DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

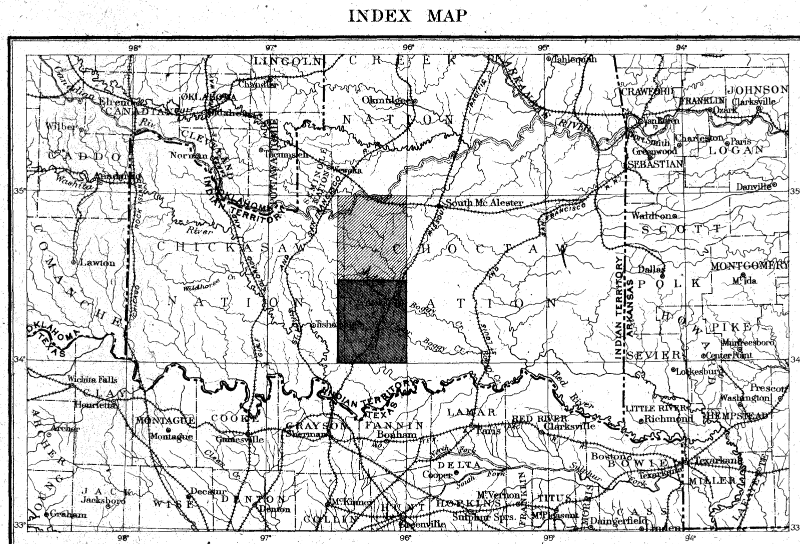
OF THE

UNITED STATES

ATOKA FOLIO

INDIAN TERRITORY

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE ATOKA FOLIO

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FOLIO 79 | LIBRARY EDITION | ATOKA

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1902

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

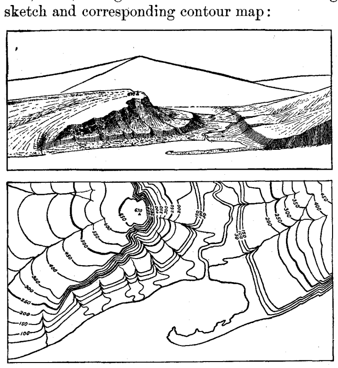


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the slope at 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 approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours — say every fifth one — are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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.—Water courses are indicated by blue lines. If the streams flow the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter of a square degree; each sheet on a 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene { Pliocene, Miocene }	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias { Jurassic, Triassic }	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Є	Pinks.
	Algonkian	A	Orange-browns.
	Archean	Æ	Any colors.

a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

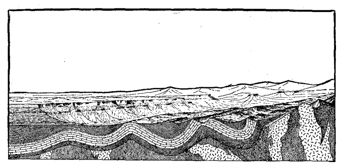


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section 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:

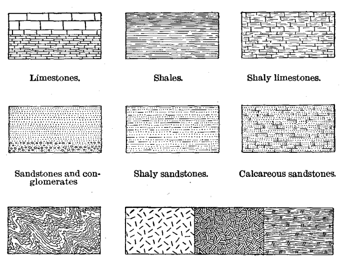


Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.*

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. 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 regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults.*

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE ATOKA QUADRANGLE.

By Joseph A. Taff.

GEOGRAPHY.

Location of the quadrangle.

The Atoka quadrangle is bounded by meridians 96° and 96° 30′ and parallels 34° and 34° 30′, and occupies one-fourth of a square degree of the earth's surface. It is 34.9 miles long and 29 miles wide, and contains about 986 square miles. The boundary line between the Choctaw and Chickasaw nations runs north and south through the quadrangle about 3 miles from its western border. The Choctaw Nation lies to the east of this line and the Chickasaw Nation to the west.

Four topographic provinces.

Four topographic provinces are represented in this quadrangle. They are the Ouachita Mountains, the Arkansas Valley, the Arbuckle Mountains, and the Red River Plain. With two other provinces these four constitute the physiographic districts of Indian Territory. The others are the Ozark Highland, which lies in southern Missouri, northwestern Arkansas, and northeastern Indian Territory; and the Prairie Plains, which extend from the Arkansas Valley region and Ozark Highland northward and westward across northwestern Indian Territory, Kansas, and Oklahoma.

The Ouachita Mountains.

The Ouachita Mountains, whose ridges enter the northeastern part of the Atoka quadrangle, extend from the vicinity of Atoka to central Arkansas near Little Rock—approximately 200 miles. The range is characterized by numerous long, low mountains and ridges, bearing generally east and west. Near the western end, however, they trend southward and, declining rather abruptly, join the Red River Plain. The principal mountains and groups of ridges of the Ouachita Range are separated by relatively wide, flat valleys. These valleys, where they lead out from the mountains, descend gradually to the level of the Arkansas Valley and the Red River Plain on either side. Near the western end of the range the crests of the ridges are at an elevation of nearly 1000 feet above the sea, and about 400 feet above the general level of the larger valleys. They rise gradually eastward and near the Arkansas–Indian Territory line attain altitudes of about 2900 feet above the sea and nearly 2000 feet above the valleys of the principal rivers. Eastward, in Arkansas, the elevation of the ridges becomes generally less, until it reaches 500 or 700 feet above sea level at the eastern end. Likewise from the sides toward the center of the range, especially in Indian Territory, the ridges increase in elevation until they are classed as mountains. Jackfork, Windingstair, Buffalo, Rich, Blackfork, Kiamichi, and Seven Devils are prominent mountains of the Ouachita Range in Indian Territory. Some of the prominent ridges at the extreme western end of the range extend a short distance into the northeastern part of the Atoka quadrangle.

The Arkansas Valley region.

The Arkansas Valley region lies between the Ouachita Range on the south and the Ozark Mountains and Prairie Plains on the north, and is characterized, especially in its western portion, by narrow and generally level-crested low ridges and rolling uplands. At the confluence of the Canadian and Arkansas rivers this region contracts, bears southwestward, and joins the Red River Plain in the central part of the Atoka quadrangle, between the Ouachita and Arbuckle mountains. Its low level ridges and flat valleys curve around conformably with the folds of the strata in the north-central part of the Atoka quadrangle. The features of the Arkansas Valley region, especially in this southern part, closely resemble reduced forms of the Ouachita Mountains. The ridges of the valley region are generally parallel with those of the range, but, with the exception of the few isolated mountains which lie in the Arkansas Valley, they have low relief and their crests fall nearly within the same plain.

The Red River Plain.

The Red River Plain is a low, nearly flat, southeastwardly inclined plain which extends along the entire southern side of Indian Territory. It is the northern side of the broad valley of Red River, which slopes gently southeastward toward the Gulf coast. It borders the south side of the Ouachita and Arbuckle mountains and touches the Arkansas Valley province between them. It joins the Prairie Plains farther west, between the Arbuckle and Wichita mountains, in western Indian Territory and southeastern Oklahoma. At the northern border of this plain south of the Arbuckle Mountains it is nearly 1000 feet above sea level, while south of the Ouachita Range in southeastern Indian Territory it is a little over 500 feet above sea.

The Arbuckle Mountain province.

The Arbuckle Mountain province extends from the vicinity of Boggy Depot, in the central part of the quadrangle, northwestward nearly across Chickasaw Nation. It is about 70 miles long, and has an average width of about 20 miles. It rises gradually from about 750 feet above the sea at its eastern end to 1350 feet at its western end. At the eastern end and along its southeastern side, to the east of Tishomingo, it coalesces with the bordering Red River Plain. In its northern and western parts it rises abruptly 100 to 200 feet above the bordering plains. The high land of the Arbuckle Mountains forms a nearly flat plain, of which only the borders are deeply cut. Two small districts in the western part of this region, known as the Eastern Wooded Hills and the Western Wooded Hills, rise above the general level of the elevated mountain plain.

Main river systems of Indian Territory.

Three main river systems, the Arkansas, the Canadian, and the Red, drain the whole area of Indian Territory. Arkansas River flows southeastward from the Rocky Mountains across the Great Plains and the Prairie Plains, and enters the broad valley between the Ozark and Ouachita mountains near the eastern border of Indian Territory. Canadian River has its source in New Mexico, flows eastward across the Great Plains and Prairie Plains, and joins Arkansas River at the border of the Arkansas Valley region. Red River rises in New Mexico, flows eastward through the southern part of the Great Plains and across the "Panhandle" of Texas, and then forms the southern boundary of part of Oklahoma and all of Indian Territory. The northern tributaries of Red River in Indian Territory drain a large area south of Canadian River. The watershed between the Canadian and Red rivers, especially in the Chickasaw Nation, lies within a few miles of the banks of the Canadian. Since Canadian River belongs to the Arkansas River system, the Canadian–Red watershed is a part of the divide between the hydrographic basins of the Arkansas and Red rivers. It also divides the waters which flow into Mississippi River from those which flow directly into the Gulf of Mexico.

TOPOGRAPHY.

ORIGIN OF THE TOPOGRAPHIC FORMS.

The various forms of the valleys and hills in this region have been produced by the dissolving and disintegrating action of water and frost, and by the erosion caused by rain and running streams. The shapes of the valleys and hills and their location depend principally upon the degree of erosion and upon the nature and structure of the rocks. Where land is uplifted and tilted the streams flow rapidly and cut deep valleys. The soft rocks are eroded more readily than hard ones, and form valleys, while the hard rocks remain as hills, ridges, and mountains. On the other hand, when the general surface of any land is originally nearly level or becomes so by erosion, streams flow sluggishly and are not able to carry away all the sediment which is swept from the higher portions of the land. Under these conditions the channels tend to become filled and the streams meander from side to side, broadening their valleys. When these conditions continue uninterruptedly the valleys become wide and silted and the hills are generally reduced to the level of the valleys.

GENERAL FEATURES OF THE QUADRANGLE.

Cretaceous plain of marine erosion.

In the Atoka quadrangle, especially north of the Cretaceous sediments, there are certain broad and well-defined topographic characteristics which are significant in considering the physiographic history of the region. The first of these is limited to a belt 10 to 30 miles in width parallel with and immediately north of the Cretaceous border. The characteristics of this topography have been studied across the Atoka and Tishomingo quadrangles and the western part of the Arbuckle Mountains, a distance of about 60 miles. As explained more fully under "Geology," the lowest Cretaceous formation, the Trinity sand, was deposited upon a smooth and nearly flat floor or plain of truncated Paleozoic rocks. This sand is the shore deposit of the Cretaceous sea, which transgressed northward and westward to an unknown distance beyond the present occurrence of Cretaceous rocks. The land at this time was probably a low coastal plain and was reduced to a surface of marine planation as the sea advanced. Since the Trinity sand is a soft rock, it is removed so rapidly in comparison with the wear of the underlying hard rocks that considerable areas of the Cretaceous plain are exposed before it is appreciably defaced. The exposed border of this marine erosion plain continues southward along the western edge of the Cretaceous sediments to central Texas. Northward the ridges of hard rock rise gradually higher above sea level and above the valleys until the remnants of the plain can no longer be recognized. In this quadrangle they reach an altitude of 800 to 900 feet above sea. In the central part of the Arbuckle region, in the adjoining Tishomingo quadrangle, the exposed Cretaceous marine erosion plain, because of the broad expanse of hard rock beneath it, extends farther north. It should be borne in mind that the crests of ridges and high lands north of the well-defined limit of this plain mark only approximately the surface of the plain, for, as soon as it is uncovered the rocks begin to wear down, and only the hardest of them remain unreduced for a long time.

Peneplain of probable Tertiary age.

A second physiographic plain, of later age and broader exposed surface, occurs in this region. The agents of erosion which have made this plain have both uncovered and obliterated much of the Cretaceous marine erosion plain north and west of its present limits above described. Spreading across the western border of the Tertiary (Eocene and Neocene) rocks in northeastern Texas, southeastern Indian Territory, and southwestern Arkansas and extending toward the Gulf there are extensive deposits of gravel and sand on the high lands. They are spread upon a peneplain, or an eroded plain, across the edges of lower Tertiary, Cretaceous, and Paleozoic strata. These deposits extend toward the Gulf as far as the border of Pleistocene coastal sediments. Although the plain upon which these gravels were deposited has been dissected by recent erosion, yet there are considerable areas near the present Cretaceous–Tertiary border where it has been but recently exposed or is still covered by thin mantles of gravel. In the Texas Tertiary region, upon the watersheds between the principal rivers east of the Brazos, there are small areas which rise above the gravel-covered plain to elevations approximating 700 feet above sea, upon which the gravels do not occur and were probably never deposited. This peneplain is analogous to the Cretaceous marine erosion plain described above in that it descends toward the coast, but it is inclined toward the Gulf at a lower angle.

Intersection of Cretaceous marine erosion plain and Tertiary peneplain.

The northern border of this gravel-covered peneplain is elevated approximately 600 feet above the sea. Leading from it upward along and near the present valleys of the principal rivers, there are remnants of flat, meandering river valleys which are but slightly depressed below the general level of the nearly flat rolling plain or peneplain and contain deposits of gravel and sand. Likewise, along and near the Arkansas and Canadian river valleys there are remnants of wide, flat meandering river channels partially filled with gravel, sand, and silt. One instance has been noted where the old elevated flat Canadian channel made a detour of more than 50 miles from the location of the present river. This peneplain stretches westward and northward across Indian Territory in the eroded surface of both Cretaceous and older strata. As explained above, this peneplain is inclined toward the south at a lower angle than is the Cretaceous marine erosion plain, and near the northern border of the Atoka quadrangle they intersect at elevations approximating 850 feet above the sea. Toward the north the Cretaceous plain projects above the land, while the Tertiary peneplain continues nearly level, being preserved in innumerable flat-topped ridges and hills of hard rocks in the Arkansas Valley region and in the uplands of the broad valleys in the Ouachita Mountain Range. The crests of many of these ridges and hills are a little below the general level of the peneplain, which in this region is about 850 feet, while a few are a little higher. The higher eminences are usually table-like, being protected by flat, hard strata, while in the lower hills the harder, ridge-making beds are either steeply upturned or are supported by thin strata only. Rising above this peneplain of level-crested ridges and hills in the Arkansas Valley region are well-defined areas where broad folds in the rocks have favored the preservation of monadnock-like mountains and peaks. Those in Indian Territory are the Sansbois, Cavanal, Poteau, and Sugarloaf mountains, which rise to heights of 1700 to 2500 feet above the sea, approaching the general levels of the mountains in the Ouachita and Ozark regions. These mountains occupy broad synclinal folds culminating in sharp crests or peaks, and are isolated in the peneplain. The broad distribution of the surficial deposits in the wide, shallow, and elevated river channels and their relations to the Tertiary gravels, as already explained, together with the almost universally equal degradation of both hard and soft rocks to the same general level, strongly support the hypothesis that the surface stood nearly at the level of the sea when it had reached its peneplain stage.

Recent peneplain in the existing broad valleys.

Since Tertiary time the land has been elevated and probably slightly tilted toward the southeast. During and following this elevation erosion became more active and has removed the softer strata so that now the wide, flat valleys of the larger streams are about 200 feet below the level of the Tertiary peneplain. These valleys are so wide and flat and are so nearly at the same level that they may be considered to form rudely a still lower plain representing the present stage of erosion. Thinner, hard, steeply tilted strata and rocks intermediate between hard sandstones and soft shales, give rise to various levels between the Tertiary and this latest peneplain.

The surface of the Atoka quadrangle, when considered in a broad way, is generally of low relief. The larger streams meander in wide valleys through deposits of silt and sand which they have deposited during floods. Where the rocks are tilted at a low angle, as in the southern half of the quadrangle, the harder limestone beds, when once uncovered, resist erosion and protect the softer shales beneath, thereby forming table-lands and escarpments or benches and terraces. Where the beds are steeply tilted, as in the north-eastern part of the quadrangle, the massive sand-stone and flint formations stand in rugged ridges, while the soft shales between are worn down to flat valleys. The gently rolling and nearly flat wooded plain that extends east and west across the middle of the quadrangle is determined by the rock formation, which is soft throughout.

The southern half of the Atoka quadrangle is a nearly level plain. A few eminences rise to the level of 750 feet, and little of the high land between the main streams falls below 650 feet. Beginning a little south of the middle of the quadrangle there is a general rise of the land toward the south—a total of about 100 feet—to the watershed between Blue River and Boggy Creek, which passes east through Caddo, at an elevation of 700 or 750 feet above the sea. From this watershed the surface slopes gently south-ward to Red River. In the northeastern part of the quadrangle, where the larger streams have encountered hard sandstones and chert, they have cut deep and narrow valleys. Where soft rocks are encountered the valley floors are flat and are coextensive with these rocks. The small tribu-tary streams in the more rugged northeastern part of the quadrangle descend in narrow, steep channels.

Drainage systems.

The waters of the Atoka quadrangle are col-lected in three large streams, all of which flow in a southeasterly direction. These are Muddy Boggy and Clear Boggy creeks and Blue River. North Boggy, the largest tribu-tary of Muddy Boggy, enters the quadrangle in the northeast corner. Clear Boggy and Muddy Boggy creeks unite southeast of the quadrangle and flow into Red River. Blue River is also tributary to Red River. The valleys of these streams are so wide and shallow that in times of flood they overflow their banks more than a mile in places. Muddy Boggy and North Boggy creeks, which have their sources in the Carbon-iferous sandstones and shales where springs do not occur, practically cease to flow during long dry seasons. Not so with Clear Boggy Creek and Blue River, which are fed continually by abundant large springs that issue from the great limestone formations in the Arbuckle Mountain region.

TOPOGRAPHIC TYPES.

The four types of topography represented in the physiographic provinces of the region, which have been briefly outlined above, occur within the Atoka quadrangle. In describing these topo-graphic types it is convenient to arrange them under their respective provinces: the Ouachita Mountains, the Arkansas Valley region, the Arbuckle Mountains, and the Red River Plain.

Ouachita Mountain type.—The Ouachita Moun-tain topography is represented by the small area of rugged, hilly country lying east of the Mis-souri, Kansas and Texas Railroad in the north-east corner of the quadrangle. These hills are the extreme western ends of mountain-like ridges which gradually rise higher eastward and develop into Rich and Kiamichi mountains in the central part of the range in Indian Territory.

Ridges of the Ouachita Mountain region.

The ridges are coextensive with the occurrence of hard rocks, which are either sandstones or flinty strata. Between the principal ridges, hills, and mountains there are flat val-leys, which are invariably located upon and limited by the surface extent of the shales or shaly formations.

The crests of the higher of these ridges in this quadrangle lie in a plain slightly inclined toward the south. Southward this plain passes beneath the Cretaceous strata and forms the eroded surface of the older rocks upon which the Cretaceous lies. It is the plain of marine gradation made by the early Cretaceous sea. As the Cretaceous border is approached going south, the hills and ridges become lower in elevation and the valleys shal-lower, until they merge into one another at the border of the Cretaceous deposits.

The ridges near the north side of the Ouachita region are less prominent than those in the central part, and decrease in elevation in that direction until they are on a level with similar ridges in the Arkansas Valley region. These bordering low ridges of the Ouachita region are represented in the Atoka quadrangle by only the Black Knob Ridge. This is a ridge of peculiar flinty rock, and it represents a phase of this topographic type not found elsewhere near the border of the Ouachita region in Indian Ter-ritory. The strata are nearly vertical and the ridge is quite symmetrical, with smooth, steep slopes and with many dome-like knobs in the crest. The central third of the ridge between North Boggy and Muddy Boggy creeks is treeless, while the ends are covered by forests of scrub oaks. The ridge ends abruptly in the northeast corner of the quadrangle, where the flinty formation is terminated by faulting. At the south end it descends gradually to the plain of soft Cretaceous rocks.

Black Knob Ridge.

The more rugged sandstone hills east of Black Knob Ridge have a different topographic form; the rocks are massive and hard and the beds are tilted toward the southeast. As a result the northwest slopes are steepest and are strewn with bowlders and talus from the broken ledges. The crest of these hills and ridges, beginning at the south, rise gradually from the Red River Plain northward. It has been previously pointed out that these crests, like those of Black Knob Ridge, lie in a plain from which the Trinity sand has been removed.

Large water gaps in Black Knob Ridge.

A peculiar feature of the drainage in this region is that the large streams, North Boggy and Muddy Boggy creeks, flow from their flat val-leys in the soft shales without obstruc-tion to the west across Black Knob Ridge and among the rugged hills farther east in narrow, sharply cut channels. In recent geologic time the Trinity sand and probably higher Creta-ceous rocks extended over this part of the quad-rangle and the streams flowed unobstructed on them toward the southeast. After the streams cut through these soft rocks into the underlying hard beds, their channels were established and could not be changed, and are now deeply cut in these hard rocks.

Arkansas Valley type.—The Arkansas Valley type of topography in the Atoka quadrangle occurs in the north-central part of the quadran-gle, between the Ouachita Mountain and Arbuckle Mountain regions, and joins the Red River Plain on the south near the Cretaceous border. As in the Ouachita topography in the northeastern part of the quadrangle, the hilltops of both hard and soft rocks are in the Cretaceous base-level plain. Northward the sandstone ridges and hills become gradually higher, until near the north border of the quadrangle the most prominent elevations are nearly 200 feet above the general level of the val-leys. The highest crests in these ridges and hills are approximately in the Cretaceous plain.

Parallel ridges and valleys of the Arkansas Valley type.

The rocks governing the Arkansas Valley type of topography in the Atoka quadrangle belong to the Carboniferous. They are chiefly sandstones and shales, occurring in alternate strata, with one series of limestones, and in this quadrangle they occupy chiefly a wide basin-like fold, the north end of which lies about 4 miles north of the border. The shales are soft and easily eroded, forming valleys and flood plains, while the sandstone beds are generally hard and stand out as more or less promi-nent ridges. These rock beds outcrop concentrically around this large fold, as indicated in part by the topography, and as can be seen on the geologic map. Since the rocks dip toward the center of the fold, the ledges of sandstone upon the western side present their more abrupt faces toward the west, while those on the eastern side have their steeper slopes toward the east. Near the center of this syncline, in the northern part of T. 1 S., R. 11 E., the rocks are nearly flat and the sandstone beds make table-like elevations, sheltering from erosion the softer shales which crop in the slopes.

The most prominent ridge-making sandstones occur in the upper part of the Atoka formation and in the Hartshorne, Savanna, and Boggy for-mations. The most elevated of these ridges are approximately 750 feet above the sea, and there are occasional knobs rising to 900 feet.

The McAlester shale and the lower part of the Atoka formation contain thin sandstone members which make low ridges, hills, or swales, and nearly level plains. Clear Boggy Creek, with its wide, swampy flood plain, occupies the central part of the area of the Atoka formation in the northwest-ern part of the quadrangle.

The Wapanucka limestone occurs near the bor-der of the Arbuckle highlands, but is separated from it by narrow but flat plains of the Caney shale. In the vicinity of Wapanucka and in the axial part of the large fold in the northwest corner of the quadrangle this limestone produces low, level-crested ridges. Elsewhere its beds are either vertical or outcrop near important streams, and consequently have been worn down nearly to the level of the plain. The Caney shale is a soft rock throughout and occupies a flat plain.

Arbuckle Mountain topography.—The areas of granite and Paleozoic rocks in the northwestern part of the quadrangle form the extreme eastern end of the Arbuckle uplift. This uplift grows gradually broader and increases in elevation west-ward. With the exception of the Sylvan shale, the rocks involved in this uplift are generally hard, and, when well uncovered, stand in relief above the bordering plain of softer Carboniferous strata.

The Cretaceous erosion plain in the Arbuckle Mountains.

The surfaces of both the hard and the soft rocks of the Arbuckle uplift in this quadrangle lie in a smooth plain—the resurrected Creta-ceous marine erosion plain. In the area west of Boggy Depot this old Cretaceous plain is only partially un-covered, while in the region west of Wapanucka and in the northwest corner of the quadrangle the Trinity sand has been long removed. Here the streams have cut channels into the softer rocks of the Carboniferous, leaving the hard beds in a plain nearly 100 feet in relief. This some-what elevated plain of hard rock has been par-tially dissected.

This erosion plain continues westward across the Arbuckle region, with Cretaceous sediments yet remaining upon its southern border, as far west as the Washita River. The plain in this western part may be recognized over broader areas, since the truncated rocks are more uniformly hard. With the exception of the Washita River gorge, near the center of the region, it is but slightly dissected, except very near the borders, where the streams descend rapidly and where soft rocks occur.

The rocks, especially upon the border of the uplift, are steeply upturned, so that the Hunton and Sylvan formations outcrop in relatively nar-row bands. The former is a hard limestone, while the latter is a homogeneous friable shale. The one forms narrow, even-crested ridges, while the other is always reduced to valleys. In the axial portion of the broad anticline in the northwest corner of the quadrangle the Hunton limestone dips at low angles toward the east. Here it pro-duces a broad ridge with low slopes eastward and steep terrace escarpments facing westward, toward the valley of the Sylvan shale.

Red River Plain.—The whole region of the Red River Plain in the Atoka quadrangle is occupied by the seven Cretaceous formations which are indicated on the geologic maps. Each of these produces characteristic minor topographic features depending upon lithologic and structural characteristics.

The Trinity sand occupies nearly a third of the area of the quadrangle across the medial portion. It is practically a homogeneous friable sandstone or compact sand, and, except at its extreme south-ern border, where it underlies the succeeding Goodland limestone, it produces a nearly flat, rolling land, gently inclined toward the south. Except in small areas in the northwestern part, the Trinity sand is covered with a dense forest, chiefly of scrub oak.

Succession of terraces or tables and slopes.

The Goodland limestone is a thin but relatively hard formation, dipping gently toward the south. It is continuously exposed and forms flat though generally narrow table-lands and benches, with accompany-ing escarpments facing the Trinity sand country below.

The succeeding Kiamitia formation, except a few thin ledges, is friable clay, forming gentle prairie slopes leading up to the outcrop of the Caddo limestone. The Caddo formation has numerous beds of sandstone, marl, and clay, with thicker and harder limestone strata occurring at the top. This in turn, like the Goodland lime-stone, is succeeded by soft clays and forms broad table-like uplands, bordered on the north by low escarpments or steep declivities.

South of the Caddo upland are numerous low, knobby hills and broken escarpments which rise to elevations of 750 or 800 feet above the sea. These knobs are capped by the harder ferruginous beds at the top of the Bokchito formation and by the succeeding hard Bennington limestone. The most prominent of these elevations are the Caddo Hills and Sugarloaf Mountain. Other similar elevations occur west of Blue River. These same hard rocks form a very tortuous and rugged, though low, escarpment in the southwestern part of the quadrangle. They also compose the floor of the broad tracts of upland in the vicinity of Bokchito and Bennington, near the southern border of the quadrangle.

The topography of the elevated country in the southwest corner of the quadrangle resembles very closely that of the Trinity sand region. The Silo formation, which occupies this area, is a soft sandstone and therefore the surface is undulating and nearly flat. Near the northern border, how-ever, the streams, which fall over the steeper terraces of the Bennington limestone immediately below, have cut back into the Silo sandstone, pro-ducing rough tracts.

GEOLOGY.

PRE-CAMBRIAN IGNEOUS ROCKS.

In the eastern part of the Arbuckle Mountain uplift there is a large area of igneous rocks the eastern end of which extends into the Atoka quad-rangle. It is bounded on the north, west, and in part on the south by Cambrian and Silurian strata. Across most of the southern portion Cretaceous sediments lap upon the igneous area and conceal it in large part by residual sands. Along the north and south margins the contacts between the igneous and older stratified rocks are not normal, but are marked by faults. Through about one-half mile of contact in the Atoka quadrangle, in sec. 28, T. 3 S., R. 9 E., and across the west end of the area in the Tishomingo quadrangle, the Cambrian strata rest normally upon the igneous rocks, the lowest formation, the Reagan sandstone, being composed of the products of disintegrated igneous rocks. These igneous rocks, consisting of granites and associated granular rocks, are there-fore older than the overlying Cambrian strata—how much older, a careful survey of the whole Arbuckle Mountain region has failed to show.

Tishomingo granite and associated igneous rocks.—The Tishomingo granite is named after the capital of the Chickasaw Nation, which is located upon it in the adjoining Tishomingo quadrangle. The granite is accompanied by other igneous rocks which appear to be dikes, but, as has been stated, the surface of the granite area in the Atoka quadrangle is extensively covered by the sands of the basal Cretaceous formation and it was not possible to trace intrusions in the granite for any considerable distance. In many places where the dike rocks were studied, the exposures are very limited and the true relations of the dikes to the granite could not be satis-factorily determined.

The following petrographic notes are by Mr. Ernest Howe.

Granite.

In general the Tishomingo granite is of rather coarse tex-ture, of pinkish or reddish color, and generally poor in the ferromagnesian silicates. Biotite is always present, but in such unimportant quantities as hardly to warrant calling the rock biotite-granite, but rather a biotite-bearing granite. In one instance the rock, possibly a contact facies, was somewhat porphyritic and contained biotite and hornblende in considerable amounts, together with a generous development of the accessory minerals. The constituents of the average granite are feldspars, quartz, and biotite. Of the feldspars, microcline is in somewhat greater amount than the orthoclase, while a plagioclase and micro-pegmatitic intergrowths of quartz and feldspar are quite sub-ordinate. As a whole, the granite of the Atoka quadrangle would be characterized as a microcline-rich granite with bio-tite always present but never prominent. The accessory minerals are not in any way unusual; zircon and apatite are quite common; magnetite is generally present, and rutile very sparingly so. Associated with the pink granite are peg-matite veins which contain the same minerals as the granites in coarse aggregates. Microcline is the prevailing feldspar, and muscovite is not uncommon, but is never in greater quan-tity than biotite. Garnet occurs in some as an important accessory.

Occurring with the granites and hardly to be distinguished from them in hand specimens are monzonites extremely rich in quartz. Of their relative importance and their general mode of occurrence practically nothing is known. A plagioclase feldspar, andesine, is equal to, or even greater than, the orthoclase; and microcline, when present, is subordinate to both. Quartz is extremely prominent, generally more so than the ferromagnesian silicates, which may be hornblende or biotite with very little pyroxene, either diopside or augite. The accessories are magnetite, titanite, and apatite. In addition to the quartz-monzonites a specimen from one locality has been called a diorite, although it can hardly be distinguished from one of the monzonites in the hand specimen. The material from which the thin section has been made is considerably decomposed, so that the feldspars can not be satisfactorily determined, but the plagioclase seems to predominate, with only a very little orthoclase. Hornblende as an original mineral equals the feldspars in amount, and a little biotite also is present.

Quartz-monzonite.

Of the six specimens of dike rocks examined which cut the pink granite five are diabase, while the sixth, though much altered, is taken to be one of the lamprophyres, probably a kersantite. With one exception the diabases contain only the bare essentials, labradorite and augite, with magnetite and apatite as accessories. The exception contained biotite in fair amount. The rocks are fairly fresh, but in most augite has been more or less altered to hornblende. The feldspar is labradorite having the composition $Ab_2\ An_3$, and it is extremely fresh. Kaolin, chlorite, and the hydrous oxides of iron are the common alteration products. In all, the structure is strongly ophitic, even in one case where the rock was included by the granite without clearly defined limits. The lamprophyritic dike is almost too far gone for satisfactory determination. A feldspar, apparently orthoclase, is almost entirely altered to muscovite. With this is biotite, hornblende, and quartz, named in the order of their importance. Hornblende is so much decomposed that it can not be determined satisfactorily as an original mineral. The biotite is the only fresh mineral present. Supposing the feldspar to be orthoclase, and the hornblende, together with the biotite, to be original minerals, this rock will be placed as one of the kersantites.

Basic dikes.

SEDIMENTARY ROCKS.

CAMBRIAN ROCKS.

Reagan sandstone.*—This sandstone is represented in the Atoka quadrangle by a single outcrop in sec. 28, T. 3 S., R. 9 E. The east end of the outcrop abuts nearly at right angles against the granite, from which it is separated by a very profound fault. Toward the west it passes unconformably beneath the Trinity sand, the basal formation of Cretaceous age. The Reagan sandstone occurs along the swampy valley of a small stream, so that the lower beds of the formation as well as the granite beneath are concealed by soil and sediment. The exposures of these beds in the Atoka quadrangle are not sufficient to afford a clear description of the nature of the formation. The part of the formation exposed, however, consists of many thin beds of brown quartzitic sandstone and grit in the lower part and thinner calcareous sandstones with shale layers in the upper part. Near the eastern end prominent ledges of brown gritty sandstone are exposed near the top of the formation. In the middle of the area only occasional outcrops of thin beds are seen. At the western end, very near the southwest corner of sec. 28, occur exposures of quartzitic sandstone in thin layers, which show a thickness of nearly 200 feet. The variable dip of the rocks here, together with marked jointing, indicates probable displacement of the strata and possible exaggeration of the true thickness of the formation.

In the central part of the Tishomingo quadrangle, which adjoins this quadrangle on the west, there are complete exposures of the Reagan formation in the vicinity of Reagan, from which village the formation derives its name. Here it rests upon the uneven eroded surface of the granite, and varies from thin calcareous sandstone strata to a formation nearly 300 feet in thickness. In contact with the granite in places there are beds of arkose consisting of granitic materials more or less completely disintegrated. These arkose beds are usually succeeded by quartzose grits consisting of sorted crystalline quartz grains, while higher still are finer and less pure sandstones with shale layers, followed by calcareous sandstones, which are overlain by the limestone of the succeeding formation.

Basal arkose on the granite.

Fossils from the Reagan sandstone were not observed in the Atoka quadrangle, nor elsewhere in the Arbuckle Mountain region, until after the classification of the rocks had been made and the maps for the folio printed. The lowest fossils that had been obtained at that time were those in the succeeding formations of lower Silurian (Ordovician) age. The Reagan sandstone was classified accordingly as Silurian, but should be mapped as Cambrian, since numerous fossil remains of mollusks and crustaceans occurring in the upper calcareous layers of this formation in the Tishomingo quadrangle show that the rocks are of Cambrian age.

*On the maps this formation name is spelled Regan; but as it is derived from the name of the town of Reagan, the spelling here used is correct.

CAMBRO-SILURIAN ROCKS.

Arbuckle limestone.—This formation occurs in five separate areas in the Atoka quadrangle, and is nowhere in undisturbed or normal contact with the underlying formation except in sec. 28, T. 3 S., R. 9 E., where it is found in regular stratigraphic succession upon the small area of Reagan sandstone. No exposure of the top of the Arbuckle limestone is known to occur in the Atoka quadrangle. On account of the very extensive folding and faulting which the Arbuckle limestone has suffered the dips of the beds and the true order of succession could not be made out in a considerable part of the area. The surface of the formation for the most part is a smooth plain, and the rocks are partially obscured by a residual mantle of Trinity sand, which until recently covered them entirely, so that fragments of the limestone or an occasional ledge projecting through the sand or soil are the only exposures found over much of the surface. In the area north of Rock Creek, in secs. 28, 20, and 21, T. 3 S., R. 9 E., it is estimated that 2000 feet of the formation are exposed from the base upward. Nearly as great a thickness of the limestone is exposed in the southernmost area, which apparently belongs in the upper half of the formation. The middle and largest area is not sufficiently exposed to yield a section of the rocks, since the surface is flat and largely soil covered. The limestone of the two areas lying north of the granite is for the most part well exposed, but the original structure is so obscured by faulting, probably within the formation as well as upon both sides, that little could be made out concerning the thickness of the strata or position in the formation. These limestones are dull blue to cream colored and generally massive. When compared with the strata of the continuous section of the same formation occurring in the middle and western part of the Tishomingo quadrangle there is little doubt that they belong within the lower half of the formation.

Farther west this formation composes the central mass of the Arbuckle Mountains (from which it receives its name), where it has an estimated thickness of 6000 feet. In this region it is folded into a broad steep-sided arch, which is itself folded and faulted, and in many places complete sections of the formation may be observed. It is composed chiefly of hard bluish-white and cream-colored limestone stratified in thin layers and beds reaching 3 feet in thickness, interbedded with slightly argillaceous layers. Occasionally siliceous limestone and shale beds were noted. Still less common are thin layers of chert and cherty oolite and limestone breccia or intraformational conglomerate. In this region, where the beds are more or less steeply tilted and generally exposed, they occur at the surface in miniature ridges a few feet in height, depending upon structure and composition. The harder and more crystalline the limestone the greater the resistance it offers against the agents of disintegration.

Thick section of limestone.

At the base there are thin sandy limestones which form transition strata, 200 to 300 feet thick, from the Reagan up to the purer limestone of the Arbuckle. Succeeding these are 500 to 600 feet of dull-blue or cream-colored limestone. Much of this massive limestone weathers into very irregular brown and sometimes black bowlders. These strata are succeeded by white limestone beds of variable hardness, which continue upward to within 400 or 500 feet of the top. As the top of the formation is approached the beds become thinner and less pure, finally culminating in sandy and marly limestone which contains occasional beds of clay and thin sandstone strata. These beds mark the transition from the pure limestone of the Arbuckle to the lowest sandstone member of the succeeding Simpson formation.

Fossil shells, which occur abundantly in the lower transition beds at the base of the Arbuckle limestone and less abundantly in the purer limestone for probably 2000 feet above, have been referred to the upper Cambrian. The age of these fossils had not been determined at the time the maps were printed and on them the whole formation is classed as Silurian. The very abundant fauna in the upper transition beds at the top of the formation, as well as that occurring down to a horizon probably 3000 feet lower, is of lower Silurian (Ordovician) age. More precise correlation of the Arbuckle limestone can not at present be made.

Age of the thick limestone.

SILURIAN ROCKS.

There are two areas of Silurian strata in the Atoka quadrangle, one in the northwest corner and the other in the northeast, belonging respectively to the Arbuckle Mountain and Ouachita Mountain uplifts. Although these areas are less than 20 miles apart, the formations are lithologically different and can not be correlated, except in a general way by fossil remains. In the Arbuckle area the formations are chiefly limestones, while in the Ouachita they are almost entirely shales and siliceous sediments. In the Arbuckle region the upper Silurian is represented by limestone containing abundant fossil remains, succeeded by Devonian sediments several hundred feet in thickness. In the Ouachita region occur local cherty deposits which are upper Silurian while Devonian strata are not known to occur. The lowest Carboniferous formation, a deposit of black shale, extends from one region to the other, resting upon Devonian rocks in the Arbuckle region and upon Silurian in the Ouachita region. For these reasons it is more convenient to discuss the Silurian formations in each province separately.

Two distinct series of Silurian sediments.

SILURIAN ROCKS IN THE ARBUCKLE UPLIFT.

Simpson formation.—This formation is exposed in the Atoka quadrangle in two small areas near the western border, west of Wapanucka. In both instances it is separated from the Arbuckle limestone by faults, the lowest beds of the Simpson being also concealed. The upper part of the formation, on the contrary, is fully exposed and is succeeded in regular order by the Viola limestone. In both areas also the rocks dip toward the north and are parts of the northern limbs of anticlinal folds. In both areas also the rocks occur near the northern border of the highland made by the granite and associated rocks, and are trenched by small streams, in consequence of which they are well exposed.

The thickness of the Simpson formation is estimated to be 1500 feet. In the Tishomingo quadrangle and in the Arbuckle Mountains farther west, where the formation is completely exposed in many places, it varies in thickness from 1200 to 2000 feet.

It is composed of sandstones and fossiliferous limestone with interbedded greenish clay shales and marls, which may be separated into several quite distinct members. At or near the base, near the top, and in the central portion there are members of sharp, brown, and in places massive sandstone. Many of the beds occurring in these members are composed of nearly pure gritty quartz sand. In places such sandstone beds are several feet in thickness, occur without distinct bedding, and are indurated, while at other localities they are found in compact but unconsolidated beds. Occasionally there are various beds, some of which are limestones interstratified with the sandstones. These sandstone members range in thickness from thin strata to beds aggregating 100 feet, the lower and middle sandstones usually being thicker than the upper one. The outcrops of the sandstone are marked by timber, while the intervening strata are generally occupied by prairie.

The limestone and marl members of the Simpson formation, except the transition beds at the top and bottom, lie between the upper and lower sandstone members and are separated from each other by the intermediate sandstone. They are composed usually of thin yellowish or bluish limestones with greenish marly clays interstratified. In places some of the limestone beds are white and pure, and at all localities a large part is composed of fragments of fossil shells. Above the uppermost sandstone member there are interstratified shell limestones and clays ranging in thickness between 400 and 500 feet. They make a lithologic transition between the Simpson and Viola formations, though the beds are for the most part closely related to the former.

The Simpson formation throughout contains an abundance of fossil shells which show that it belongs in the lower Silurian (Ordovician).

Viola limestone.—The Viola limestone receives its name from the village of Viola, which is located close to the occurrence of the formation 5 miles west of Wapanucka. This limestone crops out in four narrow exposures near the northern border of the granite and in a fifth and much larger area in the northwest corner of the quadrangle. Full sections of the Viola limestone are exposed only in the two localities west of Wapanucka. In these and the other two areas near the granite the rocks dip steeply toward the north, while in the large area to the north, where only the upper part of the formation is exposed, the dips are low toward the east.

The Viola formation represents a continuous and slightly variable deposition of limestone approximately 700 feet thick. In fresh exposures the limestone is massive in appearance, with stratification planes faintly showing. On weathered surfaces there are shown beds of limestone ranging in thickness from thin strata to a few feet, and with them are occasional irregular bands and nodular masses of chert or flint. This chert is most abundant in the lower and middle portions of the formation. The texture of the limestone for the most part is fine and dense. Some beds are coarsely crystalline, while others are composed chiefly of shells and shell fragments. The abundant fauna occurring throughout the Viola limestone show that it is of lower Silurian (Ordovician) age.

At the base there is a gradual transition from thin-bedded shell limestone and greenish shale of the Simpson formation into the mass of the Viola limestone, while at the top there is an abrupt change from limestone to the dark-blue and greenish shales of the succeeding formation.

Sylvan shale.—This formation takes its name from the village of Sylvan, in the central part of the Tishomingo quadrangle, near which it is typically exposed. It is a formation of soft, greenish, fissile shale which weathers easily to a fine soft earth. In the Atoka quadrangle it is estimated to be not more than 50 feet thick, while farther west, in the Arbuckle Mountains, it increases to nearly 300 feet. The Sylvan shale rests upon the Viola limestone and is succeeded as abruptly by nearly equally hard beds of the Hunton limestone.

Soft, greenish shale.

As the Sylvan shale is a soft rock, it invariably occupies swales or valleys between the harder limestone ledges of the contiguous formations. The talus from these adjoining limestones covers a large part of the outcrop of the Sylvan; and since the shale is occupied by forest, it is rarely exposed, and at no place is it completely exposed.

The Sylvan shale crops in four separate areas, three of which lie near the northern border of the granite. A fourth and the largest area occurs near the northwest corner of the quadrangle. In the three southern areas the formation dips steeply to the northeast, while in the northern it dips at a low angle toward the east and north.

The Sylvan shale represents an interval of time between the known lower Silurian, or Ordovician, and the upper Silurian in this region. Fossils have been found only in the green shales near the base of the formation, in two localities near the north-central part of the Arbuckle Mountains, and indicate lower rather than upper Silurian age.

Hunton limestone.—At the close of the Sylvan shale epoch there came a change in sedimentation and nearly pure white limestone and limy marls were deposited to a thickness of approximately 150 feet. This limestone takes its name from the village of Hunton, near which it is typically and completely exposed. Here also it contains in great numbers well-preserved fossils of upper Silurian type. The formation represents the closing episode of Silurian time in this region.

The Hunton limestone varies in thickness in the Arbuckle uplift from a thin bed to about 300 feet. Near the Ouachita River, in the southern portion of the uplift, it is absent for a space of 10 miles. In the northern and eastern parts of the

Beds of stratified oolite.

uplift the formation is practically the same as that shown in exposures near Hunton. Beginning at the base, there are variable beds of white oolite, in parts of which coarse and fine spherical granules appear as if originally sorted and stratified. Elsewhere spherules ranging in size from that of a small pea to fine grains appear intermingled. In places also the oolite is silicified, so that bowlders and fragments of the siliceous oolite are left upon the surface after the limestone has been removed. Following the oolite are bluish and cream-colored granular and fine-textured limestones and marly beds attaining a combined thickness of about 100 feet. Many of the beds in this part of the section are crystalline and hard, while others are composed in large part of comminuted shell fragments. Near the top are marly beds which carry an abundance of well-preserved fossils, some of which are silicified. The uppermost 50 feet of the formation is for the most part hard and thin bedded. Many nodular cherty concretions and numerous fossils, some of which are beautifully silicified, occur in these beds.

SILURIAN ROCKS IN THE OUACHITA UPLIFT.

In the western part of the Ouachita Range there has been uplifted a mass of Silurian (more specifically, upper Ordovician) strata aggregating approximately 12,000 feet in thickness. It is estimated that more than 11,000 feet of this section are exposed in the northeastern part of the Atoka quadrangle and are included in four distinct formations described below.

Correlation of Ouachita and Arbuckle sediments.

Fossil remains have not been found in the Stringtown shale, the lowest formation, except at its top. These fossils, with those occurring in the Talihina chert, in the upper part of the Standley shale, and in the limestone immediately above the Jackfork sandstone, show that the whole series of rocks belongs to the upper Ordovician division of the Silurian and is of the same age as the Viola limestone, which occurs in the upper part of the Silurian section in the Arbuckle uplift.

Stringtown shale.—Only the upper part of this formation comes to the surface in this quadrangle, and the base of the formation has not been observed anywhere in Indian Territory. The only clear exposure of the shale in the Atoka quadrangle is in one small area about a mile southeast of Atoka. It occurs below the Talihina chert which forms Black Knob Ridge, and crops along the western side of it, between Stringtown and the Cretaceous area to the south. It is limited on the western side by Carboniferous strata, from which it is separated by the great fault which follows the western border of the Ouachita uplift in this region. This faulting is described under "Geologic Structure."

The single locality southeast of Atoka where this formation is partially exposed shows the shales to be very much crushed and deformed, so that no reasonable estimate of the thickness could be made. What appeared to be the upper part of the formation is a black, fissile, cherty shale, and below it are green clay shales. Elsewhere in the quadrangle the formation makes smooth slopes, in most part prairie land, and there is no indication of other rocks than shales beneath the soil.

The upper part of the Stringtown shale crops out in the dome-like uplift 8 miles northeast of Tuskahoma, near the center of the portion of the Ouachita uplift in Indian Territory. It occurs in this locality in a flat circular cove surrounded by prominent ridges of the overlying Talihina chert. The upper part of the shale crops beneath the talus of this chert, while the soft green shales lower in the formation lie in the flat, partly wooded plain of the cove. The upper part is composed of black, siliceous, slaty shales similar to those in the vicinity of Atoka and contains lower Silurian graptolites (upper Ordovician age). Below these beds are greenish fissile and friable shales with occasional inclusions of calcareous cone-in-cone and ironstone concretions.

Talihina chert.—This formation occurs at the surface in this quadrangle only in Black Knob Ridge, which extends from a point 2 miles south of Atoka nearly to the northeast corner of the quadrangle. With local exceptions, to be noted under the heading "Geologic Structure," it is steeply tilted toward the east. At the southern end it comes from beneath the flat Cretaceous rocks, and at the northern end it is cut off abruptly by an extensive fault, along which the rocks have been thrust upward and westward.

The formation takes its name from the town of Talihina, in the Tuskahoma quadrangle, near which place it occurs with large exposures in the mountains.

Chert beds forming Black Knob Ridge.

The Talihina chert is approximately 1200 feet thick and is composed of three not very well-defined members. The lowest of these members consists of flint, chert, black and bluish shales, and lentils of dense limestone interstratified. It is estimated to be 600 feet in thickness. In most parts these flints, cherts, and limestones are in sheets rarely exceeding 6 inches in thickness, while the shales occur as thin laminae or fissile layers. The cherts and flints are black, gray, whitish, with a few greenish flinty beds in the upper part. This member grades up into the middle member, which is composed of fissile shales and thin cherty layers and has an estimated thickness of 300 feet. It occurs at the eastern base of the prominent ridges made by the lower chert, and in consequence is almost invariably concealed beneath the abundant talus from this chert. This member also grades upward into the upper chert in such manner that its limit can not be well defined. The upper member is also estimated to be about 300 feet in thickness, and is composed of chert and shale in all respects like the lower member except that the individual layers are generally thinner. Exposures of this member have not been found sufficiently fresh to indicate the presence of limestones. This chert produces a line of low, round knobs and occasionally ridges which lie at the eastern bases of the prominent ridges and knobs made by the lowest member of the formation.

On account of the variable strata and thin beds, the talus of angular and sharp chert is thick from the bases of the hills almost to the crests, except where the rocks are being actively eroded by the streams.

Thick section of shales.

Standley shale—This formation follows the Talihina chert in gradual transition. Siliceous chert, black shale, and greenish clay shales occur in alternate members for nearly 800 feet above the base. There are two cherty members, 30 and 40 feet in thickness, which were noted in sec. 7, T. 2 S., R. 12 E., 550 and 800 feet, respectively, above the base of the formation. These cherty strata resemble many of the thin and more shaly cherts found in the Talihina formation. Continuing upward in the section, there are greenish and dark shales alternating with drab or brown and moderately hard sandstones until the formation reaches an estimated thickness of 6000 feet. Distinct sandstone members range in thickness from 20 to 100 feet and are separated by shales or shales interstratified with sandy beds 140 to 2000 feet in thickness. The best section of the formation in this quadrangle was noted across secs. 7, 8, and 9, T. 2 S., R. 12 E.

The sandstones are so soft that they produce little more effect upon the surface configuration than do the clay shales in which they are embedded. The whole formation invariably crops in nearly level plains or valleys and in such steep slopes at the borders of these valleys as are protected by the harder overlying formation.

The Standley shale is found in the wide valley plain extending from the northeast corner of the quadrangle down Chickasaw Creek and across North Boggy and Muddy Boggy valleys to the broad plain of the Trinity sand south of Atoka. It also extends eastward up Chickasaw and Little Chickasaw creeks, joining the broader plains and valleys of McGee and Jackfork creeks and Kiamichi River in the central part of the Ouachita Range in Indian Territory. The formation takes its name from the village of Standley, in the Kiamitia Valley, where it is extensively exposed.

Thick section of sandstones.

Jackfork sandstone.—The Jackfork sandstone is the mountain-making formation of the Ouachita Range in Indian Territory. It represents an almost continuous sedimentation of 5000 feet of brown and gray sandstone. It receives its name from Jackfork Mountain, in which a large part of the formation is exposed. It is estimated that about 3800 feet of this formation from the base up are exposed in the Atoka quadrangle. It crops in one large and three small areas in the hill country in the northeastern portion of the quadrangle. These areas are the extreme west ends of large exposures which extend into the Ouachita Range, making the Rich, Jackfork, and Kiamitia mountains.

The Jackfork sandstone consists of a series of generally even-textured, fine-grained, brown and gray sandstone strata ranging from thin layers to massive beds 50 feet in thickness. Occasionally interstratified with these beds are thin strata of clay shale and shaly sandstone. The shaly beds are very rarely exposed on account of the protection afforded by the sandstone beds and sandstone talus.

The Jackfork formation has not yielded fossils of any kind, but in the Kiamichi Mountains, on the southern border of the McAlester quadrangle, it is directly overlain by thin limestone and cherty strata of lower Silurian age (upper Ordovician). Occurring, therefore, between two formations containing upper Ordovician fossils, the Jackfork sandstone is also of the same age.

In Caney Creek Valley, at the southern border of the McAlester quadrangle, these Silurian limestones are succeeded by the Caney shale of the lower Carboniferous, which formation occurs with but little variation in both the Ouachita and the Arbuckle Mountain sections. At other localities in secs. 3, 4, and 5, T. 2 N., R. 15 E., in the same quadrangle, upper Silurian chert and limestone strata immediately underlie the Caney formation.

DEVONIAN ROCKS.

Rocks of Devonian age, so far as at present determined, are confined to the Woodford chert, which rests conformably upon the Hunton limestone, which is of Silurian age. This formation is known only in the Arbuckle uplift, around and in which it is found where there are suitable conditions for its exposure.

Cherty beds occur in the Ouachita uplift east of the Atoka quadrangle directly beneath the formation which overlies the Woodford chert in the Arbuckles, but fossils from these cherts belong to the upper Silurian. The stratum or interval which represents the Devonian as it is known in the Arbuckle uplift is concealed by faulting at the western end of the Ouachita uplift in the northeastern part of the Atoka quadrangle. These Devonian rocks have yielded but few fossils, and the exact parting between the Devonian and Carboniferous can not at present be determined. The fossils obtained from the Woodford chert, however, show that the larger part of the formation belongs to the Devonian.

Woodford chert.—This formation outcrops in the Atoka quadrangle in five separate areas. In the three areas lying north of the granite it is steeply upturned, dipping toward the northeast, while in the large area in the northwest corner of the quadrangle it dips low toward the east across the axial part of the large fold. At the southern border of the large Silurian area 2 miles northwest of the Chickasaw Rock Academy another small outcrop was observed.

Beds of flinty chert.

The Woodford chert is composed of thin strata of dark chert, cherty shale, and black, fissile, bituminous shale aggregating 500 to 700 feet in thickness. The formation is variable as to thickness and as to position of the beds which compose it. In places the cherty beds approach flint in texture, and some layers are several inches in thickness. Locally such beds make a large part of the formation, occurring in either the middle or lower portion. Elsewhere little can be found except thin, fissile, siliceous black shale. Locally also bluish shale has been noted interstratified with black shale and chert. Near the base of the formation in places there are lentils and large concretions of almost pure flint.

Some of the cherty beds are in places calcareous and approach siliceous limestone. Certain flint shales contain numerous small, round, marble-like concretions which may be phosphatic.

Large fragments of silicified fossil wood have been noted upon the surface of the Woodford chert and at one locality in the adjoining Tishomingo quadrangle a broken trunk of a fossil tree was found embedded in this stratified chert. Fossil shells are of rare occurrence in the Woodford formation, but those found in the chert west of the Atoka quadrangle proved to be of Devonian age, while others found near at hand in the clay shale immediately above the chert are of lower Carboniferous age.

CARBONIFEROUS ROCKS.

Caney shale.—Shales of lower Carboniferous age, known as the Caney shale, succeed the Woodford chert in the northwestern part of the Atoka quadrangle and elsewhere throughout the Arbuckle Mountain region. The same formation in the northeastern part of the quadrangle is concealed by displacement along the fault which separates the Silurian from the Carboniferous rocks. This formation outcrops, however, in numerous places farther east in the Ouachita Range and is found resting upon the Silurian limestones and cherts which occur above the great thickness of sandstones and shales in the northeastern portion of the quadrangle.

Black bituminous shale.

The Caney shale in its lower part consists of black, bituminous, fissile shale with spherical calcareous segregations and irregular, dense, blue limestone bodies. This bituminous shale is succeeded by clay shales which include small ironstone concretions and occasional calcareous septaria.

The surface of the Caney shale area is flat, and the rocks are so concealed that the structure can not be made out with sufficient accuracy to determine the thickness of the formation. It is roughly estimated, however, to be 1600 feet.

The formation outcrops in a very irregular area across the eastern end of the Arbuckle uplift and is limited upon the eastern side by the outcrop of the succeeding Wapanucka limestone. It is cut by numerous normal faults, shown upon the map, which bring it in contact with all the formations below it in the region except the Reagan sandstone. Such faults, which bring formations of different nature in contact, can be easily detected, whereas faults within the shale can not be located. Local narrowing of the Caney shale outcrop, such as that 1½ miles west of Wapanucka, can only be explained by faulting within the shale, but the line of displacement can not be determined.

The black shale in the lower part of the Caney formation contains fossil remains of lower Carboniferous (Mississippian) age. The blue shales higher up in the formation have not yielded fossils, and the dividing line between lower and upper Carboniferous is not known, since the limestone immediately succeeding is of Coal Measures (upper Carboniferous) age.

Wapanucka limestone.—The Wapanucka limestone has been traced throughout the extent of its outcrop from the northeastern side of the Arbuckle uplift northeastward along the north side of the Ouachita Range nearly to the Arkansas State line. Broadly considered it is a lens 400 feet thick in the middle, thinning out at its edges. Across the Atoka, McAlester, Tuskahoma, and part of the Coalgate quadrangles, however, it is continuous; although it varies somewhat in thickness, it is to be considered a formation.

The Carboniferous limestone.

This limestone occurs only in the northwestern part of the quadrangle. The displacement along the great fault west of Black Knob Ridge in the northeastern part of the quadrangle has caused the Silurian strata to be brought in contact with Carboniferous rocks younger than the Wapanucka limestone, thereby concealing it from view. Two normal faults, one upon each side of the flat-pitching anticline in the northwestern part of the quadrangle, displace the Wapanucka limestone for a distance of about half a mile. Elsewhere the formation crops in its normal position.

The formation comes from beneath the flat Cretaceous deposits one mile northwest of Boggy Depot and continues northwestward in its tortuous outcrop to about 6 miles beyond the northwest corner of the quadrangle, where it becomes so thin that it can not be traced farther. At this western extremity it joins beds of limestone conglomerate which thicken westward to enormous proportions around and across the northwestern part of the Arbuckle Mountain uplift.

The width of the outcrop of the formation is governed chiefly by variations of dip but also in part by the limestone ridges, though there is a slight thinning of the rocks from southeast to northwest. Where the formation is shown in its narrowest outcrop in the southern part of T. 1 S., R. 8 E., the dip is 60° to 70°. Elsewhere the dip varies from 10° to 15°. Northwest of Wapanucka and in the axial part of the anticline in the northwest corner of T. 1 S., R. 9 E., the limestone makes considerable ridges, thereby broadening the outcrops.

Southeast of Wapanucka the formation is approximately 125 feet thick, and is composed of several members of calcareous and cherty sandstone, limestone, and shale. An exposed section in the NW. ¼ of sec. 32, T. 2 S., R. 9 E., shows at the base 36 feet of shale and calcareous brown sandstone, followed by 24 feet of shaly and hard bluish limestone. Above this limestone there are 15 to 20 feet of dark-blue and black fissile shale. The shale is succeeded by 10 to 12 feet of hard, cherty limestone and calcareous sandstone which in turn is followed by beds of hard limestone 40 feet thick. Succeeding strata to the top of the formation were concealed by the soil. The sandstone beds at the base thin out toward the west and are not found near the northwest corner of the quadrangle, where the limestone layers are also thinner. A thick bed of white oolitic limestone occurs at the top of the formation in the northwestern part of T. 1 S., R. 9 E., where the formation has broad exposures. Below this oolite are limestone and shale to the base of the formation.

White oolite.

The Wapanucka limestone yields a considerable number of fossil shells of Coal Measures (upper Carboniferous) age.

Atoka formation.—With the exception of thin lentils of limestone and of calcareous cherty sandstone near the base in the northwest and northeast corners of the quadrangle, the rocks of the Atoka formation are sandstone and shale. They are estimated to be nearly 3000 feet in thickness, the shale as a whole being very much thicker than the sandstones. The formation is divided by the sandstone strata into shale members varying from thin sheets to beds several hundred feet in thickness.

The shales are friable clays and sandy clay shales and crop in smooth valleys and in the lower slopes of ridges and hills. Under such conditions fresh exposures of the shales are exceptional and little is known of their original color or physical appearance. When partly weathered, however, they show various shades of yellow and blue. Some fresher exposures in sec. 11, T. 2 S., R. 9 E., on Clear Boggy Creek and in Delaware Creek Valley, show dark-blue to black clay shales.

The sandstone beds are many, and vary from thin plates embedded in shale to massive strata making prominent sandstone members. These thicker sandstones are generally variable in thickness and would be classed as lentils. Several of these occur in the upper part of the formation east of Clear Boggy Creek and make prominent ridges, especially in their northern outcrops. Another member near the base makes local rough sandstone hills southeast of Wapanucka. Prominent local beds of conglomerate composed of fine brown sand and subangular chert pebbles make high ridges and hills immediately west and southwest of Stringtown. Conglomerate beds of similar nature occur also in the upper part of the formation west of North Boggy Creek and north and west of Atoka. A peculiar feature of this chert conglomerate is that its limit in range north and south corresponds with the occurrence of Silurian chert in Black Knob Ridge. The sandstone strata in the northwest corner of the quadrangle are in many respects unlike those of the northeast corner. In the former locality they are softer and more ferruginous. Sandstone beds of considerable thickness occur near the base of the formation in the northwest corner, and associated with them are local beds of thin, impure limestone. In places the sandstone makes prominent ridges and hills, while elsewhere the beds can not be located in the plain. In the northeast corner of the Atoka quadrangle and in the southeast corner of the Coalgate quadrangle west of the great fault, the lower beds of the Atoka formation have been so folded and faulted that the same beds are repeated many times in long, narrow, parallel belts for a width of nearly a mile. Southeast of this faulted strip the sandstone and shale beds are folded and steeply inclined toward the southeast.

Carboniferous chert conglomerate in vicinity of Black Knob Ridge.

Chickachoc chert lentil.—The Chickachoc cherty sandstone is a lentil in the lower part of the Atoka formation and occurs in the faulted strip above referred to. Because of its peculiar and characteristic texture and hardness it has been separated from its associated beds and mapped. It is about 80 feet thick and is composed of stratified, yet massive, calcareous and cherty sandstone. There is but little variation in the character and texture of the rocks in the Chickachoc lentil. Occasionally however, thin stringers of almost pure flint and siliceous limestones occur in exposures of unweathered rock. When weathered the whole mass becomes nearly white and breaks down into thin, coarse, hackly plates, which feel as if composed of sharp grit. The folding in this part of the Atoka formation has been so excessive that the beds are now mostly vertical and the chert bed has been repeated numerous times by faulting, forming sharp, narrow parallel ridges. At their southern ends these chert ridges are abruptly terminated by the great fault which has thrust them against higher beds in the Atoka formation. Near the ends of some of these ridges the chert has been thrown into peculiar distorted folds, which can be explained only by the great pressure brought to bear against the ends of the upturned beds. All of the known exposures of this chert occur in the Coalgate quadrangle except one small area which extends into the Atoka quadrangle and terminates against the fault near the railroad in sec. 4, T. 1 S., R. 12 E.

Sharp parallel ridges formed by a faulted cherty bed.

Hartshorne sandstone.—This sandstone is important chiefly on account of its association with the lowest and most valuable coal bed in the Choctaw coal field. The coal is immediately above the sandstone and is usually separated from it by a variable thin bed of shale. The Hartshorne sandstone is composed of many beds of sandstone, varying from thin plates to massive strata 3 feet in thickness. Thin beds of shale occur in places interstratified with the sandstone, but the sandstone beds are so much more conspicuous in outcrop that the shales are rarely seen or their presence detected. The sandstone grades into the shale formations above and below through shaly sandstone beds, and the dividing line must usually be arbitrarily chosen. The thickness of the formation is estimated at about 200 feet.

The sandstone below the Atoka coal.

In this quadrangle the Hartshorne sandstone and all succeeding Carboniferous formations occur only in the basin about Lehigh. In the western portion of the Lehigh basin the sandstone is fine grained and usually hard and is brown on weathered surfaces. Here the rocks dip 4° to 5° toward the east and northeast and make ridges of considerable prominence. In the eastern portion of the basin they are steeply upturned, and, except where locally worn down by Boggy Creek, they form narrow, sharp ridges. Going eastward around the southern side of the Lehigh basin the beds change from a brown sandstone to a chert conglomerate with a matrix of brown sand. In the southeastern part of the basin, opposite the southern end of Black Knob chert ridge, a large part of this formation is chert conglomerate which continues along the eastern side of the syncline to the northern border of the quadrangle. It is evident from this fact that during this portion of Carboniferous time the Silurian chert beds of Black Knob Ridge or its former extension contributed the chert to these Carboniferous conglomerates.

Origin of the chert conglomerate.

McAlester shale.—Shale, sandstone, and clay constitute this formation. Its thickness is estimated to be nearly 2000 feet, and the total thickness of the shales is nearly ten times that of the sandstones. The shales are laminated and are blue and black when freshly exposed. They are chiefly clay shales, though sandy shales and shaly sandstones occur interstratified with them. Two local beds of sandstone in the lower half of the formation, separated by nearly 400 feet of shaly strata, outcrop in low ridges west and southwest of Lehigh. Two or more thin beds of sandstone occur also in the upper part of the formation, and in places make low hills, but their ledges usually do not outcrop. In the western part of the Lehigh basin, where the rocks dip at low angles, the various beds occur in broader areas. Between the low ridges of sandstone the shale surfaces are spread in wide, flat, and shallow prairie valleys. In the eastern part of the basin where the formation is steeply upturned, the outcrops are narrow. The surface is more elevated and the harder beds make rough low hills and ridges. Like the Hartshorne sandstone the sandstones of this formation occur in the western part of the Lehigh basin, while in the eastern portion many of the sandstone beds are replaced by chert conglomerates.

There are two coal beds in the McAlester shale; one at the base and the other about 200 feet below the top. Both of these beds are of workable thickness and the upper one is extensively mined in the vicinity of Phillips and at Lehigh. The coals in this formation will be considered under the heading "Coal." An interesting feature, however, of the Lehigh coal, which is the upper bed and the one mined extensively at Lehigh, Phillips, and Coalgate, is the shale bed which forms its roof. This is a black bituminous shale, about 18 inches thick, containing numerous molluscan shells and the teeth and scales of fish.

The coal-bearing formation.

Savanna sandstone.—Above the McAlester shale there is a succession of sandstones and shales about 1150 feet thick. The shale beds combined are probably thicker than the sandstones, but the latter are better exposed and their presence is so strongly impressed upon the observer in the prominent ridges that sandstone seems to be a more appropriate term to apply to the formation. There are five, and in some places more, groups of sandstone beds, which vary in thickness from about 50 to nearly 200 feet, those at the top and those near the base being generally thicker than the intermediate beds. These sandstones are so nearly alike in physical appearance that they can be distinguished only by their position in the section or by their thickness. They are generally brown or grayish in weathered exposures, and are fine grained and compact except in certain localities in the eastern part of the Lehigh basin. Here many of the sandstone beds contain considerable quantities of subangular chert pebbles, in places so abundant as to form beds of conglomerate. The formation as a whole becomes thicker from west to east across the quadrangle. The sandstone beds are thicker, coarser, and generally harder in the more eastern exposures.

Immediately north of the Atoka quadrangle in the northeastern corner of T. 1 S., R. 9 E., thin siliceous limestones are found associated with the highest sandstone horizon of the Savanna formation, and in places these impure limestones contain abundant fossil remains.

In the outcrop of the formation in the eastern portion of the Lehigh basin the sandstone beds are most prominent and steeply inclined, producing many low parallel ridges. In the western and southwestern portions of the same basin or syncline the sandstone ridges are generally covered by strips of forest while the valleys are prairie or open timber land. Here the sandstone beds generally dip at low angles, the ridges are less prominent, the valleys wider, and there is less diversity in the landscape.

No coal of any importance has thus far been located in the Savanna formation. It was reported, however, that coal beds had been found in the vicinity of Nixon, 6 miles northwest of Phillips, but their thickness and extent were not determined.

Possible coal-bearing strata.

Boggy shale.—Above the Savanna sandstone there is a mass of interstratified shales and sandstones having a total thickness of nearly 2000 feet. Approximately 800 feet of the lower part of this formation occur in the central part of the Lehigh basin in the Atoka quadrangle. This group of strata has been named the Boggy shale because of its broad outcrop in the valley of Muddy Boggy Creek in the Coalgate quadrangle. There are probably in the formation not less than 20 sandstone beds, ranging from thin strata to beds about 50 feet in thickness and separated by shales which in some places exceed 600 feet. Some of these sandstone beds, a large part of which are composed of chert conglomerate, are like those in the lower formations in the eastern portion of the Lehigh basin.

The sandstones in the upper part of the formation in the Coalgate quadrangle vary but little in physical character and are generally brownish or gray, and in places rather ferruginous. The shales are exposed to only a very limited extent on account of the generally low relief of the land and the wide, shallow valleys of the streams, but in the few steep slopes and stream cuttings where fresh exposures were observed they consist of laminated, bluish, clay shale, containing small ironstone concretions, thin, wavy, sandstone plates, and shaly sandstone beds. Boggy Creek, which flows along the eastern side of the area, affords a number of exposures of bluish shales in the lower part of the formation.

In the lower part of the formation as exposed east of Lehigh the sandstone and conglomerate beds are thickest and make rough ridges and hills. Certain shale beds which lie nearly flat in the central part of the area give rise to smooth prairie tracts among the timbered sandstone hills.

CRETACEOUS ROCKS.

Cretaceous strata occupy approximately the southern two-thirds of the Atoka quadrangle. Like all the other stratified rocks in the region they were deposited in a nearly flat position. Their history since their formation, however, has been very different from that of the older strata. Instead of being folded, fractured, and faulted, as are the latter, they remain practically in their original flat position, slightly inclined southward toward the old Cretaceous sea. The only disturbance these rocks have suffered is that of vertical movement, they having been elevated as a body above the level of the sea.

Trinity sand.—The Trinity sand is the beach and near-shore deposit of the lower Cretaceous sea which encroached upon the land from the south. Its progress was so slow and its work so complete that all of the Paleozoic rocks—granite, sandstone, limestone, and shale—both hard and soft alike, which are now exposed along the northern border of the Cretaceous rocks, were worn down to practically a smooth plain or base-level. Upon this plain across the edges of the older strata the Trinity sand was laid down in the relative position we now find it.

The Trinity formation is composed of local coarse conglomerate and finely packed though incoherent sand, with occasional sandy clay and clay lenses, aggregating 200 to 400 feet thick. The conglomerate occurs invariably at the base and ranges in thickness from a thin stratum to beds approximating 50 feet. It is cross bedded and interstratified with sand and sandy clay. It is composed of various kinds of smooth, rounded particles of quartz and quartzite, ranging from sand grains to pebbles more than 6 inches in diameter, and of chert pebbles, usually small and only partially rounded. The quartz pebbles are foreign to the region, while the chert is local, being derived from the Talihina chert, near which it is most abundant in the vicinity of Black Knob Ridge. Upward the conglomerate pebbles become smaller, grading finally into grits of quartz or chert.

Local chert conglomerate in the Cretaceous.

The conglomerate at the base of the formation is coarsest and most abundant in the region south of Atoka. In the western part of the quadrangle, where the Trinity sand overlies the granite, the basal part of the formation is composed chiefly of quartz grit derived from the disintegrated granite. The basement rocks here are composed of hard limestone and granite, and it is striking that both rocks alike should be reduced to fine sediment by the Cretaceous sea which eroded them.

From the conglomerate at the base to the top of the formation against the Goodland limestone the Trinity formation is the same fine, friable sand, which breaks down readily into loose sandy soil. Occasionally, both in the conglomerate and the sand, silicified fragments of trees are found, which were originally driftwood swept into the sea from the shore. The Trinity formation extends continuously in broad outcrop

Fossil driftwood.

westward and southward from this region into central Texas, where its broad areas in the region of Trinity River have given the formation its name.

Goodland limestone.—Next above the Trinity formation there is a massive white limestone about 25 feet thick. The outcrop of this white limestone is continuous across this quadrangle, bearing generally east and west. Like the other Cretaceous formations it dips at a very low angle toward the south and makes cliffs and terraces above slopes of the friable Trinity sand. Soft shales form the next formation above and these are easily eroded, exposing quite broad tracts of the flat Goodland limestone between the valleys of the larger tributary streams flowing north toward Blue River and Clear Boggy Creek.

The Goodland limestone is a representative, in part at least, of several formations which occur in the lower Cretaceous in central Texas, from which region to Indian Territory it is continuously exposed.

A bed of oyster shells is usually found at the base in contact with the Trinity sand. Higher in the limestone there are numerous fossils common to the Comanche series of the lower Cretaceous in Texas.

Typical exposures of this limestone occur at Goodland, on the St. Louis and San Francisco Railroad in southeastern Choctaw Nation, and as the first of these limestones to be described were from this locality, the name Goodland has been applied to the formation.

Kiamichi formation.—Lying upon the Goodland limestone there are thin layers of slightly siliceous limestone with a thin stratum of shale marl interstratified. These together are but a few feet in thickness and are not usually exposed in the flat land immediately above the floor of the Goodland limestone. Blue clay marl about 30 feet thick succeeds the thin, shaly strata and then follow approximately 20 feet of blue clay marl and oyster-shell beds interstratified. These shell beds usually are less than a foot in thickness. They are composed almost entirely of oyster shells ranging in size from very small to 3 inches in length, cemented by marly lime. The more or less indurated beds are generally exposed as ledges or slabby fragments forming a continuous outcrop at the top of the formation.

Thin oyster-shell beds in marl.

The Kiamichi formation, with other Cretaceous deposits occurring in the Atoka quadrangle, crops across the southern portion of the Choctaw Nation. Prominent exposures of this formation have long been observed in the plain of Kiamichi River near the St. Louis and San Francisco Railroad in southeastern Choctaw Nation and for this reason the formation has been so named.

Caddo limestone.—This formation consists of clay, calcareous marls interstratified with white or yellowish marly limestone, and semicrystalline limestone, making a section about 150 feet thick. The marly beds are thickest near the base, the lower 60 feet being composed chiefly of clay marls. Above this there are 20 to 30 feet of lime marls with some chalky white limestone strata interbedded. In this member are some oyster-shell beds similar to those at the top of the Kiamichi formation. Higher still in the formation the marly beds become thinner, while the limestones increase in number and thickness until near the top the marl occurs as thin strata or mere partings between the limestone beds. Finally, at the top of the formation, there is a bed of oyster shells similar to those occurring below and at the top of the Kiamichi formation.

The harder limestone at the top of the formation projects as a ledge in the escarpment which it produces in the vicinity of Caddo and in many places east and west across the quadrangle. Many valleys have their heads in the escarpment and some cut across it, and the streams in these valleys make fresh exposures of the limestone and marl. The Caddo formation throughout contains great numbers and many kinds of marine fossil shells.

Bokchito formation.—This formation is so named because of its splendid exposures on Bokchito Creek in the vicinity of the village of the same name. It is composed chiefly of clay and sandy clay, with beds of friable sandstone, siliceous shell limestone, and ironstone segregations and concretions, aggregating approximately 140 feet. Ninety feet of the formation from the base upward is of sandy clay shale with some ferruginous limestone segregations and ironstone nodules. East of Caddo Hills these beds crop in the lower slopes of hills and in flat prairie land near the north border of the formation. West of Caddo Hills they form broad tracts of generally flat country across the valley of Blue River besides occurring in the lower slopes of hills near the west border of the quadrangle. Above these sandy layers are friable sandstone beds 20 to 30 feet in thickness. In many places these beds are seen to be false bedded, alternating with and including deposits of sandy clay. These local beds are succeeded by bluish shell limestone strata separated by friable shales. The limestone layers are hard and usually semicrystalline and upon weathering turn yellowish brown or reddish. The calcareous matrix and the oyster shells are usually of equal hardness, so that the latter weather in sections on the face of the rock. The limestones project in many places as ledges and bowlders, but the shales are rarely exposed. These beds with limestones at the top and base vary in thickness from 10 to 20 feet. Finally, at the top of the formation, there are about 50 feet of sandy and clay shales and locally friable sandstone strata. It has been observed that these sandstone beds in places are cross bedded, indicating variable currents in the waters during their accumulation. In the clay strata and in some of the iron and lime concretions there are many fossils with the original shell, and in some cases the nacreous luster, still preserved.

Clay with ironstone concretions.

Cross-bedded sandstones.

Bennington limestone.—The Bennington limestone is at the top of the lower Cretaceous in this region. In the Texas region this formation is represented by from 80 to 100 feet of calcareous fossiliferous clays. Coming northward these clays gradually thin and change to limestone and clay interstratified and then into a hard limestone which occurs in southern Indian Territory and the Atoka quadrangle.

In the Atoka quadrangle the Bennington limestone is generally massive dull-blue limestone 10 feet or less in thickness. It is composed in large part of countless specimens of a peculiar small oyster, *Exogyra arietina*, by which name the clays representing this formation in central Texas have been known. Locally there are thin deposits of marly limestone resting upon the harder beds of the Bennington which are the representative in age, in part at least, of the succeeding limestone formation in central Texas. A good exposure of this rock occurs near the road one mile northwest of Bennington. The Bennington limestone, although a thin formation, is generally exposed in low bluffs and terraces, the rocks above and below being friable and more easily eroded. West of Robbers Roost, near the border of the quadrangle, it crops in the crest of some remnental buttes, and south of Caddo it forms the cap rock of Caddo Hills. It is the surface formation of a considerable area of flat fertile land in the southeastern part of the quadrangle.

Limestone capping Caddo Hills.

Silo sandstone.—Only the lower part of the Silo sandstone occurs in the Atoka quadrangle. The whole formation is estimated to be approximately 500 feet thick in north Texas adjoining Red River, the nearest locality to the Atoka quadrangle where it is completely exposed.

The Silo sandstone is the basal formation of the upper Cretaceous, and, like the Trinity sand, it was deposited near the shore of the Cretaceous sea, but upon a very slightly eroded surface. It consists of fine brown sand and sandy clays interstratified. The sandy beds are thickest in the lower middle part of the formation, and occasionally extend to the base, although the basal beds are usually clays and sandy clays. Some of the sandstone beds contain segregations of brown siliceous iron ore which occur as stony fragments upon the surface where the including sand has been removed.

Basal sand of the upper Cretaceous.

Toward the upper part of the formation as it occurs in this quadrangle the sands are finer, less abundant, and more generally disseminated in the clays, making deposits of siliceous clays or argillaceous sand not so distinctly stratified as are similar strata toward the base of the formation.

The outcrop of the lower and more sandy deposits is usually occupied by forest, while that of the upper part is occupied by prairie land interspersed with clumps of timber and open wood.

CORRELATION OF CRETACEOUS FORMATIONS.

The change in the nature of the Cretaceous strata from Indian Territory southward through Texas is such that it is necessary to use different names for the formations deposited during the same geologic time in the two regions. The formations named in this folio or their equivalents have been traced continuously from the Atoka quadrangle in Indian Territory to the Austin quadrangle in central Texas and the accompanying table is introduced to show the correlation of strata.

Correlation table of Cretaceous formations.

Names used in this Folio.	Names used in the Austin Folio.
Silo sandstone.	Eagle Ford formation.
Bennington limestone.	Buda limestone. Del Rio clay.
Bokchito formation. Caddo limestone. Kiamichi formation.	Georgetown limestone.
Goodland limestone.	Edwards limestone. Comanche Peak limestone. Walnut clay.
Trinity sand.	Glen Rose formation Travis Peak formation.

NEOCENE (?) GRAVELS.

There are scattered deposits of coarse, hard, well-rounded pebbles, 1 to 4 inches in diameter, occurring in many places in this region, and at various altitudes from the hilltops to the present stream valleys. These gravels are composed chiefly of pebbles of quartz and quartzite, many of which have become rough or pitted upon the surface and are partly disintegrated through long exposure. Such deposits are found in this quadrangle upon the eroded edges of Carboniferous and Silurian rocks, and farther south upon Cretaceous rocks. They are too thinly spread over the surface to be mapped, and it is not believed that they now occupy their original position, since they occur distributed at various levels. The age of these deposits is problematic. Considerable quantities of pebbles, which are found in the vicinity of Stringtown and northeastward, came probably from the conglomerate member at the base of the Trinity sand which is considered to have once spread over extensive areas north of its present border. Some of these gravels at least are of much later age than the Cretaceous, since they are found scattered over the edges of the Cretaceous formation in the southern part of the quadrangle and in northern Texas beyond the valley of Red River, and they are tentatively regarded as Neocene. Their relation to the Tertiary peneplain is not known.

Scattered surficial deposits of quartz pebbles.

GEOLOGIC STRUCTURE.

All stratified rocks, especially those of broad extent, were deposited beneath the water in nearly flat positions. Their elevation into land and their tilting, folding, and breaking are due to forces of deformation within the earth. Simple tilting or warping of the strata in one direction is termed monoclinal folding. Bending of the rocks upward into arches and domes and downward into troughs and basins is termed anticlinal and synclinal folding respectively. Such structures are considered to be produced by compressive forces acting approximately parallel to the surface of the earth, and crumpling the nearly flat rocks into folds as the leaves of a book may be folded by the hands. If the forces producing such folding cause sufficient movement, the rocks may be broken and the strata upon one side may be thrust past those upon the other, producing what are called thrust faults or overthrusts. The planes of such overthrusts vary in position from horizontal to an angle of 45° from the horizontal, and the rocks above this plane move upward with respect to the rocks beneath it. Another form of dislocation may occur along planes that approach a vertical position. In this case the forces causing the dislocation are considered to act chiefly in a vertical direction and the rocks above the fault plane move down with respect to the rocks beneath it. The effect is termed normal faulting. All these kinds of deformation have affected pre-Cretaceous rocks of the Atoka quadrangle and occurred long prior to Cretaceous time.

The composition of the rocks now exposed in this region indicates that no elevation of the strata into prominent land occurred between the Cambrian and lower Carboniferous. Near the beginning of upper Carboniferous time the western part of the Arbuckle region was elevated to land and in part to mountainous conditions. The Cambrian, Silurian, Devonian, and lower Carboniferous rocks, aggregating 8000 to 10,000 feet, were thus elevated and folded, and their erosion produced extensive Carboniferous limestone conglomerates bordering the uplift. Similar chert conglomerate deposits occuring at intervals through several thousand feet of upper Carboniferous strata contiguous to the west end of the Ouachita Mountains, where a thick chert and flint formation of Silurian age is exposed, indicate that a part of the Ouachita Range also was elevated into land during upper Carboniferous time.

Evidences of land areas during upper Carboniferous time.

At the close of, or shortly after, the Carboniferous period the Ouachita and Arbuckle regions were entirely uplifted into land and the rocks folded and faulted as now found. The length of time required for the production of these structures is not known. It occurred however, between the Carboniferous and Cretaceous periods and most probably ended long prior to the transgression of the Cretaceous sea. The almost universal lack of local coarse material, even at the base of the Trinity sand, which is the beach deposit, would indicate that the land was low and had little relief at the time of the encroachment of the Cretaceous sea.

Since Cretaceous time the whole region has been uplifted and but slightly tilted southward without folding. This late oscillation of the land and the progress of recent denudation has already been discussed under the heading "Topography."

STRUCTURE SECTIONS.

The folding and faulting which have occurred in this district are graphically shown on the Structure Section sheet. The sections represent the earth cut vertically along the lines shown on the map to a depth of 2500 feet below the level of the sea, and the face of the cut presented to view. By taking the McAlester formation, which is shown in strong color in Section BB, a fair idea of the folding in the Lehigh syncline may be obtained. This formation, if projected upward toward the east, would approach the great fault several thousand feet above the present surface of the land. Section CC illustrates the extensive normal faulting in the granite and in the Silurian and Carboniferous rocks; also the low-dipping monoclinal Cretaceous rocks farther south.

Section AA illustrates the axial pitch of the eastern end of the flat anticline in the northwestern corner of the quadrangle.

STRUCTURAL PROVINCES.

The rocks of the Atoka quadrangle have been affected by varying forces producing distinct forms of structure occupying separate areas. These areas are but small parts of structural provinces which extend toward the north, east, south, and west, and which coincide practically with the geographic provinces referred to under the heading "Geography." In the discussion of the structure it will be convenient to use the same titles applied there.

OUACHITA UPLIFT.

This uplift is limited on the north by the northern border of the Ouachita Range, which extends through southwestern Arkansas and southeastern Indian Territory to the vicinity of Atoka. The folds in the central portion of the range, both in western Arkansas and in eastern Indian Territory, bear nearly east and west. Near the western end of the uplift the folds, both large and small, curve gradually toward the south and disappear beneath a covering of flat-lying Cretaceous sediments. The uplift may be divided longitudinally into two belts, northern and southern. The southern portion is worn down and in part concealed by the Cretaceous deposits. The northern half of the uplift in Indian Territory contains a great number of interlapping, nearly parallel, narrow folds, which have been formed by northwestward thrusts and in many instances have been overturned and broken.

In Indian Territory this greatly folded belt is limited abruptly on the north by a very extensive fault. This great displacement, called the Choctaw fault, separates the more gently folded northwestward-dipping rocks on the northwestern side from the overthrust southeastward dipping, older rocks on the southeastern side.

Choctaw fault.

This great fault enters the northern part of the quadrangle near the Missouri, Kansas, and Texas Railroad, and bears nearly due south along the western side of the Talihina chert ridge. The Silurian rocks upon the eastern side have been thrust upward and westward over the upper Carboniferous rocks upon the west. The Stringtown shale, Talihina chert, and Standley shale, probably 8000 feet of strata, are not represented upon the western side of the fold, having been concealed by the overthrust faulting. Other thrust faults of extensive displacement occur in the Ouachita Range near the axes of large folds parallel with the trends of the rocks. In all these cases of faulted folds the overthrust is to the northwest. The western ends of four of these faulted folds enter the northeastern part of the Atoka quadrangle and die out in the Standley shale. The recurrence of the lower part of the Jackfork sandstone along three of these faults, dipping always toward the southeast, is evidence that the corresponding southern limbs of these synclines are faulted out.

Belt of faulted folds.

In line with these faults toward the southwest there are corresponding northeastward pitching narrow folds in the Talihina chert and lower part of the Standley shale, which would indicate that these rocks were deeply buried at the time of their folding and that they have since been uplifted and tilted eastward when they were thrust up along the great fault at the west side of Black Knob Ridge.

ARKANSAS VALLEY REGION.

As described under "Geography" the Arkansas Valley region is a broad physiographic basin lying between the Ouachita Mountains upon the south and Ozark Highland on the north. It is a deep structural basin, much folded, especially on the southern side.

Structurally the Arkansas Valley region is a direct northward continuation of the Ouachita uplift, but the folds are generally flatter. In western Arkansas and eastern Indian Territory there is a gradual change northward from the overturned broken folds into the more symmetrical structures of the Arkansas Valley region. In the western part of the Ouachita uplift the change is more abrupt.

Arkansas Valley structure continuation of Ouachita uplift.

The folding of the Arkansas Valley region in eastern Indian Territory decreases gradually northward into the very slightly undulating structure of the immediate valley of the Arkansas River. The folds gradually decrease in intensity westward and, one after the other, merge upon the northern side into the monoclinal structure of the Prairie Plains.

The Lehigh syncline represents the extreme southwestern limit of the Arkansas Valley structure. From a southwestward course, parallel to the general folding of the region farther northeast, it turns due south into the Atoka quadrangle and comes to an end in a deep, unsymmetrical, spoon-like basin between the Ouachita Mountain and Arbuckle Mountain regions. The form of this syncline has been affected by the forces which produced the contiguous structures of the Ouachita and Arbuckle uplifts. On the eastern side the rocks have been tilted steeply by the overthrust faulting. On the southwestern side the trends of the rocks in the syncline conform rudely to the folding in the eastern portion of the Arbuckle structure.

ARBUCKLE UPLIFT.

The western part of this uplift is coincident with the Arbuckle Mountains. The rocks of the eastern part have been worn down to the level of the Cretaceous erosion plain, and are in part concealed at the southeastern border by the flat Cretaceous deposits.

During early Carboniferous time the rocks in the region of the Arbuckle Mountains were flat and were covered by the sea. At the beginning of Coal Measures age the western part was uplifted and folded into a mountainous country and the soft lower Carboniferous strata were eroded and again transported into the sea. More than this, streams cut down into harder Silurian and Cambrian rocks in this mountainous district and brought into the upper Carboniferous sea great quantities of limestone, which formed limestone conglomerates along the northern and southern sides of the uplift west of the Atoka quadrangle. At this time the Wapanucka limestone and many succeeding beds were formed.

Unconformity at base of upper Carboniferous.

After the close of the Carboniferous period the whole Arbuckle region was elevated, and thousands of feet of Carboniferous rock as well as the central mass of older limestone and granite which are now exposed in the center of the uplift were tilted, folded, and faulted.

This uplift is a broad, wrinkled, and broken anticline. The strata on both sides, including many formations of Carboniferous, Devonian, and Silurian age, dip steeply away. The central part of the uplift is composed of several broad, shallow folds. The axial parts of the anticlines, wherein are exposed a great thickness of massive Cambrian and Silurian limestone, are generally broadly flexed; while the younger, softer, and thinner rocks in the intervening synclines are crumpled into many small folds. These synclines are broken and displaced in an extraordinary degree by tension or normal faulting which took place probably during or since the folding.

At the eastern end of the Arbuckle uplift one of the northern folds, called the Hunton anticline, enters the northwest corner of the Atoka quadrangle, pitching eastward at an angle of 10°. The axial portion is broad and flat while the sides are sharply flexed downward and even faulted. The displacement of the faulted strata on each side of the fold is several hundred feet. Toward the east these faults die out in the Carboniferous strata, but toward the west they increase and join a number of fractures of the same nature.

Hunton anticline.

A flat eastward-pitching syncline occurs immediately south of the Hunton anticline. This may be called the Wapanucka syncline because it occupies the broad flat valley of Wapanucka Creek. This syncline becomes broader and flatter eastward until it dies out or joins indistinctly with the Lehigh basin in the coal field. Westward it contracts by faulting toward the axial part until it practically ceases as a fold 6 miles west of the quadrangle. Still farther west across the Tishomingo quadrangle it occurs in parts along a faulted zone. The southern limb of the Wapanucka syncline in the Atoka quadrangle is very extensively fractured and displaced by a system of faults. In each case the displacement is downward toward the northeast. Where two or more of these faults having displacements in the same direction join, the combined throw is very great. One mile east of the border of the quadrangle Carboniferous shales are brought down in contact with lower Silurian or Cambrian limestone in a displacement of probably 4000 feet. Two miles south of Wapanucka the displacement is even greater. At this place nearly the whole Cambrian and Silurian section of about 8000 feet is concealed by cumulative faulting.

Wapanucka syncline.

Extensive faulting.

The long granite area which extends northwestward from the vicinity of Boggy Depot occupies the axial part of an anticlinal fold, the sides of which have been faulted in an extraordinary manner. This fold will be called the Belton anticline from the town of Belton which is located upon it 5 miles west of the quadrangle. The contacts between the Silurian and Cambrian limestones and the granite, with the exception of one instance in sec. 28, T. 3 S., R. 9 E., are along faults. Originally, before the rocks had been disturbed, nearly 9000 feet of Cambrian, Silurian, and lower Carboniferous rocks rested normally above the granite. Now they are steeply tilted and fractured, approaching the granite abruptly at various angles. The flat Cretaceous sediments conceal a large part of the rocks upon the southern side of the anticline.

Belton anticline exposing granite.

RED RIVER MONOCLINE.

That part of the Red River Plain in the Atoka quadrangle is confined to the area of Cretaceous rocks. The Cretaceous rocks were deposited after the folding of the older rocks in the northern part of the quadrangle and the sediments were spread across their worn edges, as has been shown in the discussion of the stratigraphy. Since Cretaceous time this region, including the Atoka quadrangle, has not been deformed but has been broadly uplifted and depressed, and the surface probably slightly inclined. At the present time these rocks are uniformly and evenly tilted toward the south at the approximate grade of 40 feet per mile.

MINERAL RESOURCES.

The mineral resources of this region are coal, granite, limestone, sandstone, and clay. Besides these resources there should be considered also the soils, some of which are very fertile. Coal is the only product that has been developed to any considerable extent. Building materials have received less attention, and clays none at all. In a region generally undeveloped, as this is, and under such civil conditions as have existed in Indian Territory, it is probable that no mineral product would be developed except under assurances of considerable profit.

All of the deposits of economic value in this region except granite occur in stratified rocks and may be definitely located in the formations which are outlined on the map. Those formations which contain the most profitable beds of coal, limestone, and sandstone are emphasized on the Economic Geology sheet. Nothing very definite is known of the qualities of the clays. Special tests are required to determine whether a clay will produce fire brick, or may be serviceable in the manufacture of cement, or is suitable for other purposes to which clays are adapted. Clays occur in the Carboniferous formations in great quantity, and it is deemed important to point out their occurrence and condition of structure, so that in the future those who wish may investigate them to the best advantage.

COAL.

There are two beds of coal of workable thickness, both of which occur in the McAlester shale. One occurs close to the base of the formation and the other about 250 feet below the top.

The lower bed, which is known locally as the Atoka coal, is about 4 feet thick and has shale in contact both above and below. This coal occupies the same stratigraphic position as the Hartshorne coal, which is worked extensively in the eastern part of the Choctaw Nation. It has been worked in this vicinity at what is known locally as the Hickory Hill mine, which is near the south end of the Lehigh basin, 4½ miles south of Lehigh. The coal at this mine dips to the northeast about 5° It has been prospected at many places east and west of the mine in the southern part of the basin. The position of this coal is immediately above the Hartshorne sandstone and it should be found beneath the soil approximately upon the contact between this sandstone and the succeeding McAlester shale. At the southern end of the basin the coal dips toward the north at an angle of about 10°. Northwest of the Hickory Hill mine the dips vary from 4° to 6°. In the northeastern part of the quadrangle the rocks at this horizon dip 60° to 80° to the northwest, but the coal is not known to occur. If it should be found, however, it probably could not be profitably mined on account of the steep dip of the rock.

Atoka coal at same horizon as Hartshorne coal.

The coal as it occurs at the Hickory Hill mine is laminated and, in mining, breaks into cuboidal blocks. In the joints of the coal and in places between the laminae there are thin filaments of iron sulphide, and near the surface there is sulphate of lime. The coal is highly bituminous and is used chiefly for steam purposes.

Character of Atoka coal at Hickory Hill mine.

The upper coal in the McAlester shale is known locally as the Lehigh bed on account of its most extensive development at the town of Lehigh, 3 miles south of Phillips. This coal runs regularly about 3½ feet in thickness and, as far as known, is without shale partings.

Lehigh coal bed.

In the northeastern part of the quadrangle rocks at the horizon of the Lehigh coal crop in a rough hilly country and dip 40° to 60° NW. The coal has not been prospected at this place and its condition is not known. Southwestward the dip decreases to approximately 25° in the axial part of the basin northwest of Atoka. On the western side of the basin the coal is well disposed structurally, dipping to the east about 4°. It is actively mined at Lehigh, Phillips, and Coalgate, the last-named place being 2½ miles north of the quadrangle.

In physical appearance the Lehigh coal is laminated and, in mining, breaks into good-sized cubical blocks. Thin filaments of iron sulphide and sulphate of lime occur occasionally in the joints of the coal. It is highly bituminous, the fuel constituents of the coal being carbon 41.12 per cent and volatile combustible matter 41.61 per cent. There is 13.7 per cent of ash, and 4.5 per cent of sulphur. These results are from an analysis of the coal from shaft No. 5, at Lehigh, about 200 feet beneath the surface. The samples were taken from the commercial product on cars ready for shipment.

Character of the Lehigh coal.

GRANITE.

The Tishomingo granite is exposed in an area of about 12 square miles in the Atoka quadrangle. As described above under "Geology" the granite is generally of rather coarse texture and is pinkish or reddish. It is variable, however, both in color and texture, ranging from a very coarsely crystalline to a fine-grained rock, and from light pink to almost red.

In parts of the area the Tishomingo granite has suffered crushing and faulting to such an extent that it can not be used successfully as a building stone. In such places the rock is intersected in many directions by fractures which cause it to break into irregular small pieces upon being quarried. In a large part of the area, however, it occurs as a massive rock, so that large masses of valuable stone could be quarried.

The Tishomingo granite will make a handsome building stone and will bear a smooth polish in working for ornamental purposes. This granite has not been quarried in the Atoka quadrangle though it occurs within 10 miles of the railroad. In the Tishomingo quadrangle it has been utilized, the Chickasaw capitol building at Tishomingo being constructed entirely of this stone. A new branch of the St. Louis and San Francisco Railroad has recently been built from northern Indian Territory to Texas across the western part of the Tishomingo granite area, which should induce development of the granite industry.

Ornamental stone.

LIMESTONE.

The Wapanucka limestone is the most important formation in this quadrangle for the production of building stone. The formation crops in ridges from the northwest corner of the quadrangle southeastward to the vicinity of Boggy Depot. This limestone occurs in ample abundance for any purpose to which it may be applied. The beds of purer limestone occur in the upper part of the formation and may be utilized in the manufacture of lime. These beds are rather hard, and may be obtained in dimensions which render them serviceable for foundations, bridge piers, and for general building purposes. A bed of fine white oolitic limestone occurs near the top of the formation, well situated for quarrying, in the northwestern part of T. 1 S., R. 9. E. This rock is moderately hard and will make an excellent building stone. The middle and lower beds contain chert and are interstratified with chert and sandy layers, and they may be used profitably for road material. The Missouri, Kansas and Texas Railroad has established a crushing plant at Chickachoc switch, near the southwest corner of the

Wapanucka limestone a good building stone.

Road ballast.

McAlester quadrangle, and has utilized very extensively the Wapanucka limestone and chert occurring near there for its road ballast.

The Goodland limestone is a nearly pure massive bed of white limestone well situated and structurally disposed for use, but it is generally too soft and weak for a good building stone. It is considered an excellent lime-producing rock and is situated upon the border of the extensive timber belt of the Trinity sands, where fuel for burning lime is abundant.

Lime-producing rock.

Certain beds of the Arbuckle, Viola, and Hunton limestones are quite crystalline and hard, but they are for the most part steeply tilted, folded, and broken, so that they can not be utilized successfully as building stone. Near the northwest corner of the quadrangle, however, parts of the Viola and Hunton limestones are nearly flat, and some of the harder beds may serve for common building purposes. Some of the limestones in these formations are cherty and others are siliceous, and they would make road metal of high quality.

SANDSTONE.

Beds of sandstone occur in the Savanna and Boggy formations which may be serviceable in many ways as building material. Many of the beds, and especially some of those of the Savanna formation, produce excellent building stone. The Savanna stone is yellowish or reddish brown, and the beds are evenly stratified and moderately hard. This stone is quarried successfully in large quantities for dwelling and business houses at South McAlester, in the adjoining quadrangle, where the Missouri, Kansas and Texas Railroad crosses the formation. The brownish sandstone at the base of the Savanna formation is quarried in the town of Lehigh and is utilized in the construction of foundations of business houses. In the eastern part of the Lehigh basin the rocks are steeply upturned and many of the beds contain fragments of angular chert, so that they are not well adapted for building. The thinner and harder beds in the Savanna and Boggy formations will make good paving flags. All of the sandstone beds of these formations except the conglomerates in the eastern part of the Lehigh basin are fine grained and yellowish or reddish brown. The cementing material which binds the sand is composed either of silica or of silica and oxide of iron together; in the lighter-colored stones it is chiefly silica, while in the darker it is in large part iron oxide. Both stones are very durable in color and strength.

Savanna sandstone a good building stone.

CLAY.

Clay and shale are the most abundant of the rocks which occur in the Carboniferous formations in this region. In the Wapanucka limestone and Hartshorne sandstone they occur in thin strata and are of local extent, but in the other formations they occur in great abundance. These beds vary in quality from very sandy strata to purer argillaceous, finely laminated clays.

Associated with coals, usually at their lower contact, are beds of almost structureless blue clay. These beds are generally thin, but the clay may prove valuable in the manufacture of fire brick. These and other clays associated with the coals may be utilized more economically than other beds because of their proximity to fuel.

Fire clay.

The clay shales usually vary in hardness with the amount of sand and other impurities contained in them. The more impure varieties are almost stony in hardness, while the purer kinds are friable and upon slight weathering are often plastic.

The structure of the formations in which the clays occur has been sufficiently explained, it is believed, to show where they may be profitably exploited.

SOILS.

The soils in the Atoka quadrangle are of great variety, ranging from an almost barren stony soil, serviceable only for grazing, to the most fertile river bottom and black marly upland. The soils, excepting those in the stream bottoms, are residual; that is, they are derived directly from the disintegrating rock of the formations lying beneath them. The classification of the soils therefore would correspond practically to the classification of the rock formations.

All of the formations composed of hard rocks—Arbuckle limestone, Simpson formation, Viola limestone, Hunton limestone, Woodford chert, Talihina chert, Jackfork sandstone, and Wapanucka limestone—because of their narrow outcrop or rugged surface, produce stony soils, and, with the exception of very limited areas, are fit only for grazing lands.

Grazing lands.

The Tishomingo granite lies in a nearly level plain, but for the most part its soils are very thin and contain an admixture of loose sand from the Trinity formation, which recently covered it.

The Caney shale is friable and calcareous, and probably phosphatic, especially in the lower part. This shale land is flat or gently rolling, and contains the most fertile soils in the northern part of the quadrangle. The country of the Standley shale is generally smooth, but its soil is not very fertile.

The Atoka, Hartshorne, McAlester, Savanna, and Boggy formations produce a variety of clay and sandy loamy soils. The relative fertility of these depends upon the proportionate mixture of sand and clay and upon the inclination of the surface. The soil of the clays is generally compact and occupies flat areas, best adapted to meadow and pasture. The sandy loams rest upon the low slopes of hills and gentle swells made by the sandy members of the formations and constitute the best tillable soils.

The Trinity sand produces a loose sandy soil or simply a loose sand without perceptible elements of soil. In places where the country is almost perfectly flat this formation makes a light loamy soil, moderately fertile, which is best adapted to the production of fruits and vegetables. In the more rolling part and in most of the flat lands, the Trinity sand area has still upon it the forest, its best product, which should be carefully preserved.

Forest-covered flat land.

The Goodland limestone produces a black calcareous clay soil, but, owing to its outcrop in terrace escarpments and steep slopes, the soil is removed as fast as formed, except in occasional small flat areas between the valleys. The succeeding Kiamichi, Caddo, and Bennington limestones form black calcareous clay soils which are very fertile. These lands are generally smooth, though rolling. The Bokchito formation, being composed of ferruginous sands and clays with occasional limestone layers and forming a more or less hilly or rolling country, produces moderately fertile reddish or brownish loams, which are best adapted to fruit growing. The Silo formation makes a reddish and brown sandy soil resembling that of the Trinity formation. It is more fertile, however, and, besides producing the usual crop of cotton and grain, it is admirably adapted to the cultivation of peaches and small fruits, especially grapes.

Fertile black soils.

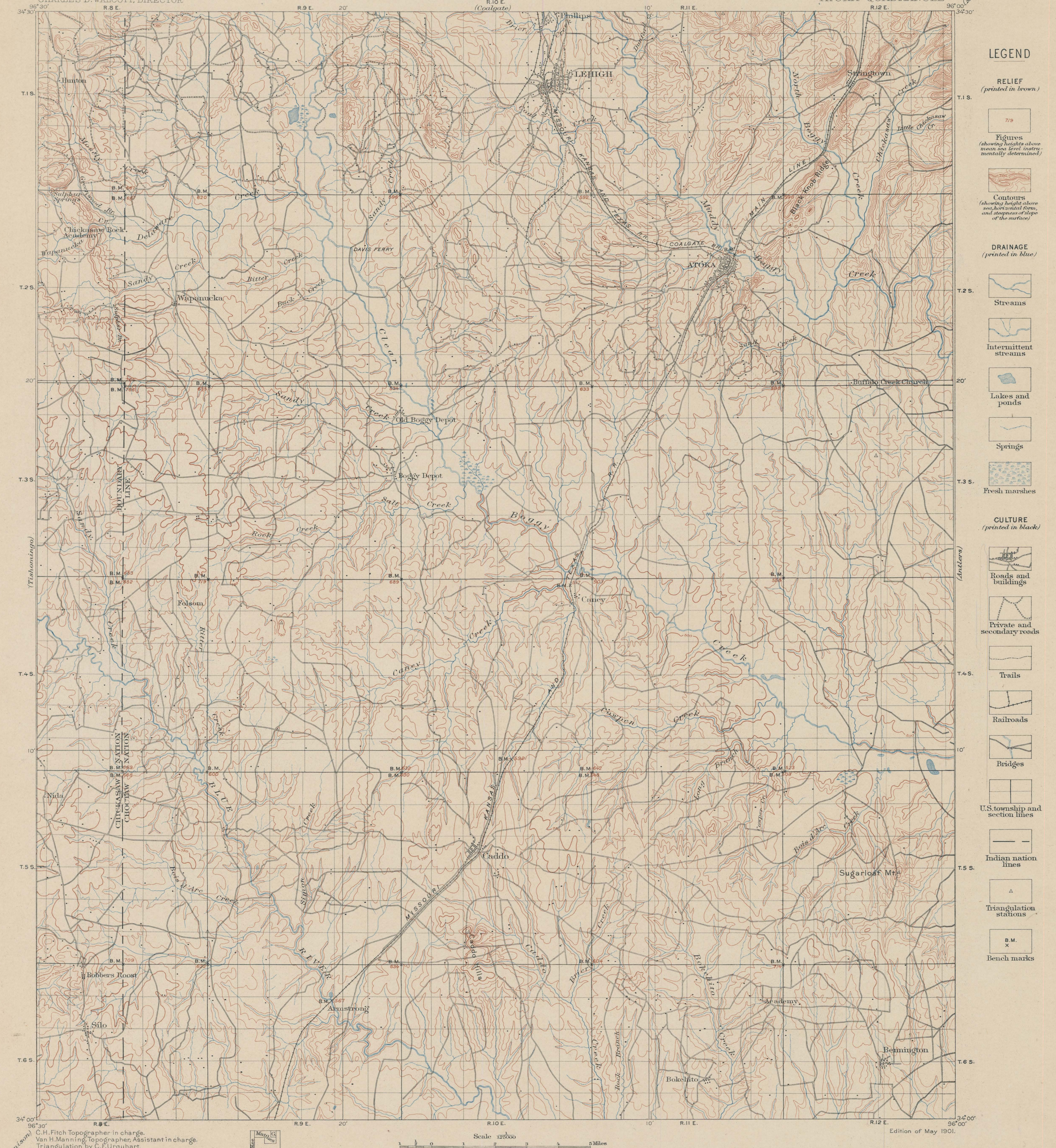
Fruit lands.

February, 1902

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

TOPOGRAPHIC SHEET

INDIAN TERRITORY
ATOKA QUADRANGLE



96°30′ R.8 E. R.9 E. 20′ R.10 E. 10′ R.11 E. R.12 E. 96°00′

C.H. Fitch Topographer in charge.
Van H. Manning, Topographer, Assistant in charge.
Triangulation by C.F. Urquhart.
Topography by W.B. Corse, F.E. Matthes, R.M. Towson, R.H. Mc Kee and C.W. Goodlove.
Surveyed in 1895-96-97-98.

Scale $\frac{1}{125000}$

Contour interval 50 feet.

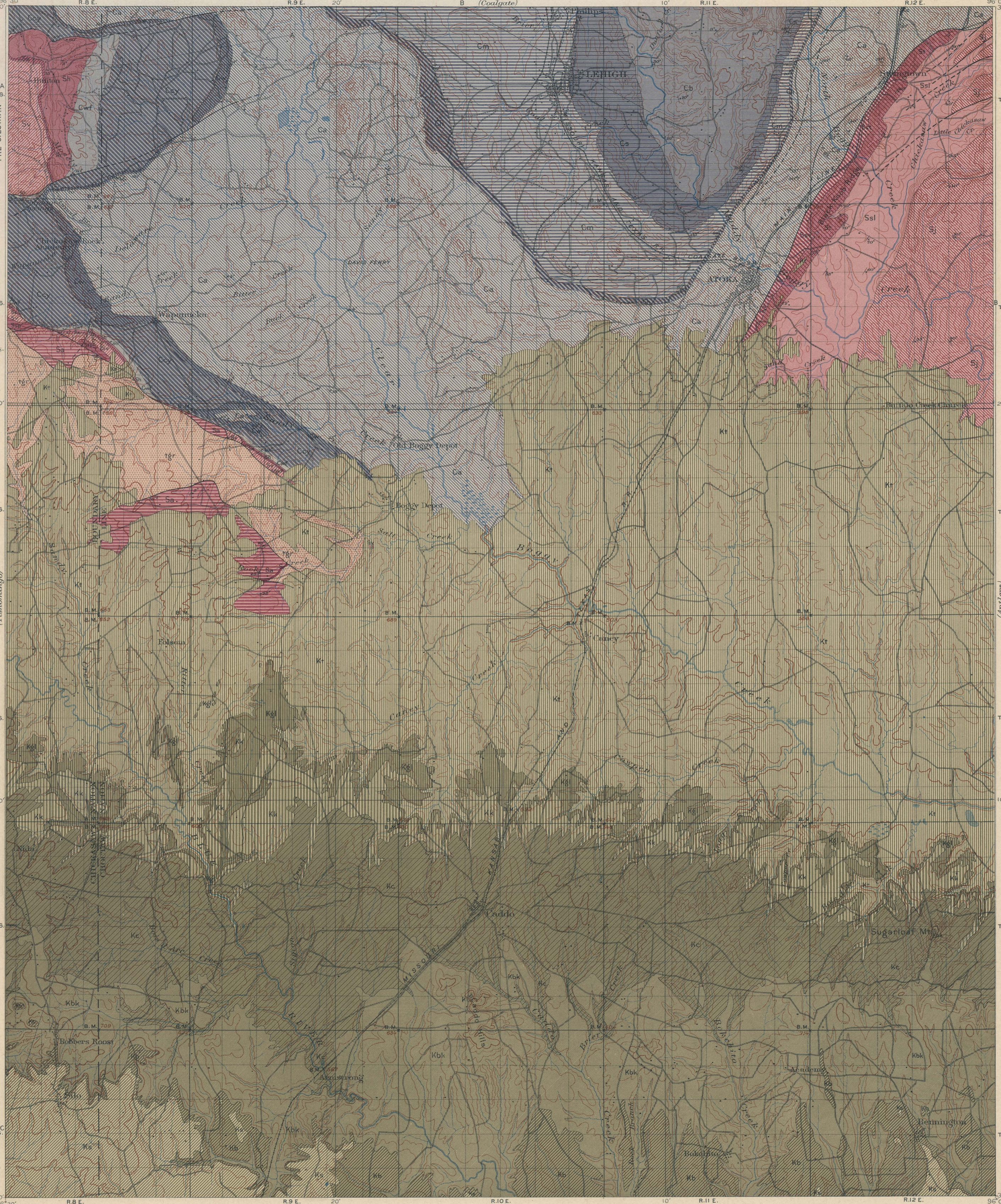
Datum is mean sea level.

Edition of May 1901.

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

HISTORICAL GEOLOGY SHEET

INDIAN TERRITORY
ATOKA QUADRANGLE



LEGEND

(continued)

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

PRE-SILURIAN

- tgr — Tishomingo granite (pink pegmatitic granite with occasional diabase dikes)

Faults

Concealed faults (continuation of known faults beneath Cretaceous strata)

Sections

20° Dip and strike of stratified rocks

LEGEND

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CRETACEOUS

- Ks — Silo sandstone (partially consolidated brown sandstone and shale)
- Kb — Bennington limestone (blue or yellowish blue compact shell limestone)
- Kbk — Bokchito formation (friable shale and sandstone with few beds of limestone)
- Kc — Caddo limestone (limestone and marly clay interstratified)
- Kk — Kiamichi formation (blue marly clay with shell limestone beds)
- Kgl — Goodland limestone (white massive and thin limestone)
- Kt — Trinity sand (yellow sand with gravel at the base)

CARBONIFEROUS

- Cb — Boggy shale (shale with many beds of brown sandstone)
- Cs — Savanna sandstone (several thick sandstone beds separated by shale)
- Cm — Mc Alester shale (shale and coal with several sandstone beds interstratified)
- Ch — Hartshorne sandstone (brown sandstone beds with some shale interstratified)
- Ca — Atoka formation (shale with many lentils of sandstone)
- Cc — Chickachoc chert lentil (white calcareous cherty sandstone in the Atoka formation)
- Cw — Wapanucka limestone (blue and white limestone with cherty sandstone and shale)
- Ccy — Caney shale (black and blue shale with chert and limestone lentils)
- Cwf — Woodford chert (black flint, chert, and shale)

SILURIAN

- Sh — Hunton limestone (white and yellow limestone)
- Ss — Sylvan shale (blue friable shale)
- Sv — Viola limestone (blue thin-bedded limestone)
- Ssp — Simpson formation (thin limestone, shale, and sandstone)
- Sa — Arbuckle limestone (blue thick-bedded limestone)
- Sr — Regan sandstone (sandstone and arkose conglomerate)
- Sj — Jackfork sandstone (massive and thin-bedded brown sandstone)
- Ssl — Standley shale (greenish and blue shale with friable drab sandstone)
- St — Talihina chert (flint, chert, and shale in thin layers)
- Sst — Stringtown shale (blue and black shale, cherty at the top)

Legend is continued on the left margin.

C.H. Fitch, Topographer in charge.
Van H. Manning, Topographer, Assistant in charge.
Triangulation by C.F. Urquhart.
Topography by W.B. Corse, F.E. Matthes, R.M. Towson, R.H. Mc Kee, and C.W. Goodlove.
Surveyed in 1895-96-97-98.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of July 1901.

Geology by Joseph A. Taff.
Assisted by George I. Adams and George B. Richardson.
Surveyed in 1897 and 98.

U.S. GEOLOGICAL SURVEY
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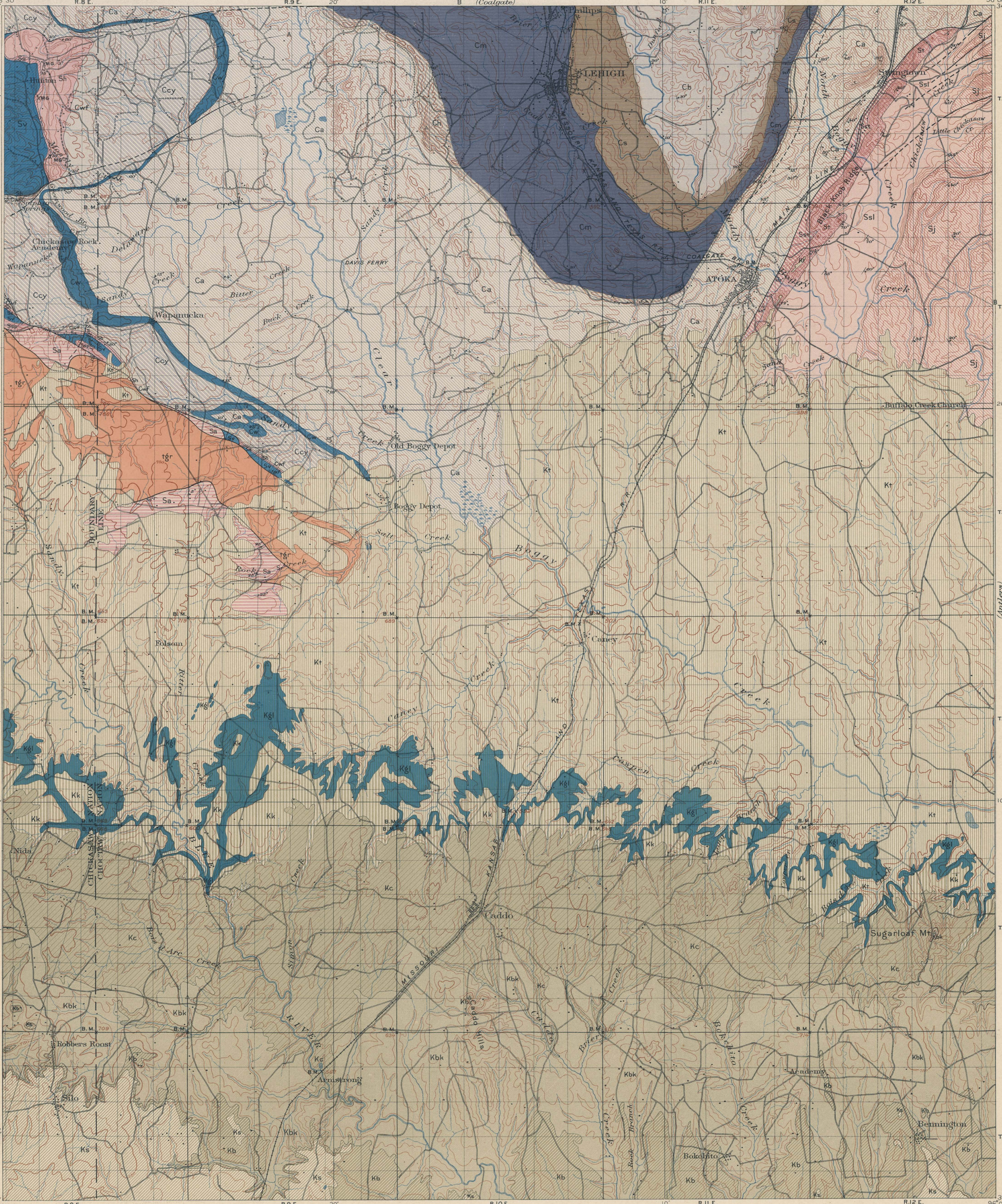
ECONOMIC GEOLOGY SHEET

INDIAN TERRITORY
ATOKA QUADRANGLE



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0 1 2 3 4 5 Miles

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LEGEND

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CRETACEOUS

- Ks — Silo sandstone *(partially consolidated brown sandstone and shale)*
- Kb — Bennington limestone *(blue or yellowish blue compact shell limestone)*
- Kbk — Bokchito formation *(friable shale and sandstone with few beds of limestone)*
- Kc — Caddo limestone *(limestone and marly clay interstratified)*
- Kk — Kiamichi formation *(blue marly clay with shell limestone beds)*
- Kgl — Goodland limestone *(white massive and thin limestone)*
- Kt — Trinity sand *(yellow sand with gravel at the base)*

CARBONIFEROUS

- Cb — Boggy shale *(shale with many beds of brown sandstone)*
- Cs — Savanna sandstone *(several thick sandstone beds separated by shale)*
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- Ccy — Caney shale *(black and blue shale with chert and limestone lentils)*
- Cwf — Woodford chert *(black flint, chert, and shale)*

SILURIAN

- Sh — Hunton limestone *(white and yellow limestone)*
- Ss — Sylvan shale *(blue friable shale)*
- Sv — Viola limestone *(blue thin-bedded limestone)*
- Ssp — Simpson formation *(thin limestone, shale, and sandstone)*
- Sa — Arbuckle limestone *(blue thick-bedded limestone)*
- Sr — Regan sandstone *(sandstone and arkose conglomerate)*
- Sj — Jackfork sandstone *(massive and thin bedded brown sandstone)*
- Ssl — Standley shale *(greenish and blue shale with friable drab sandstone)*
- St — Talihina chert *(flint, chert, and shale in thin layers)*
- Sst — Stringtown shale *(blue and black shale, cherty at the top)*

Legend is continued on the left margin.

LEGEND
(continued)

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

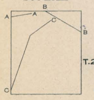
PRE-SILURIAN

- tgr — Tishomingo granite *(pink pegmatitic granite with occasional diabase dikes)*

Faults

Concealed faults *(continuation of known faults beneath Cretaceous strata)*

Sections



20° *Dip and strike of stratified rocks*

⚒ Coal mines
× Coal prospects
× MG Manganese prospects

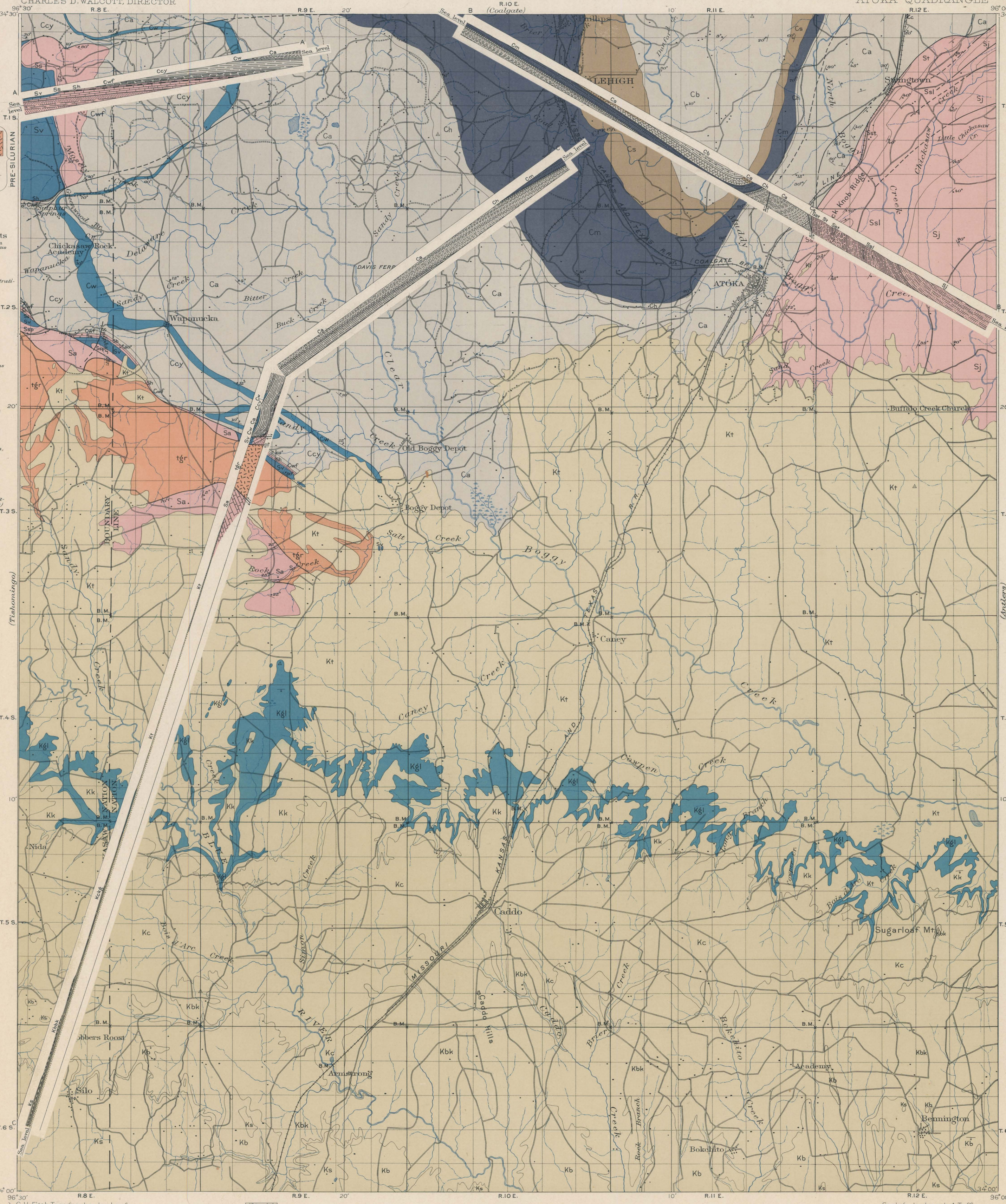
Known productive formations

- Cm — *Coal* *(Mc Alester shale contains workable coal beds)*
- Cs — *Building stone* *(Savanna sandstone suitable for building)*
- Kgl-Cw-Sv — *Limestone* *(Goodland, Wapanucka, and Viola limestones suitable for lime and building stone)*
- tgr — *Granite* *(Tishomingo granite suitable for building stone)*

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

STRUCTURE-SECTION SHEET

INDIAN TERRITORY
ATOKA QUADRANGLE



LEGEND (continued)

IGNEOUS ROCKS

SHEET SYMBOL	SECTION SYMBOL	
ŧgr	ŧgr	Tishomingo granite (pink pegmatitic granite with occasional diabase dikes) — PRE-SILURIAN

Faults

Concealed faults (continuation of known faults beneath Cretaceous strata)

Dip and strike of stratified rocks

Known productive formations

Cm	Coal (Mc Alester shale contains workable coal beds)
Cs	Building stone (Savanna sandstone suitable for building)
Kġl-Cw-Sv	Limestone (Goodland, Wapanucka, and Viola limestones suitable for lime and building stone)
ŧgr	Granite (Tishomingo granite suitable for building stone)

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL	SECTION SYMBOL	Formation	System
Ks	Ks	Silo sandstone (partially consolidated brown sandstone and shale)	CRETACEOUS
Kb	Kbbk	Bennington limestone (blue or yellowish blue compact shell limestone)	CRETACEOUS
Kbk	Combined with Bennington limestone on section	Bokchito formation (friable shale and sandstone with few beds of limestone)	CRETACEOUS
Kc	Kckġ	Caddo limestone (limestone and marly clay interstratified)	CRETACEOUS
Kk	Combined with Caddo limestone on section	Kiamichi formation (blue marly clay with shell limestone beds)	CRETACEOUS
Kġl	Combined with Caddo limestone on section	Goodland limestone (white massive and thin limestone)	CRETACEOUS
Kt	Kt	Trinity sand (yellow sand with gravel at the base)	CRETACEOUS
Cb	Cb	Boggy shale (shale with many beds of brown sandstone)	CARBONIFEROUS
Cs	Cs	Savanna sandstone (several thick sandstone beds separated by shale)	CARBONIFEROUS
Cm	Cm	Mc Alester shale (shale and coal with several sandstone beds interstratified)	CARBONIFEROUS
Ch	Ch	Hartshorne sandstone (brown sandstone beds with some shale interstratified)	CARBONIFEROUS
Ca	Ca	Atoka formation (shale with many lentils of sandstone)	CARBONIFEROUS
Cc		Chickachoc chert lentil (white calcareous cherty sandstone in the Atoka formation)	CARBONIFEROUS
Cw	Cw	Wapanucka limestone (blue and white limestone with cherty sandstone and shale)	CARBONIFEROUS
Ccy	Ccy	Caney shale (black and blue shale with chert and limestone lentils)	CARBONIFEROUS
Cwf	Cwf	Woodford chert (black flint, chert, and shale)	SILURIAN
Sh	Sh	Hunton limestone (white and yellow limestone)	SILURIAN
Ss	Ss	Sylvan shale (blue friable shale)	SILURIAN
Sv	Sv	Viola limestone (blue thin-bedded limestone)	SILURIAN
Ssp	Ssp	Simpson formation (thin limestone, shale, and sandstone)	SILURIAN
Sa	Sa	Arbuckle limestone (blue thick-bedded limestone)	SILURIAN
Sr		Regan sandstone (sandstone and arkose conglomerate)	SILURIAN
Sj	Sj	Jackfork sandstone (massive and thin-bedded brown sandstone)	CARBONIFEROUS
Ssl	Ssl	Standley shale (greenish and blue shale with friable drab sandstone)	CARBONIFEROUS
St	St	Talihina chert (flint, chert and shale in thin layers)	CARBONIFEROUS
Sst	Sst	Stringtown shale (blue and black shale, cherty at the top)	CARBONIFEROUS

Legend is continued on the left margin.

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Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

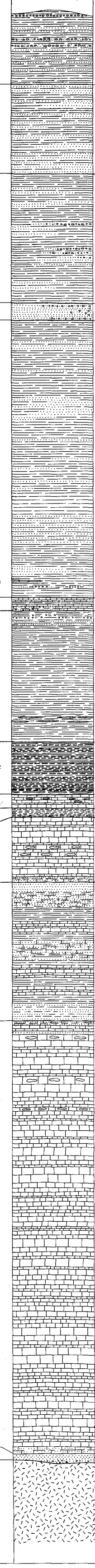
1 ½ 0 1 2 3 4 5 Kilometers

Edition of Oct. 1901.

Geology by Joseph A. Taff.
Assisted by George I. Adams and George B. Richardson.
Surveyed in 1897 and 98.

COLUMNAR SECTION SHEET 1

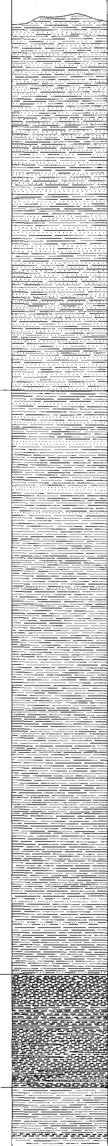
GENERALIZED SECTION FOR THE NORTHERN PART OF THE ATOKA QUADRANGLE.
SCALE: 1 INCH = 1000 FEET.

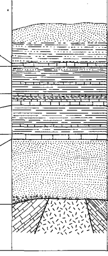
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CARBONIFEROUS	Boggy shale.	Cb		800+	Shale, brown sandstone, and conglomerate of white chert pebbles in brown sandstone matrix.	Ridges and high, rough, hilly land.
	Savanna sandstone.	Cs		750–1100	Brown sandstone and shale.	Ridges and high, rough, hilly land in the east; low, smooth ridges and level valleys in the south and west.
	McAlester shale.	Cm		1150–1500	Shale, brown sandstone, and conglomerate of white chert pebbles in brown sandstone matrix.	Ridges and rough, hilly land in the east; low, smooth ridges and level valleys in the south and west.
	Hartshorne sandstone.	Ch		150–200	Brown sandstone, locally a chert conglomerate.	Low and nearly level ridges and hills.
	Atoka formation.	Ca		3200	Shale and brown sandstone, variable in thickness, texture, and hardness.	Nearly level undulating plains, valleys, and low ridges.
	(Chickachoc chert lentil.)	(Cc)			Thin lentil of chert and limestone in the northeast, and a conglomerate bed of iron concretions toward the southwest.	
	Wapanucka limestone.	Cw		100–150	White oolitic and blue limestones, shale, and locally cherty calcareous sandstone.	Low ridges.
	Caney shale.	Ccy		1500	Blue shale with thin sandy lentils and small ironstone concretions. Black fissile shale with dark-blue fossiliferous limestone concretions.	Level plains and valleys.
DEV.* ?	Woodford chert.	Cwf		600	Thin-bedded chert and fissile black shale. Blue flint lentils at the base.	Low ridges and hilly land.
SILURIAN	Hunton limestone.	Sh		160	White and yellowish limestones with flint and chert concretions in upper part.	Sharp narrow ridges and terraced hills.
	Sylvan shale.	Ss		50–100	Blue clay shale.	Narrow valleys.
	Viola limestone.	Sv		750	White and bluish limestones with flint concretions in the middle.	Low ridges and hilly land.
	Simpson formation.	Ssp		1600	Sandstone, calcareous sandstone, and shale. Thin fossiliferous limestone and shale. Calcareous sandstone and shale. Fossiliferous limestone and shale. Sandstone and shaly beds.	Slopes of shallow valleys.
SILURIAN ? CAMBRIAN*	Arbuckle limestone.	Sa		4000–6000	Massive and thin-bedded white and light-blue limestones with cherty concretions. Dull-blue massive and thin limestones.	Slightly dissected plain of recently uncovered Cretaceous base-level.
CAMBRIAN*	Regan sandstone.	Sr		50–100	Coarse dark-brown sandstone.	
PRE-CAMBRIAN*	Tishomingo granite.	tgr			Coarse red granite with dikes of basic rocks.	

*Study of the fossils collected in this region has shown that the Regan sandstone and the lower portion of Arbuckle limestone belong in the Cambrian, and that the Woodford chert belongs in the Devonian. These facts were learned too late to permit the necessary changes to be made in the maps.

JOSEPH A. TAFF,
Geologist.

COLUMNAR SECTION SHEET 2

GENERALIZED SECTION FOR THE NORTHEAST CORNER OF THE ATOKA QUADRANGLE. SCALE: 1 INCH = 1000 FEET.						
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
SILURIAN	Jackfork sandstone.	Sj		3800+	Brown and drab sandstone, shaly sandstone, and thin shale beds.	Stony, high, rough, hilly land.
	Standley shale.	Ssl		6100	Bluish and greenish fissile shales and massive and thin-bedded friable drab sandstones. Siliceous and cherty fissile shale.	Nearly level plains and valleys.
	Talihina chert.	St		1150	Blue, greenish, and white stratified flint and chert. Cherty and clay shales. Black, bluish, and white stratified flint, chert, and cherty shale with thin lentils of blue limestone.	Rounded, smooth knobby ridges.
	Stringtown shale.	Sst		600+	Black and blue shales with a bed of cherty shale.	Lower slopes of ridges and level land.

GENERALIZED SECTION FOR THE SOUTHERN PART OF THE ATOKA QUADRANGLE. SCALE: 1 INCH = 500 FEET.						
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CRETACEOUS	Silo sandstone.	Ks		200+	Brown friable sandstone, locally indurated by ferruginous cement, shale, and shaly sandstone.	Low round hills and shallow valleys.
	Bennington limestone.	Kb		10–15	Blue shell limestone.	Level land and low escarpments.
	Bokchito formation.	Kbk		140	Red and blue shale with thin ferruginous limestone and lentils of friable sandstone.	Hill slopes and rolling low lands.
	Caddo limestone.	Kc		60	Yellow and white limestone interstratified with thin marly beds.	Low northward facing escarpments and rolling southward sloping land.
	Kiamichi formation.	Kk		150	Blue friable shale with thin shell limestone beds in lower portion.	Lower slopes of escarpments and rolling prairie land.
	Goodland limestone.	Kgl		25	Massive white limestone.	Small level benches and low escarpments.
	Trinity sand.	Kt		200–400	Fine yellow sand with conglomerate beds locally at the base. UNCONFORMITY	Low round hills and wide valleys.
	Carboniferous, Silurian, and Cambrian sediments and pre-Cambrian granite.					Very slightly dissected plain of recently uncovered Cretaceous base-level.

JOSEPH A. TAFF,

Geologist.

Information Concerning

Topographic and Geologic Maps and Folios

and Other Publications of the Geological Survey

can be had on application to

The Director, U. S. Geological Survey,

Washington, D. C.