that occurs in the Winslow quadrangle, giving the rocks a low northward dip on the northern side of the divide, may prevail farther east, but the surveys made to the present time do not indicate this. The structure of the southern portion of the Boston Mountains is monoclinal, the rocks dipping southward, generally at a low though easily perceptible angle. A certain amount of faulting occurs along the east-west line where the Boston Mountains pass into the Arkansas Valley, but neither the horizontal extent nor the vertical displacement is yet known. The downthrow of these faults is on the south side.

STRUCTURE OF THE WINSLOW QUADRANGLE.

GENERAL STATEMENT.

The structure of the quadrangle is indicated in the sections forming figs. 3 and 4, which show the positions in which the rock beds would be seen if they were cut through on a north-south line and the rocks on the east side removed, leaving those on the west side exposed to view.

The rocks of the northern portion of the quadrangle lie for the most part in horizontal layers, but their position is somewhat varied locally by small folds and faults. Those of the southern two-thirds dip as a whole to the south, forming a continuous monocline. The dip is generally at a low angle and is here and there interrupted by horizontal stretches or dips of minor importance in other directions. In places, along certain lines, the dip is as much as 15°, forming upon the general monocline secondary monoclinal folds which greatly affect the structure. Over the northern third of the quadrangle the rocks dip northward at a low angle, making the structure over the northern half of the quadrangle that of a low anticline.

MONOCLINAL FOLDS.

Frisco monoclinal fold.—A pronounced monoclinal fold extends south of east from Anderson Mountain, near the western border of the quadrangle. Another, of equal importance, extends north of east from Whitzen Hollow. Each of these folds is about 2 miles wide and the dip probably nowhere exceeds 10°. The two monoclinal folds appear to unite in the valley of Blackburn Creek, from which they extend as one fold to the eastern border of the quadrangle. This structural feature is well marked at the bend of the railroad above the town of Frisco and is therefore called the Frisco monocline. On the areal geology map these folds can be traced by inliers of lower formations, such as the Pitkin and Hale, in the deep ravines south of the divide, where these lower rocks have been cut into along the tops of the folds and are thus exposed over small areas, as shown on the map.

SYNCLINES AND ANTICLINES.

Near the middle of the western portion of the quadrangle there is what appears to be the eastern terminus of an anticline that enters the quadrangle from the west. The northern limb of this anticline has a pronounced north dip and, with the north fork of the Frisco monoclinal fold, forms at the extreme western margin of the quadrangle a syncline which, a little farther east, passes into the Evansville fault, to be described later. For a distance of about 3 miles the top of the anticline is flat. Its southern limb forms the western part of the south fork of the Frisco monoclinal fold. This anticline is not noticeable east of Cove Creek.

West of Natural Dam, between Mountain Fork and Lee Creek, there is an anticline similar to the one described above, but of much less extent. This also appears to be the eastern terminus of an anticline entering from the west.

FAULTS.

General statement.—Within the quadrangle there are two sets or systems of faults, one of which extends from northeast to southwest and the other mainly from east to west. They are of the class known as normal faults, and the displacement seldom exceeds 100 feet. In neither system does there appear any rule of downthrow. In some faults it is on one side, in others it is on the other. The character and relation of these faults to the monoclinal folds will be understood by reference to the areal geology map and the structure sections. The shortness of the distance over which some of the faults are mapped is due to the similarity of the sandstones and shales constituting the Winslow formation, which prevented the detection of faults in those areas where the lower rocks are not exposed.

White River fault.—Of the northeast-southwest faults, one is located in the northwestern part of the quadrangle. This fault has an extent of only a few miles within the Winslow quadrangle, but passes southwestward into Indian Territory, and northeastward into the Fayetteville quadrangle, whence it extends eastward into the Eureka Springs quadrangle. In the Winslow quadrangle the downthrow of this fault is small and is on the southeast side. It has been described in the Fayetteville folio as the White River fault.

Price Mountain fault.—The most prominent fault extending in a northeast-southwest direction is the one along Cove Creek. In places it is a well-defined fault; in others it is represented by a monoclinal fold, extending for several miles along the valley. The same line of disturbance is shown in a fault west of Onda post-office and in local steep dips along Illinois River. Farther to the northeast, in the Fayetteville quadrangle, it becomes again a well-defined fault several miles in extent, and it reappears as a fault in the Eureka Springs quadrangle. The total length of the line of disturbance is about 55 miles. Along Cove Creek the displacement by this fault is only about 50 feet, and the downthrow is on the southeast side. This has been described in the Fayetteville folio as the Price Mountain fault and syncline.

A small fault belonging to this series follows the St. Louis and San Francisco Railroad for about 2 miles, its north end being at the bend of the railroad just south of Brentwood. The downthrow is on the west side and the displacement is small. What is probably the same line of disturbance is shown in slight faulting in the bed of Howard Fork, south of Winslow, and in a fault on Frog Bayou, south of Chester, at the mouth of Jones Fork.

Mulberry fault.—A northeast-southwest fault occurs in the southeastern part of the quadrangle. Entering the quadrangle in the northwestern part of sec. 36, T. 10 N., R. 30 W., it extends northeastward for about 5 miles, to a point above the junction of Little Mulberry and Rock creeks. From this point it can not be traced eastward, but it appears to pass into the southward-dipping monocline that is so pronounced in the southern part of the quadrangle. It is this fault that causes the escarpment bordering the Arkansas Valley in Lafayette and Vine Prairie townships. The downthrow is on the southeast side. The amount of throw is uncertain, but if a thin bed of coal outcropping in the southern part of sec. 21, T. 10 N., R. 29 W., at an elevation of about 450 feet, is the same as a similar one outcropping in the southern part of sec. 13, T. 10 N., R. 30 W., at an elevation of 750 feet, the throw is about 300 feet. The agreement in the thickness, character, and stratigraphic relations of these coals indicates that they are the same bed.

Evansville Creek fault.—Of the east-west faults the most pronounced is the one along Evansville Creek, extending eastward beyond Fall Creek. The same general line of disturbance is indicated by the Frisco monoclinal fold, which is notably displayed on Lee Creek near the Washington-Crawford county line, and in the fault north of the town of Porter.

Along Cove Creek where the fault crosses the Price Mountain fault the structure is somewhat unusual. The Price Mountain fault brings the base of the Winslow in the northeast quadrant made by the crossing of the faults down to the level of the Brentwood limestone in the northwest quadrant. Likewise the Evansville Creek fault brings the Winslow in the northeast quadrant down to the level of the Brentwood limestone in the southeast quadrant. In the southwest quadrant the Pitkin limestone occurs at two very different levels as a result of the bending down of the rocks by the drag of the fault on the upthrown side and the subsequent erosion of the crest of the arch.

This fault follows the axis of a syncline from its western end, south of Anderson Mountain, to some point east of Cove Creek, but at Fall Creek it is on the south limb of the syncline. The displacement of this fault does not exceed 100 feet, and the downthrow is on the north. The fault north of Frisco, which is in the same general line of disturbance, is on the Frisco monoclinal fold. The downthrow of this fault is on the south.

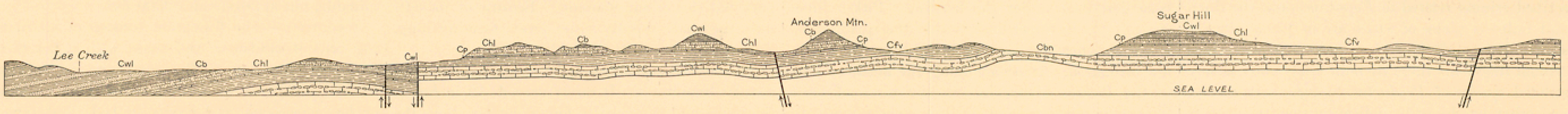


FIG. 3.—South-north section through Anderson Mountain, along line A-A on areal geology map.

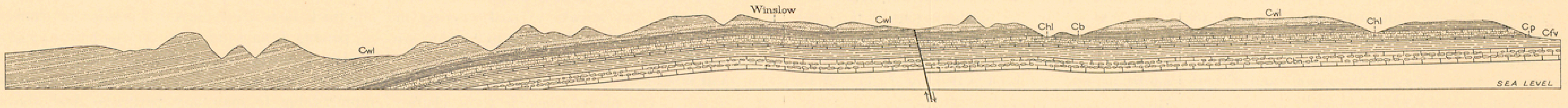


FIG. 4.—South-north section through Winslow, along line B-B on areal geology map.

Horizontal scale: 1 inch = approximately 2 miles. Vertical scale: 1 inch = 2000 feet.

Cbn, Boone formation; Cfv, Fayetteville formation; Cp, Pitkin limestone; Chl, Hale formation; Cb, Bloyd shale; Cwl, Winslow formation.

Mountain Fork faults.—In the upper part of Mountain Fork valley, at the western border of the quadrangle, there are two parallel east-west faults about one-half mile apart. These are plainly discernible on account of the variety of the formations exposed in the locality mentioned, but they can not be traced far eastward because of the uniform character of the rocks of the Winslow formation, into which they pass about 2 miles east of the State line. The deformation consists of a block let down between the two faults, the downthrow being 100 feet along the south fault and 500 feet along the north one.

Smaller faults.—A fault crosses Lee Creek and Ellis Branch a short distance above their junction. The downthrow is on the north side, and is about 100 feet. Another crosses Lee Creek in T. 14 N., R. 31 W., in which the downthrow is nearly 200 feet and is on the south side. Another which has a downthrow of about 50 feet on the north side occurs in the same township northwest of Onda post-office, and still another occurs in sec. 31, T. 14 N., R. 29 W., in the eastern part of the quadrangle. The direction of the downthrow of the last fault was not determined, but it is probably on the north side. All the faults mentioned in this paragraph either occur in the Winslow formation or run into it within short distances. On account of the similarity of the Winslow rocks it is not practicable to map the faults therein, although they may extend for considerable distances.

HISTORICAL GEOLOGY.

SEDIMENTARY RECORD.

General historical events.—Probably from Archean time, during long geologic periods, the area occupied by northern Arkansas and adjoining regions was covered by the waters of the ocean, except at intervals when parts of it were temporarily uplifted into land areas.

The final emergence of the Ozark area began with the central part of the uplift and, except during occasional interruptions, gradually spread in all directions, so that those parts far removed from the center were late in appearing. Most of the Ozark Plateau was a land area long before the Boston Mountain region emerged from the sea. During this time denudation was going on over the Ozark Plateau, and the detrital material resulting therefrom was carried by streams and deposited over the present area of the Boston Mountains and farther south along the Arkansas Valley. That the Boston Mountain region formed an area of subsidence during this time is shown by the great thickness of Pennsylvanian rocks it comprises.

That the Ozark region has not stood at a constant level since its final uplift from the sea, but has suffered oscillations, is indicated by the character of its stream valleys and by the overlapping of Cretaceous and Tertiary deposits on the eroded edges of the older rocks of the area. Differential movement at the time of the original uplift or subsequently, or both at the time of uplift and later, produced the crustal warping and the faults above described. But the movements over the area were comparatively uniform, leaving the rocks horizontal or with only low dips.

Local geography in Ordovician time.—Although no rocks lower than the Carboniferous appear at the surface of the Winslow quadrangle they doubtless occur beneath, and would be penetrated by deep drilling. That is to say, the geographic conditions in pre-Carboniferous time were much the same within the area of this quadrangle as in adjacent regions where older rocks are exposed. The Ordovician rocks are magnesian limestones interbedded with small amounts of shale and larger amounts of sandstone. Their sandy parts show ripple marks of short wave length, and the limestone, on weathering, frequently shows similar marks. Sun cracks are also seen in them. The ripple marks indicate a shallow sea and the sun cracks signify shore-line conditions. These markings and the fact that nearly all these rocks are limestones indicate that during Ordovician time there was a shallow sea of clear water over the entire area, with low neighboring land areas.

Local geography in Silurian time.—In the eastern part of the highland region of northern Arkansas the Silurian is represented by the St. Clair limestone. But in the western part of Missouri and northwestern Arkansas rocks of this age do not outcrop and may be wanting also beneath the cover of later rocks. At Marble, Ind. T., however, about 18 miles west of the southern half of this quadrangle, the St. Clair outcrops in great force, so that it is quite possible that it may extend eastward from that point into this area. Where the Silurian is wanting, rocks of Devonian or Carboniferous age rest upon the Ordovician. Most if not all of the area over which Silurian rocks are absent was land during Silurian time, and consequently was undergoing erosion. The rocks constituting that land body in northern Arkansas and vicinity were of Ordovician age, and the material eroded from them entered into the composition of the Silurian rocks that were being laid down in the neighboring seas.

Local geography in Devonian time.—During late Devonian time the geography of the region changed so as to extend the sea over a considerable portion of what had been land during Silurian time. This extension resulted in the deposition, over parts of northern Arkansas, of Devonian rocks, which consist for the most part of sandstones and shales. The Sylamore sandstone and the Chattanooga shale were laid down at this time. It appears that the sea advanced from the south toward the north, and that the Sylamore sandstone was laid down along the advancing coast line and was followed by the Chattanooga shale. Where the Silurian rocks are present the Devonian rocks rest upon them; elsewhere the Devonian rocks lap over on the Ordovician.

Local geography in Carboniferous time.—During the greater portion of Carboniferous time the area occupied by northern Arkansas was covered by the sea, so that all the general divisions of the rocks of that age are there represented. Occasional changes of level resulted in the local absence of certain formations and parts of others, but the intervals represented by such changes are comparatively short.

The conditions seem to have been those of low-lying land areas and shallow marginal seas, in which only slight elevations or subsidences of the land were necessary to cause the sea to recede or advance.

Sandstones in themselves are evidence of shallow water, but in addition to this, those of both the Mississippian and Pennsylvanian series are ripple-marked where thin, and cross-bedded where heavy, indicating deposition in shallow water along a seashore. The same conditions are indicated by the conglomeratic nature of the northern border of the Pitkin limestone, certain parts of the Kessler limestone, and some of the beds of the Winslow formation.

Numerous beds of black, carbonaceous shale constitute a large part of the Carboniferous rocks above the Boone formation. Probably these were laid down in shallow water and were composed of detrital material from low-lying, vegetation-covered land areas, over which flowed sluggish streams that were unable to carry coarser-grained material. The shallow-water origin of some of the shale beds is confirmed by the presence in them of thin beds of ripple-marked sandstone.

The Pitkin limestone, which occurs throughout the Boston Mountains at the top of the Fayetteville formation, represents a time of minimum deposition of detrital material and consequently a clear sea, which, as above stated, was probably shallow.

The Hale formation, which rests upon the Pitkin limestone, represents a resumption of land sedimentation, which appears to have continued throughout the time occupied by the deposition of the Morrow group and the Winslow formation, except during the two intervals in which the Brentwood and Kessler limestones were put down. These limestones occur in the black, argillaceous, coal-bearing shale of the Bloyd formation and seem to indicate radical physical changes, a sea that received a great deal of muddy sediment being followed by one that was practically free from such deposits.

The numerous recurrent beds of sandstone in the shales of the Winslow formation are attributable either to uplift of the land supplying the material, resulting in renewed vigor of the streams, sufficient to enable them to carry coarse material; or to the reverse action, encroachment of the sea upon the land, during which process the sorting power of the water would separate the sand from the finer parts of the soil, depositing the coarser material near the shore and carrying the finer muds seaward. Possibly some of the sandstone beds owe their origin to the one process, and some to the other; but the sequence of the rocks from argillaceous shales upward through sandy shales to massive sandstone, which is the one so often repeated in the region, favors the theory that the sandstones were the result of land elevation rather than sea encroachment.

UNCONFORMITIES.

General statement.—While the region was beneath the ocean, detrital material carried from land areas by streams was forming sedimentary rocks upon it. Such parts as were from time to time lifted above the ocean level and temporarily added to the land suffered erosion during the time they stood above sea level, while adjacent marine areas continued to receive deposits. After these temporary land areas had subsided beneath sea level, deposition upon them was resumed, but the formations that were deposited in the surrounding seas while the land area was suffering erosion were wanting over this area. The part removed by erosion was also wanting. In such cases there is a gap between the older rocks and the overlying younger ones, known as an unconformity. The amount of rock thus lacking in the geologic column at any particular point depends upon the thickness of strata deposited while the area was land, and the amount eroded from the land during this time. Several notable unconformities have already been determined in this general area, but most of them occur in rocks older than those exposed in the Winslow quadrangle. However, there are two, one at the top of the Boone limestone and one at the top of the Pitkin limestone, which enter into the history of the exposed rocks in the quadrangle.

Unconformity at top of Boone formation.—In the eastern part of the Paleozoic region of northern Arkansas the Boone formation is overlain by the Moorefield shale, mentioned in the accompanying table of formations and general time scale. This in turn is overlain by the Batesville sandstone. The Moorefield shale is wanting over western Arkansas, and both formations are wanting in the Winslow quadrangle. The history of the unconformity is as follows: After the Boone formation was deposited northern Arkansas was lifted above sea level, becoming a land area which suffered more or less erosion. The period of erosion was followed by one of subsidence, bringing a portion of the area below ocean level and resulting in the deposition of the Moorefield shale. It appears that this subsidence did not submerge northwestern Arkansas, which remained land; but a later subsidence brought the greater part of it beneath sea level during a period in which the Batesville sandstone was deposited in certain areas. This period seems to have been of short duration, for the Batesville sandstone is nowhere very thick, and at its close the northwestern part of the Arkansas area was again elevated, giving rise to erosion by which the Batesville sandstone was partially removed. Apparently this sandstone was either not deposited over the Winslow quadrangle at all or it was wholly removed from it. In those parts of this region where the Batesville sandstone is absent the Fayetteville shale, the next formation deposited, rests directly on the Boone formation.

Unconformity at top of Pitkin limestone.—The northern border of the Pitkin limestone is in the southern part of the Fayetteville quadrangle, which joins the Winslow quadrangle on the north. Around its northern border this limestone is truncated by erosion, the overlying Hale formation resting unconformably upon it and lapping over on the Fayetteville formation. This condition is significant, because it indicates that a land area then existed north of the Winslow quadrangle, and only a short distance away. It follows that the rocks of the Morrow group and probably later formations are made up in whole or in part of waste from this land area.

It is also true that along its northern border the Pitkin limestone is conglomeratic. This indicates an elevation of the land, resulting in the rejuvenation of the streams sufficient to enable them to carry pebbles of considerable size. These pebbles were deposited around the borders of the sea at the time the Pitkin limestone was being deposited, and in that way became a part of that formation.

The very uniform thickness and even surface of the top of the Pitkin limestone in the Winslow quadrangle and the fact that it is everywhere found there at the proper horizon indicate that the unconformity does not reach into the Winslow quadrangle. The Hale formation here rests upon the Pitkin in such a way as to indicate that the periods of the deposition of these two were not separated by an interval of erosion, but that the one was placed without interruption upon the other. At any rate it seems certain that the erosion interval following the Pitkin, if there was such an interval, was here relatively short.

Emergence of the area.—Deposition seems to have continued almost uninterruptedly over the Boston Mountain region during the latter part of Mississippian (Lower Carboniferous) time and during a large portion and probably all of Pennsylvanian (Upper Carboniferous) time. The region may have been a land area during the later part of Pennsylvanian time, in which case it was washed on the south by the sea which then occupied the valley of the Arkansas. However this may have been, the region was affected, either by increased uplift of the land or by entire emergence from the sea, by the widespread crustal movements that brought Carboniferous time to a close. Except, possibly, for a brief time, during which the waters of the Tertiary sea that covered the lower portions of the State may have encroached somewhat upon its present slopes, the Boston Mountain area has since remained land.

PHYSIOGRAPHIC RECORD.

Oscillations of the region.—The forces which produced the above-mentioned uplift and which resulted in the folding of the rocks along east-west lines south of Arkansas River caused them to be lifted vertically upward so as to leave the rock beds practically horizontal in the Ozark region. However, it should be remembered that a monoclinal fold, which has already been described under the heading "Structural geology," extends southward from near the summit to the southern base of the Boston Mountains. The present altitude of the rocks is not the result of a single impulse that first lifted them from beneath sea level, for at least twice since the first uplift the region subsided sufficiently to bring the waters of the Gulf far inland and was again uplifted, forcing the water border seaward. The first of these subsidences occurred during Cretaceous time and resulted in extending the waters of the Gulf over a large portion of the area now occupied by the Gulf Coastal Plain. This subsidence was followed by an uplift and this in turn by another subsidence, bringing the Gulf as far north as the mouth of Ohio River. The last subsidence occurred during Tertiary time, and the following uplift forced the water border back to about its present position.

The structure of the Ozark region is the combined result of its oscillations, including the initial uplift from the sea and its subsequent movements. Its present altitude is the net result of its oscillations and the amount lost by erosion. The maximum amount of uplift within the region occurred in the vicinity of the St. Francis Mountains, a fact which explains the general dip of the rocks away from that center. As the rock strata throughout the region are so nearly horizontal, it is concluded that the force producing the uplift acted in a vertical and not in a horizontal direction. There was little of the lateral thrust that tends to produce folds. The region as a whole was lifted bodily upward. There is reason for believing that by a late movement the Boston Mountains were forced up higher than the country farther north. This uplift is indicated by the present height of those mountains, which is greater than that of any other part of the Ozark uplift; by their drainage, which is north and south from the divide; by the deep and youthful character of the canyons through which the streams flow; and by the drainage eastward into White River and westward into the Arkansas, along the north base of the mountains. It is therefore thought that the Boston Mountains owe their height not only to excessive erosion of the region to the north, but in part to differential uplift.

Erosion of the region.—Had the region not suffered erosion after uplift it would have stood much higher than it now stands, and the surface of the Winslow quadrangle would have been a flat arch, with its southern base several hundred feet lower than its northern one; but no sooner was the region lifted out of the sea than streams began to form on it. The main lines of drainage at first developed were White River to the north and Arkansas River to the south. From these main streams tributary streams gradually cut back toward the divide, many of them having now passed beyond that line, so that their heads interlock in the manner already described. From these streams smaller ones have been developed in such numbers that the region is now completely dissected by them.

Erosion has been much more effective in the region north of the Boston Mountains than in the mountains themselves, for it has reduced a large part of Missouri and northern Arkansas to a comparatively low altitude, leaving the Boston Mountains standing up above the area thus eroded, their front forming a rather bold escarpment. The summits of many of the outliers north of the Boston Mountains stand several hundred feet above the general level of the area about them, furnishing incontrovertible evidence of a part of the erosion that has taken place over the area.

Influence of structure on the drainage.—The preservation of the Boston Mountains from the marked erosion which has affected the region to the north is due in part to their structure, which, as already stated, is that of a flat anticline. The divide was located by the structure, and only the headwaters of the streams were at work in the Boston Mountains. Since the reduction of the surface is latest along the small streams the rocks of the anticline are there least removed. Their preservation in places is due also to the massive beds of sandstone of which they are in part composed, and which is able to withstand erosion for a long time. Most important among these sandstone beds is the heavy ledge at the base of the Winslow formation.

The steep slopes within the Winslow quadrangle caused the streams that flow northward and southward from the divide to be swift and to cut down their beds rapidly, without much side or lateral cutting, a process which has formed the steep, narrow valleys of the region. The alternating layers of hard and soft rocks have given rise to numerous small waterfalls and rapids, which appear along the course of each stream at the outcrops of the hard layers.

Streams develop easily in the direction of the dip and along the strike of rocks, but with difficulty in other directions. This is well exemplified in the streams of the southern part of the Winslow quadrangle. By reference to the topographic map it will be seen that the main streams south of the divide flow nearly southward, with here and there a stretch extending eastward or westward. Over the southward parts of their courses they flow with the dip of the rocks, and over the eastward or westward parts they flow along the strike. Thus the general direction of Lee Creek is southwestward to the latitude of Natural Dam, from which point it flows westward for several miles, following the strike of the southward-dipping rocks. The abrupt turn of Cove Creek to the east, north of Grapevine Knob, is caused by the upturned edges of the rocks along the Frisco monocline. The influence of the strike on the course of streams is observed also in the courses of Webber Creek and Cedar Creek west of Rudy, in those of McCaslin Branch west of Chester and Jack Creek south of Patrick Mountain, and in the lower part of Little Mulberry Creek. The tendency of streams to follow fault lines is shown in Cove Creek from its source to the point where it turns eastward, in Evansville Creek, and in the lower part of Garrett Hollow.

The effect of structure is shown not only in the main streams of the region, but is even more marked in their tributaries. It is interesting to note that the northern tributaries of Lee Creek, Webber Creek, Cedar Creek, and Little Mulberry Creek are numerous and comparatively strong and well developed, while those from the south are few and feeble. This condition is due to the general southward dip of the rocks, permitting streams flowing in that direction to develop with ease but prohibiting the development of large northward-flowing streams.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The resources of the Winslow quadrangle consist of limestone, clays, a small amount of coal and possibly of natural gas and oil, soils, water, and timber. At present practically no use is made of the limestone and the only point at which clay is utilized is near Prairie Grove, where one plant uses it for manufacturing brick and tile. It is probable that the limestone and clay which occur in association at the northern base of the Boston Mountains would make good cement. Coal is mined only for local blacksmithing.

LIMESTONE.

The Pitkin limestone occurs in sufficient amounts at all points of its outcrop to permit its being quarried. It is a fairly pure, homogeneous nonmagnesian limestone of a uniform gray color. Its coarse texture and the large number of fossils it contains indicate that it would be neither strong nor durable as a building stone. Except for local use for temporary structures its employment as a building stone is made more improbable by the large amount of good limestone and marble available for this use in northern Arkansas.

The limestone beds of the Hale contain streaks of sandstone and are therefore, as a rule, so heterogeneous as to make them undesirable for use as building stone. However, at a point on Lee Creek, 2½ miles north of Barcelona, this limestone occurs in massive beds, more than 40 feet thick, and was utilized many years ago for the manufacture of lime.

The Brentwood limestone is very similar in character and general appearance to the Pitkin, but it is not so massive and its occurrence in considerable quantities is uncertain.

The Kessler limestone is generally so thin that it could not be quarried with advantage, and it has no qualities to recommend it for any purpose which the Pitkin or Brentwood would not serve as well.

Any of the limestones of the region could be used for macadamizing the roads, but the large amount of sand in the limestone of the Hale would probably render it exceptionally suitable for this purpose.

CLAYS.

The decomposition of the numerous beds of shale that outcrop on practically all the hill slopes gives rise to an equal number of belts of residual clay. The wash over these softened shales has carried considerable portions of the clay down the slope and deposited it along the bases of the hills. This condition is especially noticeable along the north base of the Boston Mountains, where the Fayetteville shale outcrops, and where the clays consist of residual clay derived from the Fayetteville shale and transported clays derived from the shale outcropping above. Because of the great similarity of the different beds of shale, especially those of the Fayetteville and Morrow formations, the resulting clays are very similar. They contain considerable amounts of carbonaceous matter, iron, and, doubtless, some lime. As would be expected, those that consist in part of transported material from the slopes above contain a quantity of sand, and consequently are lean clays. Fat residual clays, derived from shales free from sand, are found in the decomposed shale of the upper part of the Morrow group and in other beds. The best clay of this character observed is at the height of 1000 feet on the hillside 1¼ miles south of Mountainburg, where it is finely exposed in the roadside.

IRON.

Ferruginous sandstone and small deposits of limonite of poor grade occur at several points in the Winslow formation, but they have no economic value.

NATURAL GAS AND OIL.

Oil has recently been struck at Muscogee, Ind. T., and small amounts of gas have been obtained in the Fayetteville quadrangle. The stratigraphic and structural conditions in the Winslow quadrangle are favorable to the storing of oil or gas if they are present in the area. There is a possibility of procuring natural gas or oil in the western part of the quadrangle, in the two anticlines already described. The portion of the northern of these two anticlines most favorable for prospecting is an area extending 2 miles on either side of the Washington-Crawford county line and from the western border of the quadrangle eastward as far as Stop post-office. In the southern anticline the most favorable prospecting ground is a small area lying between Mountain Fork and Lee Creek and extending westward from a line a mile west of Natural Dam to the township line. In neither of these would it be worth while to drill more than a few feet below the base of the Boone formation.

ZINC AND LEAD.

The zinc and lead in southwestern Missouri and vicinity occurs in the Boone formation. This formation in northwestern Arkansas has never been carefully exploited for these metals, and while no assurance can be given of their occurrence in large quantities in the region, they may yet be discovered in deposits large enough to be profitably mined. Small amounts of sphalerite have been found by surface prospecting near Morrow post-office. Prospecting for zinc and lead ores within the Winslow quadrangle should be confined to the most promising places along those parts of the White River fault, Price Mountain fault, and Evansville Creek fault where the Boone formation is near the surface. These points can be located by reference to the areal geology map.

COAL.

Coal in the Bloyd shale.—In the Bloyd shale at some places there is a bed of coal, usually from 10 to 12 inches thick. This is the coal and shale referred to in the reports of the late Geological Survey of Arkansas as the coal-bearing shale. This coal is worked within the quadrangle for local use only, at several points on the northern slopes and along Cove Creek and Ellis Branch on the southern slopes. It is a coal of superior quality and is sought for blacksmithing, but the bed is too thin for extensive development.

Coal in the Winslow formation.—A small bed of coal was passed through by a prospect shaft at Chester, but it probably did not exceed 2 or 3 inches in thickness. The record of a drilled well in the valley of Frog Bayou, a mile south of Rudy, shows that 2 feet of coal was struck at a depth of 30 feet from the surface. Though this well is almost 1500 feet deep, it penetrates no other coal bed. In the southeastern part of the quadrangle, in the shales that constitute the upper part of the Winslow formation, coal outcrops at several points in beds that range in thickness from 3 to 10 inches. These outcrops are too thin to be traced, but their stratigraphic relations indicate that the coal is not confined to a definite horizon, but occurs in lenses at different horizons. This coal has been worked for local use at a few points, and these, together with the points at which the coal of the Bloyd shale has been worked, are shown on the map.

WATER RESOURCES.

Springs are common in the northern and western parts of the quadrangle and at places south of the divide where streams have cut down into the limestone. The water of these springs is distributed to all parts of the quadrangle by means of streams, most of which furnish a constant supply of excellent quality. In places where springs are not common it is generally easy to obtain water by means of wells. There are four important water-bearing formations within the area, namely, the Boone, Pitkin, Hale, and Winslow.

Boone horizon.—The Boone is much jointed and its cherty parts are fractured, conditions which permit it to receive and readily transmit a large amount of water. This is by far the most important water-bearing formation in northern Arkansas, and the large amount of water it furnishes is of excellent quality. The area over which this is the surface rock in the Winslow quadrangle is so nearly level that only a few springs emerge from it, and the water it contains must be procured by means of wells.

Pitkin horizon.—The Fayetteville shale, on which the Pitkin limestone rests, holds the water up in the limestone, through which it moves along joints as small underground streams, issuing here and there along the hillsides in strong, beautiful springs. The historic springs at Boonsboro issue from the Pitkin formation, and there are numerous others along its northern outcrop. Many springs also flow from this horizon on the south slope, where the limestone is exposed in the ravines, such as Cove Creek, Low Hollow, Garrett Hollow, Whitzen Hollow, and Mountain Fork.

Hale horizon.—The upper portion of the Hale formation, being of an open, porous nature, forms an excellent water reservoir, from which issue a large number of fine springs at short intervals along its outcrop in the northern part of the quadrangle, in the deep ravines south of the divide, and along the western border as far south as Lee Creek.

Winslow horizon.—Springs emerge from the Winslow formation on the hillsides of the north slope, but they are of minor importance, in both size and number. However, the Winslow sandstone furnishes water in abundance from wells of moderate depth, even on the summits of the highest hills. Over the area in which this is the surface rock the people rely almost wholly on wells for their culinary and drinking supply. In the ravines of the south slope springs issue here and there from sandstone. These springs owe their existence to the general southward dip of the rocks and the alternation of beds of shale and sandstone, the water moving through the sandstone. Such are Dripping Springs, at Stattler; Oliver Spring, 2 miles west of Rudy; Dean Spring; Fine Spring; and many others.

Character of the water.—All the water of the limestone beds is clear, cold, and sparkling, and is unsurpassed in purity among natural waters. As would be expected, that issuing from the Pitkin limestone is hard, being heavily charged with lime. That from the Boone and Hale, while hard, does not contain so much lime as that from the Pitkin, owing to the large amount of silica that is included in these formations—in one as chert, in the other as sandstone. The water from the Winslow formation is soft, coming from sandstone.

Mineral springs.—About 1½ miles northeast of Uniontown there is a spring strong in sulphur, which has been inclosed and is locally used for medicinal purposes. It issues from the Winslow formation. At Sulphur City, a local resort, in the northeastern part of the quadrangle, a similar spring issues from the Wedington sandstone.

Uses of the water.—The water flowing in the streams of the Winslow quadrangle is practically unutilized except for domestic and stock purposes. The city of Fayetteville, north of the quadrangle, receives its water supply from West Fork of White River, the water being pumped 2 miles into a reservoir on a hillside overlooking the city. The water supply of Van Buren, south of the quadrangle, is procured from Lee Creek. Many of the springs on the hill slopes could be utilized for irrigating small vegetable and fruit farms, and water could be piped from them into houses below, or forced by hydraulic rams to those above.

SOILS.

Practically all the soils within the area are residual—that is, they have been formed by the disintegration of the rocks on which they rest. Only narrow strips along the lower parts of Lee Creek, Frog Bayou, and Mulberry River are composed of alluvium.

Soil of the Boone formation.—The soil overlying the Boone formation consists of a mixture of clay and chert fragments, the insoluble residue of that formation. In most places it is fairly productive, a result apparently due to the prevention of evaporation of the soil water by the loose chert fragments of the surface.

Soil of the Fayetteville formation.—The disintegration of the Fayetteville shale, which covers a considerable part of the northern portion of the quadrangle, has produced a clay of fair fertility, free from stone débris. This soil is cold and wet, and would doubtless be much improved by underdraining.

The bench of the north slopes at the base of the Pitkin limestone is of unusual fertility, the soil being the product of the joint weathering of the upper shales of the Fayetteville formation and the limestone above, but as the width of this bench does not at many places exceed 200 yards, it is adapted only to small vegetable and fruit farming.

Soil of the Morrow group.—The Hale formation at the base of the Morrow group, consisting of shale, sandstone, and limestone, forms a soil of excellent quality when it is so situated as to permit its disintegrated parts to accumulate, as it does over considerable areas in the northern part of the quadrangle. The unusually rich soil about Boonsboro is produced in a large measure by the disintegration of this rock. The Bloyd shale, which constitutes the upper part of the group, forms a poor, unproductive soil.

Soil of the Winslow formation.—As a rule the northern slopes above the Bloyd shale are too steep and their soil is too poor and rocky to be worth much as agricultural land. The soils at the top and on the south slope of the Boston Mountains are formed by the disintegration of sandstones and shales, and although fairly productive, are not rich. Their partial sterility is probably due largely to the drying up of the humus by the hot rays of the summer sun. The narrow flood plains along the lower parts of Lee Creek, Frog Bayou, and Mulberry River are, of course, productive.

TIMBER.

The region was formerly covered by an excellent growth of timber, but all timber of commercial value is rapidly being removed. The principal varieties are oak, hickory, and ash. Some walnut is found. The bench on the north slope at the base of the Pitkin limestone carries a good deal of sugar maple. Many of the north slopes have rich growths of black locust, but this is rapidly being removed and shipped for posts. Some pine and a small amount of cedar grow on the south slopes.

January, 1907.

U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHY

ARKANSAS - INDIAN TERRITORY
WINSLOW QUADRANGLE

Jno. H. Renshawe, Geographer in charge.
Triangulation by Geo. T. Hawkins.
Topography by H. B. Blair and R. H. Mc Kee
Surveyed in 1898.

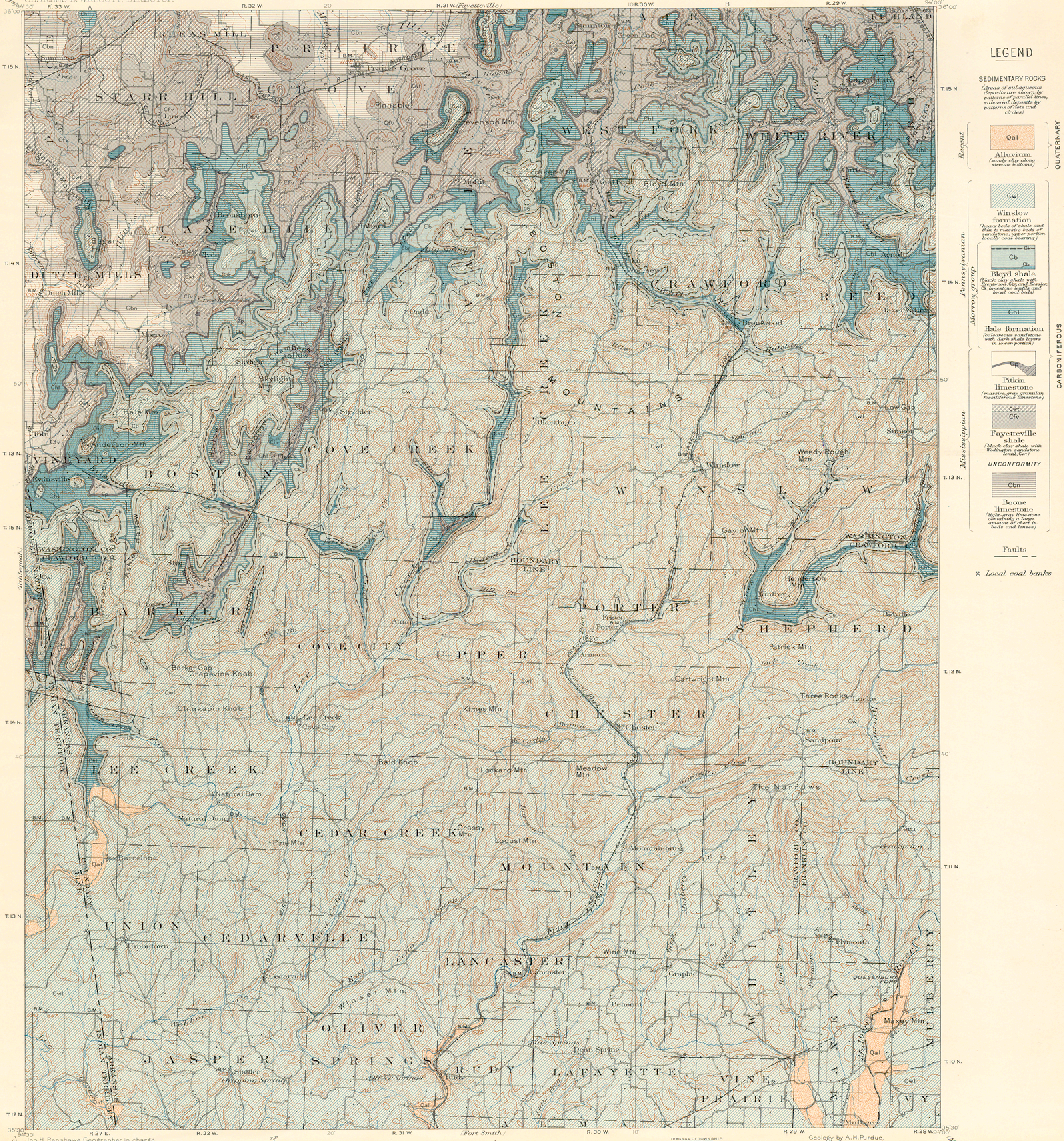
Scale $\frac{1}{125000}$
Contour interval 50 feet.
Datum is mean sea level.

Edition of June 1901, reprinted Oct. 1907.

U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

AREAL GEOLOGY

ARKANSAS - INDIAN TERRITORY
WINSLOW QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Triangulation by Geo. T. Hawkins.
Topography by H. B. Blair and R. H. Mc Kee.
Surveyed in 1896.

APPROXIMATE MEAN DECLINATION 1907.

Scale $\frac{1}{125000}$

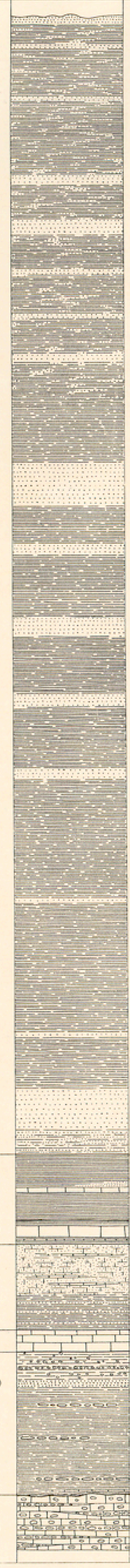
Contour interval 50 feet.
Datum is mean sea level.

Edition of Dec. 1907.

Geology by A. H. Purdue,
assisted by Geo. I. Adams, R. D. Mesler,
and M. K. Shaler.
Surveyed in 1903 and 1904.

COLUMNAR SECTION

GENERALIZED SECTION FOR THE WINSLOW QUADRANGLE.
SCALE: 1 INCH = 200 FEET.



System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	PENNSYLVANIAN	Winslow formation.	Cwl		2300	Sandy carbonaceous shale, in places coal bearing, alternating with rather massive beds of brown to gray micaceous sandstone. Thick bed of black carbonaceous shale, alternating with beds of brown sandstone, 3 to 60 feet thick. Certain sandstones in the lower part contain small waterworn quartz pebbles.	Dissected, gradually sloping plains on the south slope of the Boston Mountains, and poorly defined ridges in the southern part of the quadrangle. Poor, sandy clay soil. Narrow benches and steep bluffs on the north slope of the Boston Mountains. Stony soil.
	PENNSYLVANIAN (MORROW GROUP)	(Kessler limestone lentil.) Bloyd shale. (Brentwood limestone lentil.)	(Ck) Cb (Cbr)		100–220	Gray to chocolate-colored limestone, in places conglomeratic. Black carbonaceous shale, locally coal bearing. Compact gray limestone.	Benches below the Winslow formation. Poor soil.
	PENNSYLVANIAN (MORROW GROUP)	Hale formation.	Chl		100–200	Calcareous sandstone pitted on weathered surface by small cavities, with interbedded limestone lenses. Dark shale interbedded with thin layers of sandstone.	Well-rounded hills and hill slopes. Good soil.
	MISSISSIPPIAN	Pitkin limestone.	Cp		10–40	Gray, coarse-textured fossiliferous limestone.	Steep bluffs.
	MISSISSIPPIAN	(Wedington sandstone member.) Fayetteville shale.	(Cwt) Cfv		150–300	Greenish to bluish shales, containing small concretions. Light-gray to brown sandstone, locally showing ripple marks and cross-bedding. Black, thinly laminated carbonaceous shale, containing large calcareous concretions and limestone locally near the base.	Good soil. Low sandstone bluff, producing a large amount of débris. Bases of slopes and valleys in northern and western parts of quadrangle. Good soil when mixed with overwash.
		UNCONFORMITY					
	MISSISSIPPIAN	Boone limestone.	Cbn		100+	Light-gray limestone, containing chert in beds and lenses.	Level areas in the northwestern part of the quadrangle. Good soil.

TABLE OF FORMATION NAMES.

System.	Series.	Formations Recognized in the Mississippi Valley East of the Ozark Region.	Names Used in this Folio.	Joseph A. Taff: Tahlequah Folio, U. S. Geological Survey, 1905.	George I. Adams and E. O. Ulrich: Fayetteville Folio, U. S. Geological Survey, 1905.	Geological Survey of Arkansas, Vol. IV, Washington County, 1888.
CARBONIFEROUS	PENNSYLVANIAN	Pottsville formation.	Winslow formation.	(Akins shale member.) Winslow formation.	Winslow formation.	Millstone grit.
			Morrow group: (Kessler limestone lentil.) Bloyd shale. (Brentwood limestone lentil.)	Morrow formation.	(Kessler limestone lentil.) Morrow formation. (Brentwood limestone lentil.)	Boston group: Kessler limestone. Coal-bearing shale. Pentremital limestone.
			Morrow group: Hale formation.	(Hale sandstone lentil.)		Boston group: Washington sandstone.
	MISSISSIPPIAN	Chester group: Kaskaskia group: Birdsville formation.	Pitkin limestone.	Pitkin limestone.	Pitkin limestone.	Boston group: Archimedes limestone.
			(Wedington sandstone member.) Fayetteville shale.	(Wedington sandstone member.) Fayetteville formation.	(Wedington sandstone member.) Fayetteville formation.	Boston group: Marshall shale.[a] Batesville sandstone.[a]
		Chester group: Kaskaskia group: Tribune limestone.				Fayetteville shale.[a]
		Chester group: Cypress sandstone.	Wanting.	Wanting.	Batesville sandstone.	Wyman sandstone.
		Chester group: Ste. Genevieve limestone.				
		Meramec group: St. Louis limestone.			Wanting.	Wanting.
		Meramec group: Spergen limestone.				
		Meramec group: Warsaw limestone.				
		Osage group: Keokuk limestone.	Boone limestone.	Boone formation.	Boone formation. (St. Joe limestone member.)	Boone chert.
		Osage group: Burlington limestone.				St. Joe marble.
		Kinderhook formation.	Not exposed.	Wanting.	Wanting.	Eureka shale (in part).

[a] In failing to recognize that the shale at Fayetteville overlies the Batesville sandstone, the Geological Survey of Arkansas confused the nomenclature and stratigraphic sequence.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, 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. When 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 found 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 often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes 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 is sometimes 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 of their metamorphism.

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.

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.......	....	Ʀ	Peacock-blue.
Paleozoic	Carboniferous.	Permian....... Pennsylvanian Mississippian..	C	Blue.
	Devonian.....	....	D	Blue-gray.
	Silurian.......	....	S	Blue-purple.
	Ordovician....	....	O	Red-purple.
	Cambrian.....	Saratogan..... Acadian....... Georgian......	€	Brick-red.
	Algonkian	....	A	Brownish-red.
	Archean	....	Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. 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 by which formations are labeled 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 recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and 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; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 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, and these are, in origin, independent of the associated material. 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 afterwards 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. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored 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 given formation, its name should be sought in the legend and its color and pattern noted, when 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 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.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which 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 the 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 of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

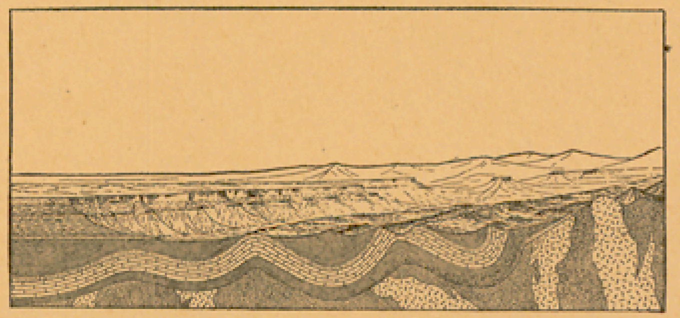


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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 symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

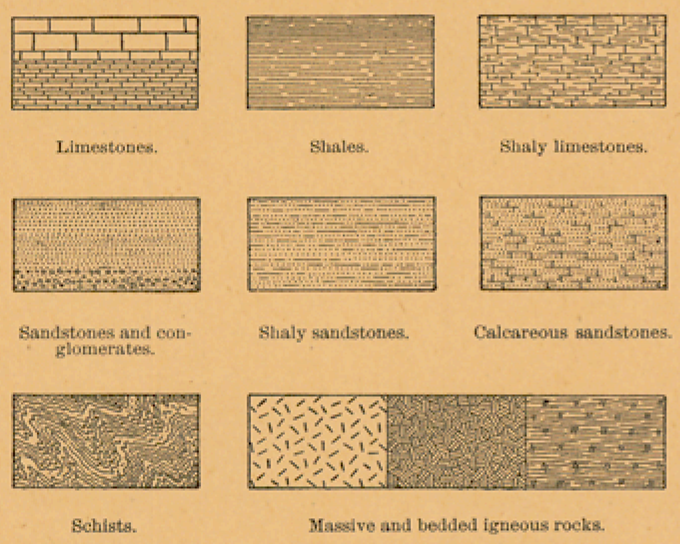


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. 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 that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; 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 fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement undergrou d can not be

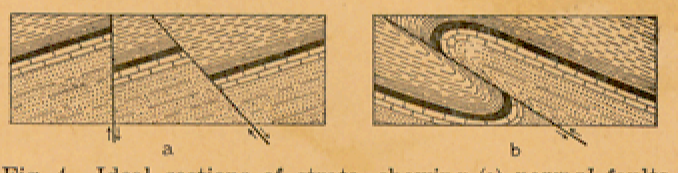


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata 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 raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. 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 at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their 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 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 suffered metamorphism; they were the scene of 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 fig. 2 are ideal, but they illustrate relations which actually occur. 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 which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which 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 which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

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111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
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142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	25
146	Rogersville	Pennsylvania	25
147	Pisgah	N. Carolina-S. Carolina	25
148	Joplin District	Missouri-Kansas	50
149	Penobscot Bay	Maine	25
150	Devils Tower	Wyoming	25
151	Roan Mountain	Tennessee-North Carolina	25
152	Patuxent	Md.-D. C.	25
153	Ouray	Colorado	25
154	Winslow	Arkansas-Indian Territory	25

* Order by number.
† Payment must be made by money order or in cash.
‡ These folios are out of stock.

Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.